C H A P T E R 2
Functions and Graphs

CHAPTER 2
Functions and Graphs

Section 2.1 Graphs of Equations

Skills Warm Up

1. $\sqrt{(2-6)^2 + [1-(-2)]^2} = \sqrt{(-4)^2 + 3^2}$

$= \sqrt{16+9} = \sqrt{25} = 5$

2. $\sqrt{(1-4)^2 + (-2-1)^2} = \sqrt{(-3)^2 + (-3)^2}$

$= \sqrt{9+9} = \sqrt{18} = 3\sqrt{2}$

3. $\dfrac{4+(-2)}{2} = \dfrac{2}{2} = 1$

4. $\dfrac{-1+(-3)}{2} = \dfrac{-4}{2} = -2$

5. $\sqrt{18} + \sqrt{45} = 3\sqrt{2} + 3\sqrt{5} = 3\left(\sqrt{2} + \sqrt{5}\right)$

6. $\sqrt{12} + \sqrt{44} = 2\sqrt{3} + 2\sqrt{11} = 2\left(\sqrt{3} + \sqrt{11}\right)$

7. $\sqrt{(4-x)^2 + (5-2)^2} = \sqrt{58}$

$(4-x)^2 + (5-2)^2 = 58$

$(4-x)^2 + 9 = 58$

$(4-x)^2 = 49$

$4 - x = \pm\sqrt{49}$

$4 - x = 7 \Rightarrow x = -3$

$4 - x = -7 \Rightarrow x = 11$

8. $\sqrt{(8-6)^2 + (y-5)^2} = 2\sqrt{5}$

$(8-6)^2 + (y-5)^2 = 20$

$4 + (y-5)^2 = 20$

$(y-5)^2 = 16$

$y - 5 = \pm\sqrt{16}$

$y - 5 = 4 \Rightarrow y = 9$

$y - 5 = -4 \Rightarrow y = 1$

9. $x^3 - 9x = 0$

$x(x+3)(x-3) = 0$

$x = 0$

$x + 3 = 0 \Rightarrow x = -3$

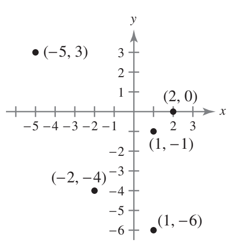
$x - 3 = 0 \Rightarrow x = 3$

10. $x^4 - 8x^2 + 16 = 0$

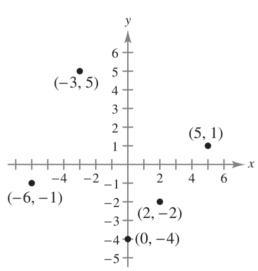
$(x^2 - 4)(x^2 - 4) = 0$

$x^2 - 4 = 0 \Rightarrow x = \pm 2$

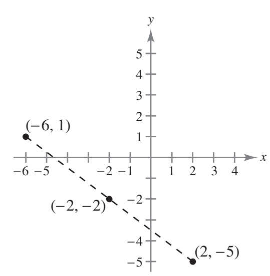
1.



2.



3. (a)

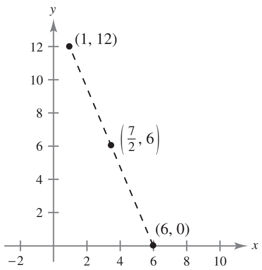


(b) $d = \sqrt{\left(2-(-6)\right)^2 + (-5-1)^2}$

$= \sqrt{64+36} = 10$

(c) $\left(\dfrac{2+(-6)}{2}, \dfrac{(-5)+1}{2}\right) = (-2, -2)$

4. (a)

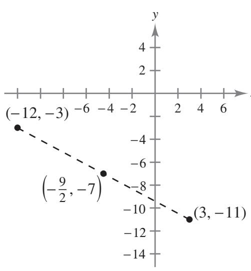


(b) $d = \sqrt{(6-1)^2 + (0-12)^2}$

$= \sqrt{25 + 144} = 13$

(c) $\left(\dfrac{1+6}{2}, \dfrac{12+0}{2}\right) = \left(\dfrac{7}{2}, 6\right)$

5. (a)

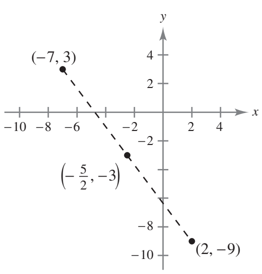


(b) $d = \sqrt{(-12-3)^2 + (-3-(-11))^2}$

$= \sqrt{225 + 64} = 17$

(c) $\left(\dfrac{-12+3}{2}, \dfrac{-3+(-11)}{2}\right) = \left(-\dfrac{9}{2}, -7\right)$

6. (a)

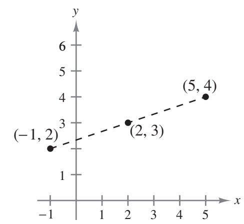


(b) $d = \sqrt{(-7-2)^2 + (3-(-9))^2}$

$= \sqrt{81 + 144} = 15$

(c) $\left(\dfrac{-7+2}{2}, \dfrac{3+(-9)}{2}\right) = \left(-\dfrac{5}{2}, -3\right)$

7. (a)

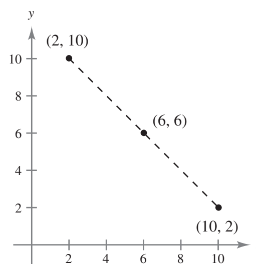


(b) $d = \sqrt{(5+1)^2 + (4-2)^2}$

$= \sqrt{36 + 4} = 2\sqrt{10}$

(c) $\left(\dfrac{-1+5}{2}, \dfrac{2+4}{2}\right) = (2, 3)$

8. (a)



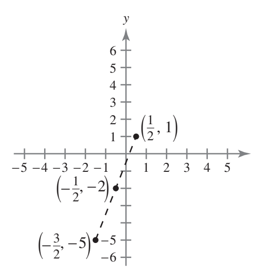
(b) $d = \sqrt{(2-10)^2 + (10-2)^2}$

$= \sqrt{64 + 64} = 8\sqrt{2}$

(c) $\left(\dfrac{2+10}{2}, \dfrac{10+2}{2}\right) = (6, 6)$

9. $\left(\dfrac{1}{2}, 1\right), \left(-\dfrac{3}{2}, -5\right)$

(a)

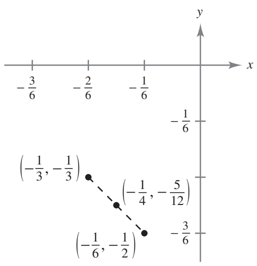


(b) $d = \sqrt{\left(-\dfrac{3}{2} - \dfrac{1}{2}\right)^2 + (-5-1)^2}$

$= \sqrt{(-2)^2 + (-6)^2} = \sqrt{40} = 2\sqrt{10}$

(c) Midpoint $= \left(\dfrac{\dfrac{1}{2} + \left(-\dfrac{3}{2}\right)}{2}, \dfrac{1+(-5)}{2}\right) = \left(-\dfrac{1}{2}, -2\right)$

10. (a)

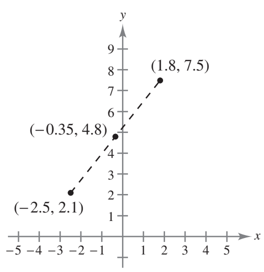


(b) $d = \sqrt{\left(-\frac{1}{3} + \frac{1}{6}\right)^2 + \left(-\frac{1}{3} + \frac{1}{2}\right)^2}$

$= \sqrt{\frac{1}{36} + \frac{1}{36}} = \frac{\sqrt{2}}{6}$

(c) $\left(\frac{-\frac{1}{3} - \frac{1}{6}}{2}, \frac{-\frac{1}{3} - \frac{1}{2}}{2}\right) = \left(-\frac{1}{4}, -\frac{5}{12}\right)$

11. (a)



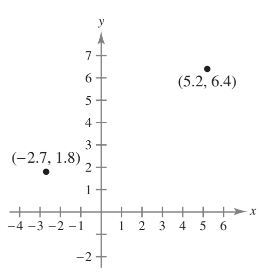
(b) $d = \sqrt{(2.1 - 7.5)^2 + (-2.5 - 1.8)^2}$

$= \sqrt{29.16 + 18.49} = \sqrt{47.65}$

(c) $\left(\frac{1.8 - 2.5}{2}, \frac{7.5 + 2.1}{2}\right) = (-0.35, 4.8)$

12. $(5.2, 6.4), (-2.7, 1.8)$

(a)



(b) $d = \sqrt{(-2.7 - 5.2)^2 + (1.8 - 6.4)^2}$

$= \sqrt{(-7.9)^2 + (-4.6)^2} = \sqrt{83.57}$

(c) Midpoint $= \left(\frac{5.2 + (-2.7)}{2}, \frac{6.4 + 1.8}{2}\right)$

$= (1.25, 4.10)$

13. (a) $a = |4 - 0| = 4$

$b = |3 - 0| = 3$

$c = \sqrt{a^2 + b^2} = \sqrt{16 + 9} = 5$

(b) $c = \sqrt{(4 - 0)^2 + (3 - 0)^2} = \sqrt{16 + 9} = 5$

14. (a) $a = |13 - 1| = 12$

$b = |6 - 1| = 5$

$c = \sqrt{a^2 + b^2} = \sqrt{144 + 25} = 13$

(b) $c = \sqrt{(13 - 1)^2 + (6 - 1)^2} = \sqrt{144 + 25} = 13$

15. (a) $a = |7 - (-3)| = 10$

$b = |4 - 1| = 3$

$c = \sqrt{a^2 + b^2} = \sqrt{100 + 9} = \sqrt{109}$

(b) $c = \sqrt{[7 - (-3)]^2 + (4 - 1)^2}$

$= \sqrt{100 + 9} = \sqrt{109}$

16. (a) $a = |6 - 2| = 4$

$b = |5 - (-2)| = 7$

$c = \sqrt{a^2 + b^2} = \sqrt{16 + 49} = \sqrt{65}$

(b) $c = \sqrt{(6 - 2)^2 + (-2 - 5)^2} = \sqrt{16 + 49} = \sqrt{65}$

17. $\sqrt{(x - 3)^2 + (5 - (-4))^2} = 15$

$(x - 3)^2 + 81 = 225$

$(x - 3)^2 = 144$

$x = 3 \pm 12 = -9, 15$

18. $\sqrt{(x + 9)^2 + (8 - (-4))^2} = 15$

$(x + 9)^2 + 144 = 225$

$(x + 9)^2 = 81$

$x = -9 \pm 9 = -18, 0$

19. $\sqrt{(-15 + 3)^2 + (y + 7)^2} = 20$

$144 + (y + 7)^2 = 400$

$(y + 7)^2 = 256$

$y = -7 \pm 16 = -23, 9$

20. $\sqrt{(-10 - 6)^2 + (y + 1)^2} = 20$

$256 + (y + 1)^2 = 400$

$(y + 1)^2 = 144$

$y = -1 \pm 12 = -13, 11$

21. $2x - 3y + 11 = 0$

(a) $2(2) - 3(5) + 11 = 0$, yes

(b) $2(3) - 3(2) + 11 = 11 \neq 0$, no

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

(a) $2(1)^2 - 7(1) + 3 = -2 \neq -1$, no

(b) $2(3)^2 - 7(3) + 3 = 0$, yes

23. $y = \sqrt{x - 5}$

(a) $\sqrt{9 - 5} = 2$, yes

(b) $\sqrt{21 - 5} = 4$, yes

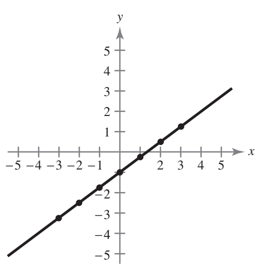
24. $y = \dfrac{x + 1}{5 - x}$

(a) $\dfrac{1 + 1}{5 - 1} = \dfrac{1}{2}$, yes

(b) $\dfrac{0 + 1}{5 - 0} = \dfrac{1}{5} \neq 1$, no

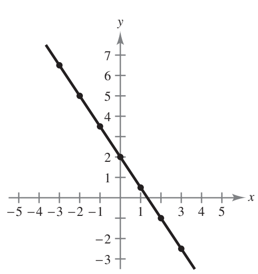
25. $y = \frac{3}{4}x - 1$

x	−3	−2	−1	0	1	2	3
y	−3.25	−2.5	−1.75	−1	−0.25	0.5	1.25



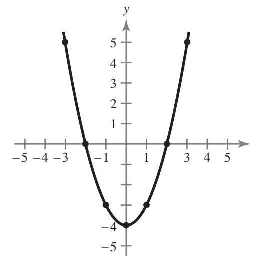
26. $\frac{3}{2}x + y = 2$

x	−3	−2	−1	0	1	2	3
y	6.5	5	3.5	2	0.5	−1	−2.5



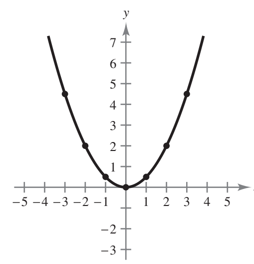
27.

x	−3	−2	−1	0	1	2	3
y	5	0	−3	−4	−3	0	5



28. $y = \frac{1}{2}x^2$

x	−3	−2	−1	0	1	2	3
y	4.5	2	0.5	0	0.5	2	4.5



29. $y = 2x - 1 = 0$

$x = \frac{1}{2}$

x-intercept: $\left(\frac{1}{2}, 0\right)$

$y = 2(0) - 1 = -1$

y-intercept: $(0, -1)$

30. $2x = -y - 6$

$2x = -0 - 6$

$2x = -6$

$x = -3$

x-intercept: $(-3, 0)$

$2(0) = -y - 6$

$0 = -y - 6$

$y = -6$

y-intercept: $(0, -6)$

31. $y = x^2 + x - 2 = 0$

$(x + 2)(x - 1) = 0$

$x = -2, 1$

x-intercepts: $(-2, 0), (1, 0)$

$y = 0^2 + 0 - 2 = -2$

y-intercept: $(0, -2)$

32. $y = 4 - x^2 = 0$

$(2 + x)(2 - x) = 0$

$x = -2, 2$

x-intercepts: $(-2, 0), (2, 0)$

$y = 4 - 0^2 = 4$

y-intercept: $(0, 4)$

33. $y = \sqrt{4 - x^2}$

$0 = \sqrt{4 - x^2}$

$0 = 4 - x^2$

$x^2 = 4$

$x = \pm 2$

x-intercepts: $(-2, 0), (2, 0)$

$y = \sqrt{4 - 0^2}$

$y = \sqrt{4}$

$y = 2$

y-intercept: $(0, 2)$

34. $y = \sqrt{x^2 + 9}$

$0 = \sqrt{x^2 + 9}$

$0 = x^2 + 9$

$x^2 = -9$

No x-intercept

$y = \sqrt{0^2 + 9}$

$y = \sqrt{9}$

$y = 3$

y-intercept: $(0, 3)$

35. $2y - xy + 3x = 4$

$2(0) - x(0) + 3x = 4$

$x = \frac{4}{3}$

x-intercept: $\left(\frac{4}{3}, 0\right)$

$2y - 0(y) + 3(0) = 4$

$y = 2$

y-intercept: $(0, 2)$

36. $x^2y - x^2 + 4y = 0$

$x^2(0) - x^2 + 4(0) = 0$

$x = 0$

x-intercept: $(0, 0)$

$0^2y - 0^2 + 4y = 0$

$y = 0$

y-intercept: $(0, 0)$

37. All the ordered pairs on the x-axis have a y-coordinate of zero: $(x, 0)$. So, to find an x-intercept, we let $y = 0$ in an equation and solve for x. Similarly, all ordered pairs on the y-axis have an x-coordinate of zero: $(0, y)$. So, to find a y-intercept, we let $x = 0$ and solve for y. (Answers will vary.)

38. It is possible for a graph to have no x-intercepts. Example: $y = x^2 + 3x + 7$. It is also possible for a graph to have no y-intercepts. Example: $y = \sqrt{x - 2}$. It is also possible for a graph to have no x- or y-intercepts. Example: $y = \frac{1}{x}$. (Answers will vary.)

39. $(-x)^4 - 2y = 0 \Rightarrow x^4 - 2y = 0$

y-axis symmetry

40. $y = (-x)^4 - (-x)^2 + 3 \Rightarrow y = x^4 - x^2 + 3$

y-axis symmetry

41. $x - (-y)^2 = 0 \Rightarrow x - y^2 = 0$

x-axis symmetry

42. $(-y)^2 = x + 2 \Rightarrow y^2 = x + 2$

x-axis symmetry

43. $y = \sqrt{16 - (-x)^2} \Rightarrow y = \sqrt{16 - x^2}$

y-axis symmetry

44. $y = \sqrt{4 - (-x)^2} \Rightarrow y = \sqrt{4 - x^2}$

y-axis symmetry

45. $-x(-y) = 2 \Rightarrow xy = 2$

Origin symmetry

46. $(-x)^3(-y) = 1 \Rightarrow x^3y = 1$

Origin symmetry

47. $-y = \dfrac{-x}{(-x)^2 - 4} \Rightarrow y = \dfrac{x}{x^2 - 4}$

Origin symmetry

48. $-y = \dfrac{-x}{(-x)^2 + 1} \Rightarrow y = \dfrac{x}{x^2 + 1}$

Origin symmetry

49. $(-x)^2 + y^2 = 25$

$x^2 + y^2 = 25$

y-axis symmetry

$x^2 + (-y)^2 = 25$

$x^2 + y^2 = 25$

x-axis symmetry

$(-x)^2 + (-y)^2 = 25$

$x^2 + y^2 = 25$

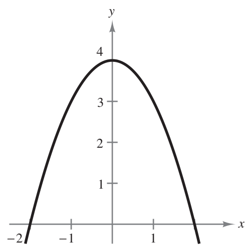
Origin symmetry

50. $(-x)^2 + y^2 = 9$ $\quad x^2 + (-y)^2 = 9$ $\quad (-x)^2 + (-y)^2 = 9$

$x^2 + y^2 = 9$ $\quad x^2 + y^2 = 9$ $\quad x^2 + y^2 = 9$

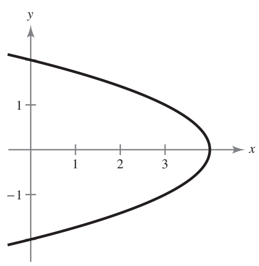
y-axis symmetry $\quad x$-axis symmetry $\quad$ Origin symmetry

51. $y = -x^2 + 4$ $\quad y$-axis symmetry



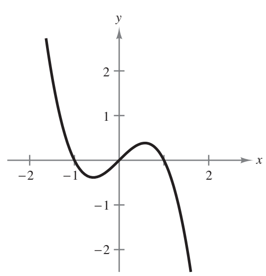
52. $y^2 = -x + 4$

x-axis symmetry



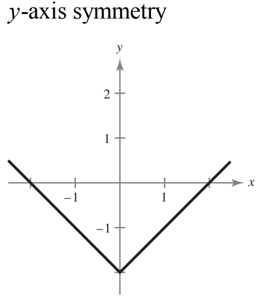
53. $y = -x^3 + x$

Origin symmetry



54. $y = |x| - 2$

y-axis symmetry



55. $y = 4 - x$ has intercepts (0, 4) and (4, 0); graph (c)

56. $y = \sqrt{4 - x^2}$ has intercepts $(-2, 0)$, $(0, 2)$, and $(2, 0)$; graph (d)

57. $y = x^2 + 2x$ has intercepts $(-2, 0)$ and $(0, 0)$; graph (f)

58. $y = \sqrt{x}$ has intercept (0, 0); graph (a)

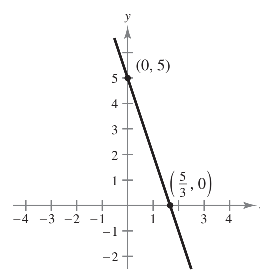
59. $y = x^3 - x$ has intercepts $(-1, 0)$, (0, 0), and (1, 0); graph (e)

60. $y = -\sqrt{4 - x^2}$ has intercepts $(-2, 0)$, $(0, -2)$, and $(2, 0)$; graph (b)

61. $y = 5 - 3x$

Intercepts: $(0, 5)$, $\left(\frac{5}{3}, 0\right)$

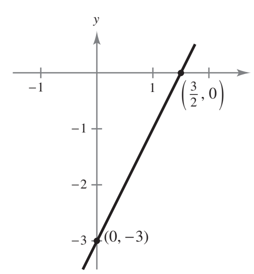
No symmetry



62. $y = 2x - 3$

Intercepts: $(0, -3)$, $\left(\frac{3}{2}, 0\right)$

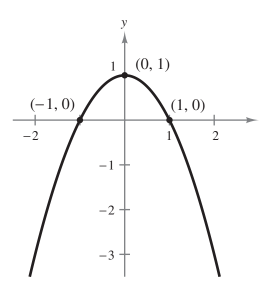
No symmetry



63. $y = 1 - x^2$

Intercepts: $(-1, 0)$, $(0, 1)$, $(1, 0)$

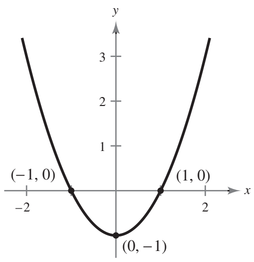
y-axis symmetry



64. $y = x^2 - 1$

Intercepts: $(-1, 0), (0, -1), (1, 0)$

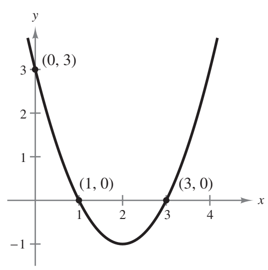
y-axis symmetry



65. $y = x^2 - 4x + 3$

Intercepts: $(0, 3), (1, 0), (3, 0)$

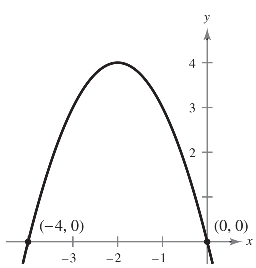
No symmetry



66. $y = -x^2 - 4x$

Intercepts: $(-4, 0), (0, 0)$

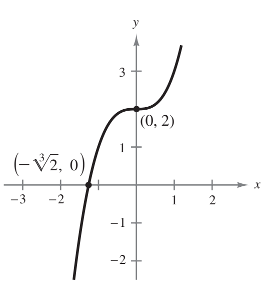
No symmetry



67. $y = x^3 + 2$

Intercepts: $\left(-\sqrt[3]{2}, 0\right), (0, 2)$

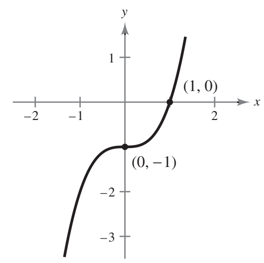
No symmetry



68. $y = x^3 - 1$

Intercepts: $(0, -1), (1, 0)$

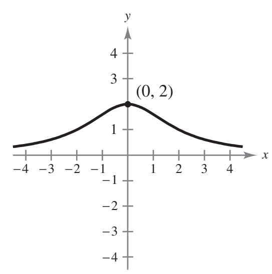
No symmetry



69. $y = \dfrac{8}{x^2 + 4}$

Intercept: $(0, 2)$

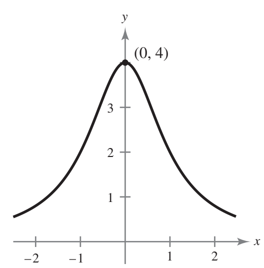
y-axis symmetry



70. $y = \dfrac{4}{x^2 + 1}$

Intercept: $(0, 4)$

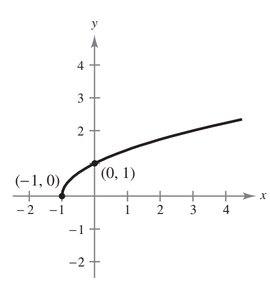
y-axis symmetry



71. $y = \sqrt{x + 1}$

Intercepts: $(-1, 0), (0, 1)$

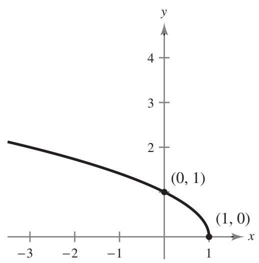
No symmetry



72. $y = \sqrt{1 - x}$

Intercepts: (0, 1), (1, 0)

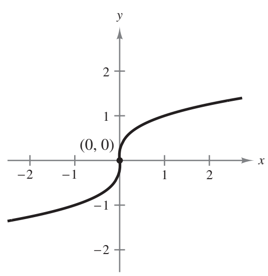
No symmetry



73. $y = \sqrt[3]{x}$

Intercept: (0, 0)

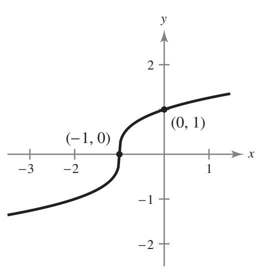
Origin symmetry



74. $y = \sqrt[3]{x + 1}$

Intercepts: (−1, 0), (0, 1)

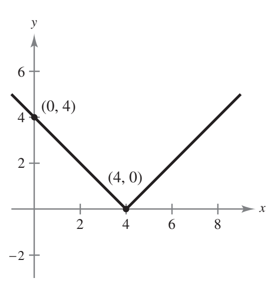
No symmetry



75. $y = |x - 4|$

Intercepts: (0, 4), (4, 0)

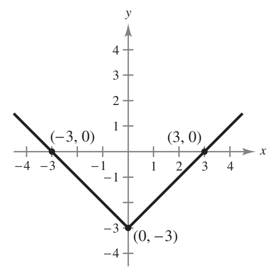
No symmetry



76. $y = |x| - 3$

Intercepts: (−3, 0), (0, −3), (3, 0)

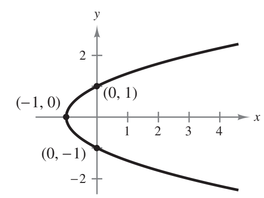
y-axis symmetry



77. $x = y^2 - 1$

Intercepts: (−1, 0), (0, −1), (0, 1)

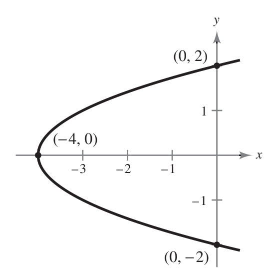
x-axis symmetry



78. $x = y^2 - 4$

Intercepts: (−4, 0), (0, −2), (0, 2)

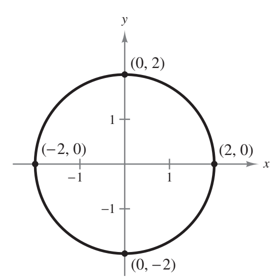
x-axis symmetry



79. $x^2 + y^2 = 4$

Intercepts: (−2, 0), (0, −2), (0, 2), (2, 0)

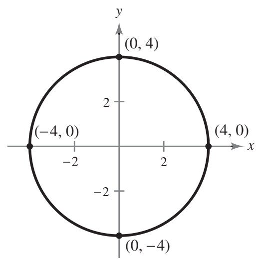
x-axis, y-axis, and origin symmetry



80. $x^2 + y^2 = 16$

Intercepts: (–4, 0), (0, –4), (0, 4), (4, 0)

x-axis, y-axis, and origin symmetry



81. $r = \sqrt{(4-4)^2 + (2-0)^2} = \sqrt{0+4} = 2$

82. $r = \sqrt{[1-(-1)]^2 + (4-4)^2} = \sqrt{4+0} = 2$

83. $r = \sqrt{(4-2)^2 + (3-2)^2} = \sqrt{4+1} = \sqrt{5}$

84. $r = \sqrt{(0-3)^2 + (3-1)^2} = \sqrt{13}$

85. Center: $\left(\dfrac{5+1}{2}, \dfrac{3+1}{2}\right) = (3, 2)$

$$2r = \sqrt{(3-1)^2 + (5-1)^2}$$
$$2r = 2\sqrt{5}$$
$$r = \sqrt{5}$$

86. Center: $\left(\dfrac{-6+1}{2}, \dfrac{-3-5}{2}\right) = \left(-\dfrac{5}{2}, -4\right)$

$$2r = \sqrt{(-6-1)^2 + (-3+5)^2}$$
$$2r = \sqrt{53}$$
$$r = \frac{\sqrt{53}}{2}$$

87. $x^2 + y^2 = 3^2$

$x^2 + y^2 = 9$

88. $x^2 + y^2 = 5^2$

$x^2 + y^2 = 25$

89. $[x-(-4)]^2 + (y-1)^2 = (\sqrt{2})^2$

$(x+4)^2 + (y-1)^2 = 2$

90. $x^2 + \left(y - \frac{1}{2}\right)^2 = \left(\frac{2}{3}\right)^2$

$x^2 + \left(y - \frac{1}{2}\right)^2 = \frac{4}{9}$

91. $[x-(-1)]^2 + (y-2)^2 = [0-(-1)]^2 + (0-2)^2$

$(x+1)^2 + (y-2)^2 = 5$

92. $(x-3)^2 + [y-(-2)]^2 = (-1-3)^2 + [1-(-2)]^2$

$(x-3)^2 + (y+2)^2 = 25$

93. $r = \dfrac{1}{2}\sqrt{(-3-5)^2 + [4-(-2)]^2} = 5$

Center: $\left(\dfrac{-3+5}{2}, \dfrac{4+(-2)}{2}\right) = (1, 1)$

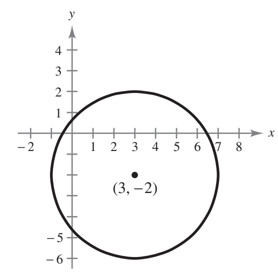
$(x-1)^2 + (y-1)^2 = 25$

94. $r = \dfrac{1}{2}\sqrt{(4+4)^2 + (1+1)^2} = \sqrt{17}$

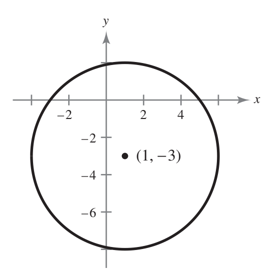
Center: $\left(\dfrac{-4+4}{2}, \dfrac{-1+1}{2}\right) = (0, 0)$

$x^2 + y^2 = 17$

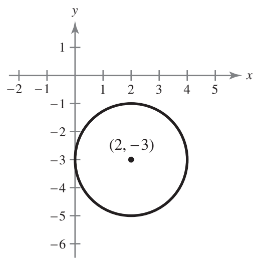
95.
$$x^2 + y^2 - 6x + 4y - 3 = 0$$
$$(x^2 - 6x + 9) + (y^2 + 4y + 4) = 3 + 9 + 4$$
$$(x-3)^2 + (y+2)^2 = 16$$



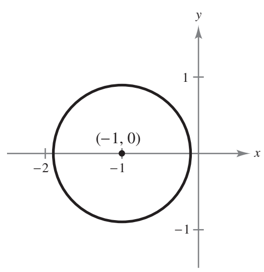
96.
$$x^2 + y^2 - 2x + 6y - 15 = 0$$
$$(x^2 - 2x + 1) + (y^2 + 6y + 9) = 15 + 1 + 9$$
$$(x-1)^2 + (y+3)^2 = 25$$



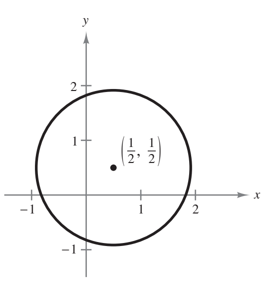
97. $$x^2 + y^2 - 4x + 6y + 9 = 0$$
$$(x^2 - 4x + 4) + (y^2 + 6y + 9) = -9 + 9 + 4$$
$$(x - 2)^2 + (y + 3)^2 = 4$$



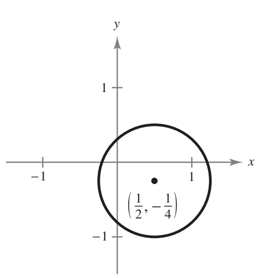
98. $$5x^2 + 5y^2 + 10x + 1 = 0$$
$$5(x^2 + 2x + 1) + 5y^2 = -1 + 5$$
$$(x + 1)^2 + y^2 = \frac{4}{5}$$



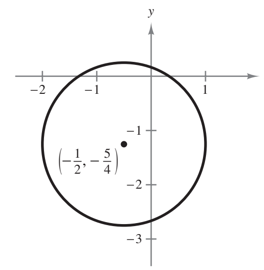
99. $$2x^2 + 2y^2 - 2x - 2y - 3 = 0$$
$$\left(x^2 - x + \frac{1}{4}\right) + \left(y^2 - y + \frac{1}{4}\right) = \frac{3}{2} + \frac{1}{4} + \frac{1}{4}$$
$$\left(x - \frac{1}{2}\right)^2 + \left(y - \frac{1}{2}\right)^2 = 2$$



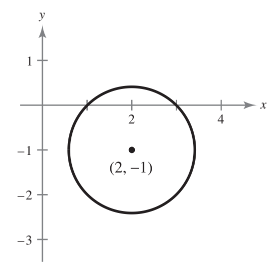
100. $$4x^2 + 4y^2 - 4x + 2y - 1 = 0$$
$$\left(x^2 - x + \frac{1}{4}\right) + \left(y^2 + \frac{1}{2}y + \frac{1}{16}\right) = \frac{1}{4} + \frac{1}{4} + \frac{1}{16}$$
$$\left(x - \frac{1}{2}\right)^2 + \left(y + \frac{1}{4}\right)^2 = \frac{9}{16}$$



101. $$16x^2 + 16y^2 + 16x + 40y - 7 = 0$$
$$\left(x^2 + x + \frac{1}{4}\right) + \left(y^2 + \frac{5}{2}y + \frac{25}{16}\right) = \frac{7}{16} + \frac{1}{4} + \frac{25}{16}$$
$$\left(x + \frac{1}{2}\right)^2 + \left(y + \frac{5}{4}\right)^2 = \frac{9}{4}$$



102. $$x^2 + y^2 - 4x + 2y + 3 = 0$$
$$(x^2 - 4x + 4) + (y^2 + 2y + 1) = -3 + 4 + 1$$
$$(x - 2)^2 + (y + 1)^2 = 2$$



103. Center: $(3, -1)$, Radius: 5
$$(x - 3)^2 + (y + 1)^2 = 25$$
$$x^2 - 6x + 9 + y^2 + 2y + 1 - 25 = 0$$
$$x^2 + y^2 - 6x + 2y - 15 = 0$$

104. Center: $\left(\frac{1}{2}, 2\right)$, Radius: $\sqrt{7}$
$$\left(x - \frac{1}{2}\right)^2 + (y - 2)^2 = 7$$
$$x^2 - x + \frac{1}{4} + y^2 - 4y + 4 - 7 = 0$$
$$x^2 + y^2 - x - 4y - \frac{11}{4} = 0$$

105. Answers will vary.

(a) From the graph, estimate the points:

1994: $(4, 2350)$

2000: $(10, 2750)$

$$\text{Percent increase} = \frac{2750 - 2350}{2350} \approx 0.17, \text{ or } 17\%$$

(b) From the graph, estimate the points:

2000: $(10, 2750)$

2008: $(18, 2975)$

$$\text{Percent increase} = \frac{2975 - 2750}{2750} \approx 0.08, \text{ or } 8\%$$

106. (a) The highest price is about \$950 in 2009.

(b) The lowest price is about \$100 in 1976.

(c) The highest average price of gold between 1975 and 2000 was about \$650 in 1985. This is not necessarily the highest price that gold ever reached, it is just the average of the 1985 prices. At some point in 1985 the price could have been higher.

107. (a) $y = 5.3(0) + 482 = 482$

y-intercept: $(0, 482)$

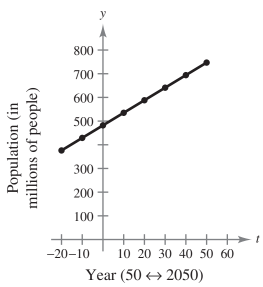
The y-intercept represents the population (in millions of people) of North America in 2000.

(b)

x	−20	−10	0	10
y	376	429	482	535

x	20	30	40	50
y	588	641	694	747

(c)



108. (a) $y = -0.03(0)^2 + 5.0(0) + 351 = 351$

y-intercept: $(0, 351)$

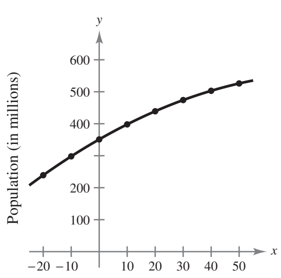
The y-intercept represents the population of South America in 2000, 351 million people.

(b)

x	−20	−10	0	10
y	239	298	351	398

x	20	30	40	50
y	439	474	503	526

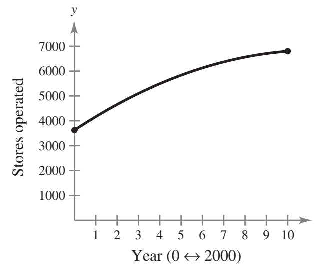
(c)



109. (a) $y = -24.91t^2 + 566.6t + 3624$

t	0	1	2	3	4
y	3624	4166	4658	5100	5492

t	5	6	7	8	9	10
y	5834	6127	6370	6563	6706	6799



(b) When $t = 11$:

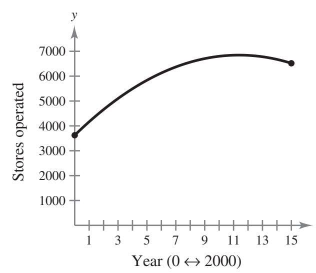
$y = -24.91(11)^2 + 566.6(11) + 3624 = 6842.49$

According to the model, in 2011 there will be about 6843 stores. The model's prediction for 2011 is not close to the plan of Family Dollar Stores.

(c)

t	12	13	14	15
y	6836.16	6780.01	6674.04	6518.25

(d)



(e) The model does not support the company's expectations since the number of stores declines from 2013 to 2015. The graph begins to decrease in 2011.

110. The center is at $(0, 75)$ and the radius is 75 m so

$$(x - 0)^2 + (y - 75)^2 = 75^2$$

$$x^2 + y^2 - 150y + 5625 = 5625$$

The model is: $x^2 + y^2 - 150y = 0$.

111. (a) The center is at $(0, 0)$ and the radius is 87.5 cm so

$$x^2 + y^2 = (87.5)^2$$
$$x^2 + y^2 = 7656.25$$

(b) Quadrant II, Quadrant III, Quadrant II, Quadrant I, Quadrant IV

(c) $d = \sqrt{[52 - (-40)]^2 + (-40 - 0)^2}$
$= \sqrt{92^2 + (-40)^2}$
$= \sqrt{10{,}064} \approx 100.3$

The rat is about 100 cm from the platform.

Section 2.2 Lines in the Plane

Skills Warm Up

1. $\dfrac{4 - (-4)}{-3 - (-1)} = \dfrac{4 + 4}{-3 + 1} = \dfrac{8}{-2} = -4$

2. $\dfrac{-5 - 8}{0 - (-3)} = -\dfrac{13}{3}$

3. $\dfrac{-1}{\frac{4}{5}} = -\dfrac{5}{4}$

4. When $m = -3$:

$-\dfrac{1}{m} = -\dfrac{1}{-3} = \dfrac{1}{3}.$

5. $2x - 3y = 6$
$-3y = 6 - 2x$
$y = \frac{2}{3}x - 2$

6. $4x + 2y = 0$
$2y = -4x$
$y = -2x$

7. $y - (-4) = 3[x - (-1)]$
$y + 4 = 3(x + 1)$
$y + 4 = 3x + 3$
$y = 3x - 1$

8. $y - 7 = \frac{2}{3}(x - 3)$
$y - 7 = \frac{2}{3}x - 2$
$y = \frac{2}{3}x + 5$

9. $y - (-1) = \dfrac{3 - (-1)}{2 - 4}(x - 4)$
$y + 1 = -\dfrac{4}{2}(x - 4)$
$y + 1 = -2(x - 4)$
$y + 1 = -2x + 8$
$y = -2x + 7$

10. $y - 5 = \dfrac{3 - 5}{0 - 2}(x - 2)$
$y - 5 = \dfrac{-2}{-2}(x - 2)$
$y - 5 = x - 2$
$y = x + 3$

1. slope $= \dfrac{\text{rise}}{\text{run}} = \dfrac{2}{4} = \dfrac{1}{2}$

2. slope $= \dfrac{\text{rise}}{\text{run}} = \dfrac{4}{2} = 2$

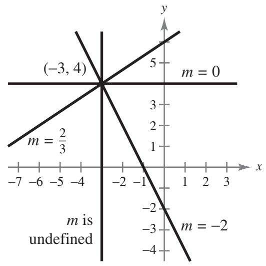
3. slope $= \dfrac{\text{rise}}{\text{run}} = \dfrac{4}{-2} = -2$

4. slope $= \dfrac{\text{rise}}{\text{run}} = \dfrac{1}{-3} = -\dfrac{1}{3}$

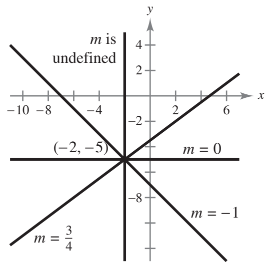
5. (a) L_2
(b) L_3
(c) L_1

6. (a) L_2
(b) L_1
(c) L_3

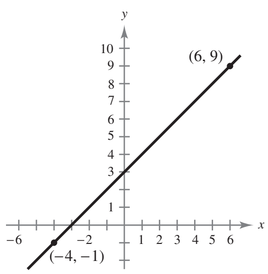
7.



8.

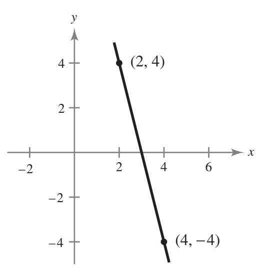


9.



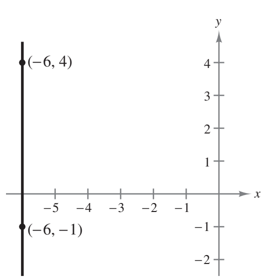
$$\text{slope} = \frac{9+1}{6+4} = 1$$

10.



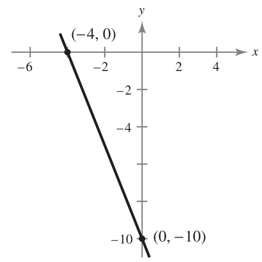
$$\text{slope} = \frac{-4-4}{4-2} = -4$$

11.



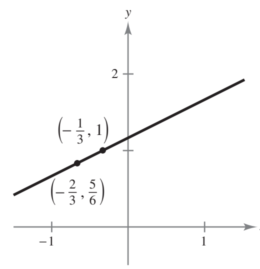
Slope is undefined.

12.



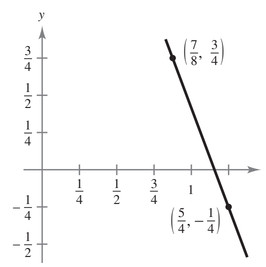
$$\text{slope} = \frac{-10-0}{0+4} = -\frac{5}{2}$$

13.



$$\text{slope} = \frac{1-\frac{5}{6}}{-\frac{1}{3}-\left(-\frac{2}{3}\right)} = \frac{1}{2}$$

14.



$$\text{slope} = \frac{-\frac{1}{4}-\frac{3}{4}}{\frac{5}{4}-\frac{7}{8}} = \frac{-1}{\frac{3}{8}} = -\frac{8}{3}$$

15. Since $m = 0$, y does not change. Three points are $(0, -2)$, $(-1, -2)$, and $(3, -2)$.

16. Since $m = 0$, y does not change. Three points are $(0, 4)$, $(5, 4)$, and $(-1, 4)$.

17. Since m is undefined, x does not change. Three points are $(2, 3)$, $(2, 0)$, and $(2, -1)$.

18. Since m is undefined, x does not change. Three points are $(-1, 0)$, $(-1, 3)$, and $(-1, 5)$.

19. Since $m = -1$, y increases by 1 for every 1 unit increase in x. Three points are $(7, -4)$, $(8, -3)$, and $(6, -5)$.

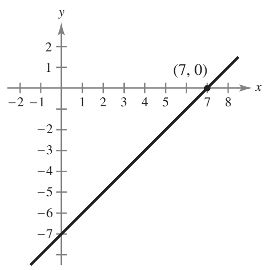
20. Since $m = -1$, y decreases by 1 for every 1 unit increase in x. Three points are $(0, 4)$, $(9, -5)$, and $(11, -7)$.

21. Since $m = \frac{1}{2}$, y increases by 1 for every 2 unit increase in x. Three points are (–4, 0), (–2, 1), and (0, 2).

22. Since $m = -\frac{2}{3}$, y will decrease by 2 units for each 3 unit increase in x. Three points are (10, –7), (13, –9), and (16, –11).

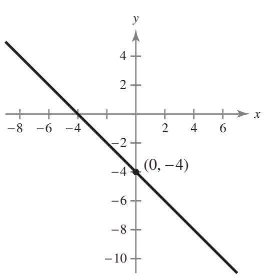
23. $y = 1(x - 7)$

$y = x - 7 \Rightarrow x - y - 7 = 0$



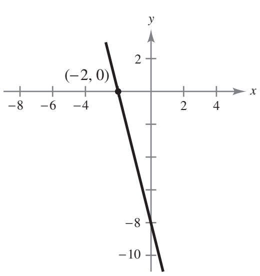
24. $y + 4 = -1(x - 0)$

$y + 4 = -x \Rightarrow x + y + 4 = 0$



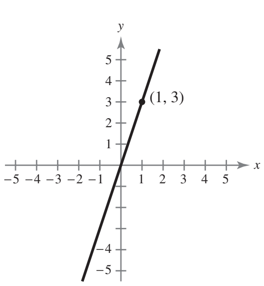
25. $y - 0 = -4(x + 2)$

$y = -4x - 8 \Rightarrow 4x + y + 8 = 0$



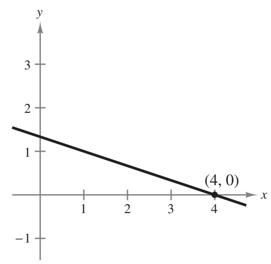
26. $y - 3 = 3(x - 1)$

$y - 3 = 3x - 3 \Rightarrow 3x - y = 0$



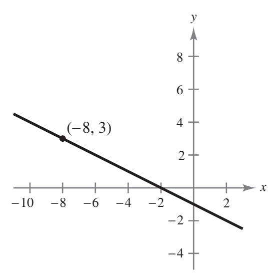
27. $y - 0 = -\frac{1}{3}(x - 4)$

$y = -\frac{1}{3}x + \frac{4}{3} \Rightarrow x + 3y - 4 = 0$



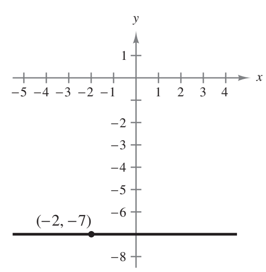
28. $y - 3 = -\frac{1}{2}(x + 8)$

$y = -\frac{1}{2}x - 1 \Rightarrow x + 2y + 2 = 0$



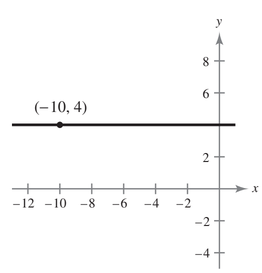
29. $y = -7$

$y + 7 = 0$



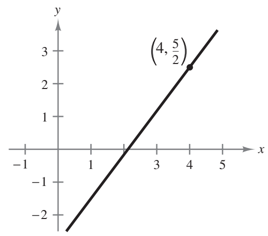
30. $y = 4$

$y - 4 = 0$



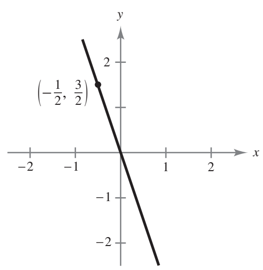
31. $y - \frac{5}{2} = \frac{4}{3}(x - 4)$

$y = \frac{4}{3}x - \frac{17}{6} \Rightarrow 8x - 6y - 17 = 0$



32. $y - \frac{3}{2} = -3\left(x + \frac{1}{2}\right)$

$y = -3x \Rightarrow 3x + y = 0$



33. $y - 0 = \dfrac{-4 - 0}{-1 - 0}(x - 0)$

$y = 4x \Rightarrow 4x - y = 0$

34. $y - 0 = \dfrac{-1 - 0}{6 - 0}(x - 0)$

$y = \dfrac{-1}{6}x \Rightarrow x + 6y = 0$

35. $y + 4 = \left(\dfrac{3 + 4}{-7 - 7}\right)(x - 7)$

$y = -\dfrac{1}{2}(x - 7) - 4$

$y = -\dfrac{1}{2}x - \dfrac{1}{2} \Rightarrow x + 2y + 1 = 0$

36. $y - 3 = \dfrac{-4 - 3}{-4 - 4}(x - 4)$

$y = \dfrac{7}{8}(x - 4) + 3$

$y = \dfrac{7}{8}x - \dfrac{1}{2} \Rightarrow 7x - 8y - 4 = 0$

37. Because both x-coordinates are –9, this is a vertical line with undefined slope.

$x = -9 \Rightarrow x + 9 = 0$

38. Because both x-coordinates are 3, this is a vertical line with undefined slope.

$x = 3 \Rightarrow x - 3 = 0$

39. Because both y-coordinates are 7, this is a horizontal line with a slope of 0.

$y = 7 \Rightarrow y - 7 = 0$

40. Because both y-coordinates are –2, this is a horizontal line with a slope of 0.

$y = -2 \Rightarrow y + 2 = 0$

41. $y - \dfrac{1}{2} = \dfrac{\frac{5}{4} - \frac{1}{2}}{\frac{1}{2} - 2}(x - 2)$

$y = -\dfrac{1}{2}(x - 2) + \dfrac{1}{2}$

$y = -\dfrac{1}{2}x + \dfrac{3}{2} \Rightarrow x + 2y - 3 = 0$

42. $y - 1 = \dfrac{-\frac{2}{3} - 1}{6 - 1}(x - 1)$

$y = -\dfrac{1}{3}(x - 1) + 1$

$y = -\dfrac{1}{3}x + \dfrac{4}{3} \Rightarrow x + 3y - 4 = 0$

43. $y - 0.6 = \dfrac{-0.6 - 0.6}{-2 - 1}(x - 1)$

$y = 0.4(x - 1) + 0.6$

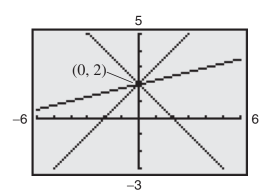
$y = 0.4x + 0.2 \Rightarrow 2x - 5y + 1 = 0$

44. $y - 0.6 = \dfrac{-2.4 - 0.6}{2 + 8}(x + 8)$

$y = -0.3(x + 8) + 0.6$

$y = -0.3x - 1.8 \Rightarrow 3x + 10y + 18 = 0$

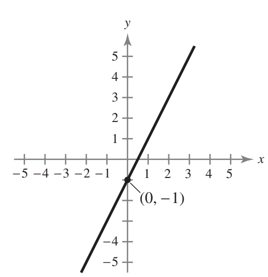
45.



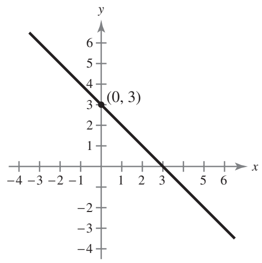
The y-intercept of each graph is $(0, 2)$.

46. The coefficient of x gives the slope of the line when the line is written in slope-intercept form.

47. $m = 2, (0, -1)$



48. $m = -1, (0, 3)$

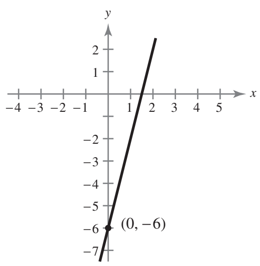


49. $4x - y - 6 = 0$

$y = 4x - 6$

Slope: $m = 4$

y-intercept: $(0, 6)$

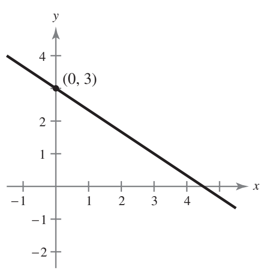


50. $2x + 3y - 9 = 0$

$y = -\frac{2}{3}x + 3$

Slope: $m = -\frac{2}{3}$

y-intercept: $(0, 3)$

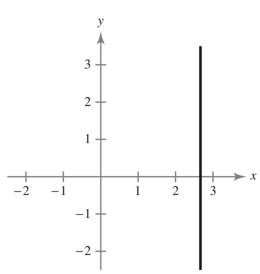


51. $8 - 3x = 0$

$x = \frac{8}{3}$

Slope: undefined

No y-intercept



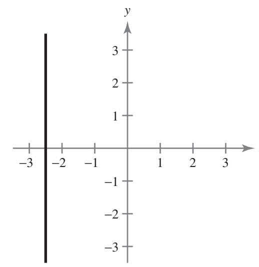
52. $2x + 5 = 0$

$2x = -5$

$x = -\frac{5}{2}$

Slope: undefined

No y-intercept

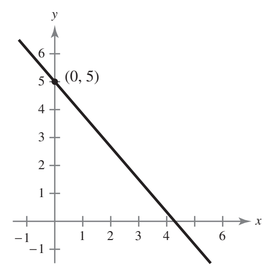


53. $7x + 6y - 30 = 0$

$y = -\frac{7}{6}x + 5$

Slope: $m = -\frac{7}{6}$

y-intercept: $(0, 5)$

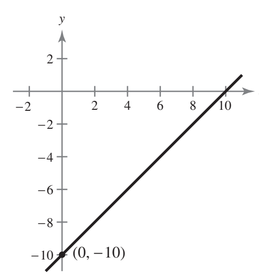


54. $x - y - 10 = 0$

$y = x - 10$

Slope: $m = 1$

y-intercept: $(0, -10)$



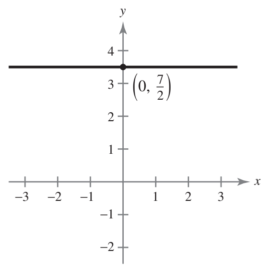
55. $2y - 7 = 0$

$2y = 7$

$y = \frac{7}{2}$

Slope: 0

y-intercept: $\left(0, \frac{7}{2}\right)$



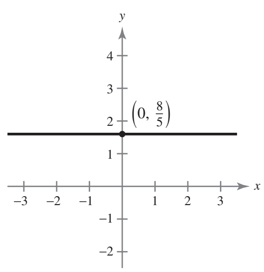
56. $8 - 5y = 0$

$-5y = -8$

$y = \frac{8}{5}$

Slope: 0

y-intercept: $\left(0, \frac{8}{5}\right)$



57. You could graph a vertical line and pick two convenient points on the vertical line. Find the slope. Regardless of the vertical line selected and the points selected, the slope formula would have zero in the denominator. Division by zero is not possible—so the slope does not exist. (Answers may vary.)

58. First, repeat the activity in Exercise 57, using a horizontal line. In this case, regardless of the horizontal line selected and the points selected, the slope formula will have zero in the numerator. Zero divided by any nonzero number is zero. For example, $\frac{0}{4}$ asks the question "what should 4 be multiplied by to yield zero?" The answer is zero. If we try to divide by zero, such as in $\frac{5}{0}$, we are asking "what should zero be multiplied by to yield 5?" There is no number that we can multiply zero by to yield 5 so division by zero is not possible and the slope is undefined. (Answers may vary.)

59. $\frac{x}{1} + \frac{y}{-4} = 1$

$4x - y - 4 = 0$

60. $-\frac{x}{3} + \frac{y}{4} = 1$

$4x - 3y + 12 = 0$

61. $\frac{x}{-2} + \frac{y}{-2} = 1$

$x + y + 2 = 0$

62. $\frac{x}{5} + \frac{y}{1} = 1$

$x + 5y - 5 = 0$

63. $\frac{x}{-1/6} + \frac{y}{-2/3} = 1$

$6x + \frac{3}{2}y = -1$

$12x + 3y + 2 = 0$

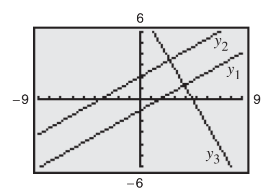
64. $\frac{x}{-\frac{2}{3}} + \frac{y}{\frac{1}{2}} = 1$

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

$3x - 4y + 2 = 0$

65. Changing the viewing window will affect the appearance of the slope of the line. Answers will vary.

66.



(a) The two lines with the same slope are parallel to each other.

(b) Perpendicular lines have slopes that are negative reciprocals of each other.

67. $m_{L_1} = 3$

$m_{L_2} = 1$

L_1 and L_2 are neither parallel nor perpendicular.

68. $m_{L_1} = \frac{3}{4}$

$m_{L_2} = -\frac{4}{3}$

L_1 and L_2 are perpendicular.

69. $2x - y = 1$ $\quad$ $x + 2y = -1$

$-y = -2x + 1$ $\quad$ $2y = -x - 1$

$y = 2x - 1$ $\quad$ $y = -\frac{1}{2}x - \frac{1}{2}$

L_1 and L_2 are perpendicular.

70. $x - 5y = -2$ $\quad -3x + 15y = 6$

$-5y = -x - 2$ $\quad 15y = 6 + 3x$

$y = \frac{1}{5}x + \frac{2}{5}$ $\quad y = \frac{1}{5}x + \frac{2}{5}$

L_1 and L_2 are parallel.

71. $x - 3y = -3$ $\quad 2x - 6y = 6$

$-3y = -x - 3$ $\quad -6y = -2x + 6$

$y = \frac{1}{3}x + 1$ $\quad y = \frac{1}{3}x - 1$

L_1 and L_2 are parallel.

72. $4x - y = -2$ $\quad 8x - 2y = 6$

$-y = -4x - 2$ $\quad -2y = -8x + 6$

$y = 4x + 2$ $\quad y = 4x - 3$

L_1 and L_2 are parallel.

73. $2x - 3y - 15 = 0$ $\quad 3x + 2y + 8 = 0$

$-3y = -2x + 15$ $\quad 2y = -3x - 8$

$y = \frac{2}{3}x - 5$ $\quad y = -\frac{3}{2}x - 4$

L_1 and L_2 are perpendicular.

74. $x - 4y - 12 = 0$ $\quad 3x - 4y - 8 = 0$

$-4y = -x + 12$ $\quad -4y = -3x + 8$

$y = \frac{1}{4}x - 3$ $\quad y = \frac{3}{4}x - 2$

L_1 and L_2 are neither parallel nor perpendicular.

75. $m_{L_1} = \dfrac{1 - 0}{-2 + 5} = \dfrac{1}{3}$

$m_{L_2} = \dfrac{2 - 1}{3 - 0} = \dfrac{1}{3} = m_{L_1}$

L_1 and L_2 are parallel.

76. $m_{L_1} = \dfrac{4 - 6}{1 + 1} = \dfrac{-2}{2} = -1$

$m_{L_2} = \dfrac{-9 + 3}{6 - 3} = \dfrac{-6}{3} = -2$

L_1 and L_2 are neither parallel nor perpendicular.

77. $m_{L_1} = \dfrac{9 + 1}{5 - 0} = 2$

$m_{L_2} = \dfrac{1 - 3}{4 - 0} = -\dfrac{1}{2} = -\dfrac{1}{m_{L_1}}$

L_1 and L_2 are perpendicular.

78. $m_{L_1} = \dfrac{0 - 6}{-6 - 3} = \dfrac{2}{3}$

$m_{L_2} = \dfrac{\frac{7}{3} + 1}{5 - 0} = \dfrac{2}{3} = m_{L_1}$

L_1 and L_2 are parallel.

79. $m_{L_1} = \dfrac{5 + 1}{1 + 2} = 2$

$m_{L_2} = \dfrac{-5 - 3}{5 - 1} = -2$

L_1 and L_2 are neither parallel nor perpendicular.

80. $m_{L_1} = \dfrac{2 - 8}{-4 - 4} = \dfrac{3}{4}$

$m_{L_2} = \dfrac{\frac{1}{3} + 5}{-1 - 3} = -\dfrac{4}{3} = -\dfrac{1}{m_{L_1}}$

L_1 and L_2 are perpendicular.

81. $m_{L_1} = \dfrac{4 - 7}{-6 + 1} = \dfrac{3}{5}$

$m_{L_2} = \dfrac{4 - 1}{5 - 0} = \dfrac{3}{5} = m_{L_1}$

L_1 and L_2 are parallel.

82. $m_{L_1} = \dfrac{-5 - 3}{2 + 1} = -\dfrac{8}{3}$

$m_{L_2} = \dfrac{-7 - 0}{2 - 3} = 7$

L_1 and L_2 are neither parallel nor perpendicular.

83. $y - 2x = -1$

$y = 2x - 1$

Slope: $m = 2$

(a) $y - 2 = 2(x - 6)$

$y = 2x - 10 \Rightarrow 2x - y - 10 = 0$

(b) $y - 2 = -\frac{1}{2}(x - 6)$

$y = -\frac{1}{2}x + 5 \Rightarrow x + 2y - 10 = 0$

84. $x + y = 8$

$y = -x + 8$

Slope: $m = -1$

(a) $y - 4 = -1(x + 5)$

$y = -x - 1 \Rightarrow x + y + 1 = 0$

(b) $y - 4 = 1(x + 5)$

$y = x + 9 \Rightarrow x - y + 9 = 0$

85. $2x - 3y = 5$

$y = \frac{2}{3}x - \frac{5}{3}$

Slope: $m = \frac{2}{3}$

(a) $y + \frac{2}{3} = \frac{2}{3}\left(x - \frac{1}{4}\right)$

$y = \frac{2}{3}x - \frac{5}{6} \Rightarrow 4x - 6y - 5 = 0$

(b) $y + \frac{2}{3} = -\frac{3}{2}\left(x - \frac{1}{4}\right)$

$y = -\frac{3}{2}x - \frac{7}{24} \Rightarrow 36x + 24y + 7 = 0$

86. $5x + 3y = 0$

$y = -\frac{5}{3}x$

Slope: $m = -\frac{5}{3}$

(a) $y - \frac{3}{4} = -\frac{5}{3}\left(x - \frac{7}{8}\right)$

$y = -\frac{5}{3}x + \frac{53}{24} \Rightarrow 40x + 24y - 53 = 0$

(b) $y - \frac{3}{4} = \frac{3}{5}\left(x - \frac{7}{8}\right)$

$y = \frac{3}{5}x + \frac{9}{40} \Rightarrow 24x - 40y + 9 = 0$

87. $y = -3$

Slope: $m = 0$

(a) $y = 0$

(b) $x = -1 \Rightarrow x + 1 = 0$

88. $x = 4$

Slope: undefined

(a) $x = 2 \Rightarrow x - 2 = 0$

(b) $y = 5 \Rightarrow y - 5 = 0$

89. $m = \dfrac{34}{30(12)} = \dfrac{17}{180} > \dfrac{1}{12}$

Because $\frac{17}{180} > \frac{1}{12}$, the ramp is steeper than recommended.

90. (a) ii; $y = -10x + 100$

(b) iii; $y = 1.50x + 12.50$

(c) i; $y = 0.51x + 30$

(d) iv; $y = -100x + 800$

91. $C - 0 = \dfrac{100 - 0}{212 - 32}(F - 32)$

$C = \dfrac{5}{9}(F - 32)$ or $F = \dfrac{9}{5}C + 32$

92.

C	−17.8°	−10°	10°	20°	32.2°	177°
F	0°	14°	50°	68°	90°	350.6°

$C = F$ at $-40°$.

93. $y - 165{,}000 = \left(\dfrac{165{,}000 - 158{,}000}{2 - 1}\right)(x - 2)$

$y - 165{,}000 = 7000x - 14{,}000$

$y = 7000x + 151{,}000$

When $x = 4$, $y = 7000(4) + 151{,}000 = \$179{,}000$.

No, sales may not follow this linear pattern.

94. Let $t =$ years since 2000
and $y =$ number of Auto Zone stores.

$y - 3483 = \left(\dfrac{4056 - 3483}{7 - 4}\right)(t - 4)$

$y - 3483 = 191t - 764$

$y = 191t + 2719$

When $t = 10$, $y = 191(10) + 2719 = 4629$.

According to the model, in 2010 Auto Zone operated 4629 stores. Because the actual number of Auto Zone stores was 4627, the actual increase appears to be approximately linear.

95. $m = \dfrac{4 - 1}{99 - 0} = \dfrac{1}{33}$ atmosphere per foot

$p - 4 = \dfrac{1}{33}(d - 99)$

$p - 4 = \dfrac{1}{33}d - 3$

$p = \dfrac{1}{33}d + 1$

96. $y - 6 = \frac{1}{2}(x + 1)$

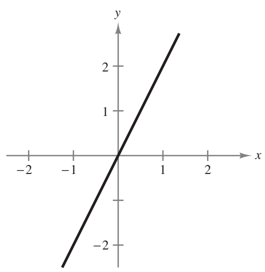
$y - 6 = \frac{1}{2}x + \frac{1}{2}$

$y = \frac{1}{2}x + \frac{13}{2}$

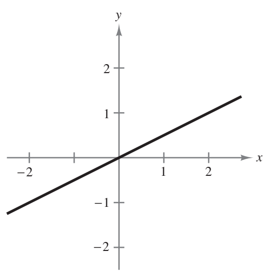
Section 2.3 Linear Modeling and Direct Variation

Skills Warm Up

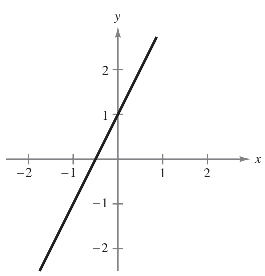
1.



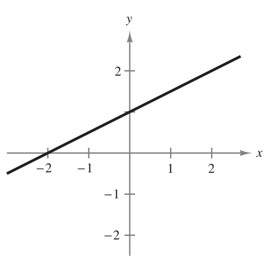
2.



3.



4.



5. $y = x + 2$

6. $y = \frac{3}{2}x + 3$

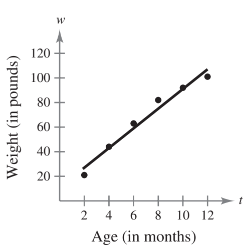
7.
$$m = \frac{8 - 3}{6 - 1} = \frac{5}{5} = 1$$
$$y - 3 = x - 1$$
$$y = x + 2$$

8.
$$m = \frac{10 - 4}{7 - 0} = \frac{6}{7}$$
$$y - 4 = \frac{6}{7}x$$
$$y = \frac{6}{7}x + 4$$

9.
$$m = \frac{4.7 - 5.2}{5 - 1} = -\frac{1}{8}$$
$$y - 5.2 = -\frac{1}{8}(x - 1)$$
$$y - 5.2 = -\frac{1}{8}x + \frac{1}{8}$$
$$y = -\frac{1}{8}x + \frac{213}{40}$$
$$5x + 40y - 213 = 0$$

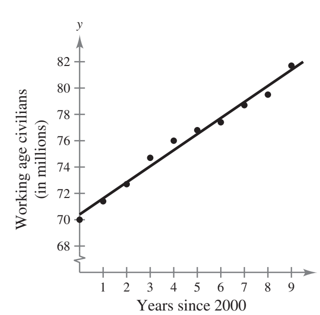
10.
$$m = \frac{3.6 - 6.5}{8 - 2} = -\frac{29}{60}$$
$$y - 6.5 = -\frac{29}{60}(x - 2)$$
$$y - 6.5 = -\frac{29}{60}x + \frac{29}{30}$$
$$y = -\frac{29}{60}x + \frac{112}{15}$$
$$29x + 60y - 448 = 0$$

1.

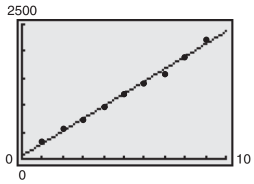


The model is a good fit for the actual data.

2.

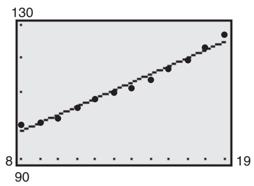


The model is a good fit for the actual data.

3. 

$y = 231.1x + 53.256$

The model is a good fit for the actual data.

4. 

$y = 2.44x + 78.75$

The model is a good fit for the actual data.

5.
$$\begin{aligned} y &= mx \\ 3 &= m(8) \\ \tfrac{3}{8} &= m \\ y &= \tfrac{3}{8}x \end{aligned}$$

6.
$$\begin{aligned} y &= mx \\ 9 &= m(5) \\ \tfrac{9}{5} &= m \\ y &= \tfrac{9}{5}x \end{aligned}$$

7.
$$\begin{aligned} y &= mx \\ 300 &= m(15) \\ 20 &= m \\ y &= 20x \end{aligned}$$

8.
$$\begin{aligned} y &= mx \\ 204 &= m(12) \\ 17 &= m \\ y &= 17x \end{aligned}$$

9.
$$\begin{aligned} y &= mx \\ 3.2 &= m(7) \\ \tfrac{16}{35} &= m \\ y &= \tfrac{16}{35}x \end{aligned}$$

10.
$$\begin{aligned} y &= mx \\ 1.5 &= m(11) \\ \tfrac{3}{22} &= m \\ y &= \tfrac{3}{22}x \end{aligned}$$

11. $H = \frac{27}{9}p = 3p$

12. $s = \frac{32}{4}t = 8t$

13. $c = \frac{12}{20}d = \frac{3}{5}d$

14. $r = \frac{25}{40}s = \frac{5}{8}s$

15.
$$\begin{aligned} I &= kP \\ 120 &= k(2000) \\ 0.06 &= k \\ I &= 0.06P \end{aligned}$$

16.
$$\begin{aligned} I &= kP \\ 280 &= k(4000) \\ 0.07 &= k \\ I &= 0.07P \end{aligned}$$

17. (a)
$$\begin{aligned} y &= kx \\ 2211 &= k(165{,}000) \\ 0.0134 &= k \\ y &= 0.0134x \end{aligned}$$

(b) When $x = 185{,}000$,

$y = 0.0134(185{,}000) = 2479.$

The property tax on a house with assessed value of \$185,000 is \$2479.

18. (a)
$$\begin{aligned} y &= kx \\ 10.22 &= k(145.99) \\ 0.07 &\approx k \\ y &= 0.07x \end{aligned}$$

(b) When $x = 540.50$, we have

$y = 0.07(540.50) \approx \$37.84.$

19. (a)
$$\begin{aligned} M &= kK \\ 64 &= k(103) \\ \tfrac{64}{103} &= k \\ M &= \tfrac{64}{103}K \end{aligned}$$

(b)

km/h	40	60	80	100	120
mi/h	24.85	37.28	49.71	62.14	74.56

20. (a) $L = kG$

$53 = k(14)$

$\frac{53}{14} = k$

$L = \frac{53}{14}G$

(b)

Gallons	5.00	10.00	20.00
Liters	18.93	37.86	75.71

Gallons	25.00	30.00
Liters	94.64	113.57

21. $V = 2540 + 140(t - 12)$

$V = 2540 + 140t - 1680$

$V = 140t + 860, \; 12 \le t \le 17$

22. $V = 156 + 4.5(t - 12)$

$V = 156 + 4.5t - 54$

$V = 4.5t + 102, \; 12 \le t \le 17$

23. $V = 20{,}400 - 2142(t - 12)$

$V = 20{,}400 - 2142t + 25{,}704$

$V = -2142t + 46{,}104, \; 12 \le t \le 17$

24. $V = 45{,}000 - 2800(t - 12)$

$V = 45{,}000 - 2800t + 33{,}600$

$V = -2800t + 78{,}600, \; 12 \le t \le 17$

25. $V = 154{,}000 + 10{,}780(t - 12)$

$V = 154{,}000 + 10{,}780t - 129{,}360$

$V = 10{,}780t + 24{,}640, \; 12 \le t \le 17$

26. $V = 245{,}000 + 5600(t - 12)$

$V = 245{,}000 + 5600t - 67{,}200$

$V = 5600t + 177{,}800, \; 12 \le t \le 17$

27. (a) 2 minutes = 120 seconds

(0, 7000), (120, 4600)

$$h - 7000 = \frac{4600 - 7000}{120 - 0}(t - 0)$$

$$h = -20t + 7000$$

(b) When the parachutist reaches the ground, we have

$h = 0$

$0 = -20t + 7000$

$t = \frac{7000}{20} = 350$ seconds

≈ 5.833 minutes.

The time will be

(2 hours + 8 minutes) + (5 minutes + 50 seconds)

= 2:13:50 P.M.

28. (a) (0, 84), (29, 56)

$$d - 84 = \frac{56 - 84}{29 - 0}(t - 0)$$

$$d = -\frac{28}{29}t + 84$$

(b) To find the time when you will reach Montgomery, let $d = 0$.

$0 = -\frac{28}{29}t + 84$

$t = 84\left(\frac{29}{28}\right) = 87$ minutes

The time will be

4 hours + 30 minutes + 87 minutes

= 4 hours + 117 minutes

= 5 hours + 57 minutes = 5:57 P.M.

29. $V = 875 - \left(\frac{875}{5}\right)t$

$= 875 - 175t, \; 0 \le t \le 5$

30. $(0, 25{,}000), (10, 2000)$

$$m = \frac{2000 - 25{,}000}{10 - 0} = -2300$$

$V = -2300t + 25{,}000, \; 0 \le t \le 10$

31. $W = 11.50 + 0.75x$

32. $W = 2500 + 0.07S$

33. (a) $H = 0.5t + 4$

(b) 1.5 years is 18 months.

$H = 0.5(18) + 4 = 13$

The hair will be 13 inches long in 1.5 years.

34. (a) $$m = \frac{1070 - 630}{18 - 10} = 55$$

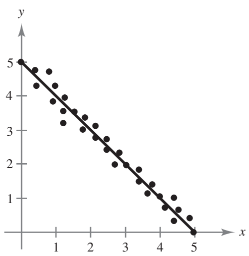
$y - 630 = 55(x - 10)$

$y - 630 = 55x - 550$

$y = 55x + 80$

(b) $y = 55(30) + 80 = \$1730$

35.



Two approximate points on the line are (0, 5) and (4.9, 0).

Thus, $y - 5 = \dfrac{0 - 5}{4.9 - 0}(x - 0)$

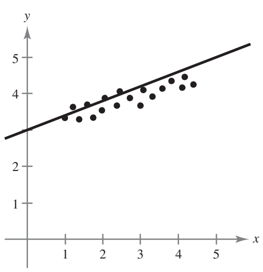
$y - 5 = -1.02x$

$y = -1.02x + 5$ or $y = -x + 5$.

36. No. The data cannot be approximated by a linear model.

37. No. The data cannot be approximated by a linear model.

38.



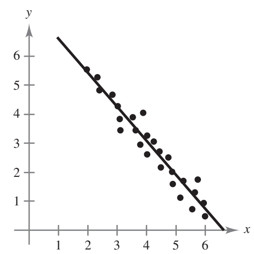
Two approximate points on the line are (1, 3.4) and (3, 4.25).

Thus, $y - 3.4 = \dfrac{4.25 - 3.4}{3 - 1}(x - 1)$

$y - 3.4 = 0.425x - 0.425$

$y = 0.425x + 2.975 \approx 0.4x + 3.$

39.



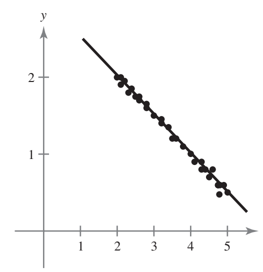
Two approximate points on the line are (2, 5.5) and (4, 3).

Thus, $y - 3 = \dfrac{3 - 5.5}{4 - 2}(x - 4)$

$y - 3 = -1.25x + 5$

$y = -1.25x + 8.$

40.



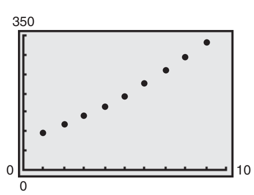
Two approximate points on the line are (2, 2) and (4, 1).

Thus, $y - 2 = \dfrac{1 - 2}{4 - 2}(x - 2)$

$y - 2 = -0.5x + 1$

$y = -0.5x + 3.$

41. (a)



Yes, the data appear linear.

(b) $C = 29.19t + 57.1$

(c) The slope is 29.19. The number of autistic children receiving disability services is increasing by about 29 thousand children per year.

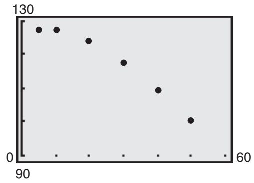
(d) For $t = 11, C = 29.19(11) + 57.1 = 378.19$.

In 2011, about 378 thousand autistic children will receive disability services.

For $t = 12, C = 29.19(12) + 57.1 = 407.38$.

In 2012, about 407 thousand autistic children will receive disability services.

The estimates are reasonable.

42. (a) 

Yes, the data appear linear.

(b) $P = -0.61t + 133.7$

(c) The slope is -0.61. The population of Japan will decrease by about 0.61 million people each year from 2005 to 2050.

(d) For $t = 25$, $P = -0.61(25) + 133.7 = 118.45$.

In 2025, the population of Japan will be about 118.45 million people.

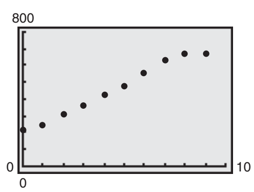
For $t = 35$, $P = -0.61(35) + 133.7 = 112.35$.

In 2035, the population of Japan will be about 118.45 million people.

For $t = 60$, $P = -0.61(60) + 133.7 = 97.1$

In 2060, the population of Japan will be about 97.1 million people.

The predictions for 2025 and 2035 fit between the projected population in millions. The prediction for 2060 follows the trend in the data. Long term population predictions using this model may fail.

43. (a) 

(b) Using $(0, 210.8)$ and $(8, 677.1)$:

$$y - 210.8 = \left(\frac{677.1 - 210.8}{8 - 0}\right)(t - 0)$$

$$y - 210.8 = 58.3t$$

$$y = 58.3t + 210.8$$

Answers will vary depending upon the selected ordered pairs.

(c) $y = 56.69t + 200.7$

Using the linear regression equation:

2010: $y = 56.69(10) + 200.7 = \$767.6$ million

2011: $y = 56.69(11) + 200.7 = \$824.29$ million

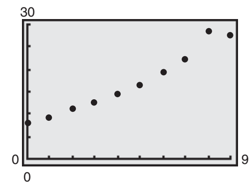
Using the equation from part (b):

2010: $y = 58.3(10) + 210.8 = \$793.8$ million

2011: $y = 58.3(11) + 210.8 = \$852.1$ million

(d) The projections by California Pizza Kitchen are lower than the predictions given by the models.

(e) Yes. Using the linear regression equation, the yearly revenue is expected to reach $y = 56.69(13) + 200.7 = \$937.67$ million by 2013. Using the equation from part (b), the yearly revenue is expected to be $y = 58.3(13) + 210.8 = \$968.7$ million by 2013.

44. (a) 

(b) Using $(0, 7.86)$ and $(8, 28.37)$:

$$y - 7.86 = \left(\frac{28.37 - 7.86}{8 - 0}\right)(t - 0)$$

$$y - 7.86 = 2.56t$$

$$y = 2.56t + 7.86$$

Answers will vary depending upon the selected ordered pairs.

(c) $y = 2.365t + 6.23$

Using the linear regression equation:

2010: $y = 2.365(10) + 6.23 = \$29.88$

2011: $y = 2.365(11) + 6.23 = \$32.25$

Using the equation from part (b):

2010: $y = 2.56(10) + 7.86 = \$33.46$

2011: $y = 2.56(11) + 7.86 = \$36.02$

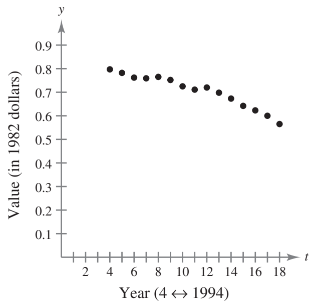
(d) The projections by California Pizza Kitchen are lower than the predictions from both models.

(e) Using the linear regression model and $t = 13$, $y = 2.365(13) + 6.23 = 36.975$.

Using the model from part (b) and $t = 13$, $y = 2.56(13) + 7.86 = 41.14$.

Yes, both models predict a revenue per share greater than \$34.00 in 2013.

45. (a)



The data appear to be approximately linear.

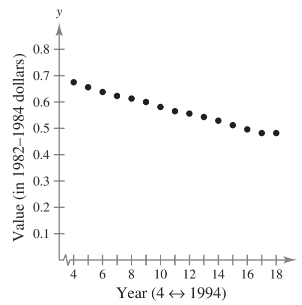
(b) $y = -0.0152t + 0.873$

(c) 2010: $y = -0.0152(20) + 0.873 = \$0.569$

2011: $y = -0.0152(21) + 0.873 = \$0.5538$

Because the data follow a linear pattern from 1994 to 2008, you can assume the estimates for 2010 and 2011 are reliable.

46. (a)



The data appear to be approximately linear.

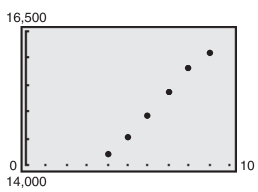
(b) $y = -0.0145t + 0.729$

(c) 2010: $y = -0.0145(20) + 0.729 = \$0.439$

2011: $y = -0.0145(21) + 0.729 = \$0.4245$

Because the data follow a linear pattern, the predictions for 2010 and 2011 are reliable.

47. (a)



The data appear to be approximately linear.

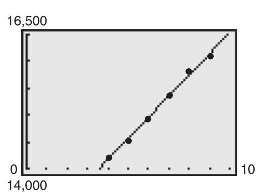
(b) $E = 394.17t + 12{,}592.9$

(c) When $t = 11$: $E = 394.17(11) + 12{,}592.9 = 16{,}928.77$

When $t = 13$: $E = 394.17(13) + 12{,}592.9 = 17{,}717.11$

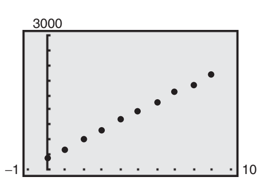
So, there will be about 16,928,770 employees in the health service industry in 2011 and about 17,717,110 employees in 2013.

(d)



The predictions are most likely going to be right because the model is a good fit for the data.

48. (a)

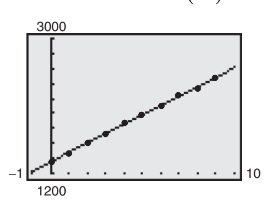


The data appear to be approximately linear.

(b) $E = 125.69t + 1351.9$

(c) 2011: $E = 125.69(11) + 1351.9 = \$2734.49$ billion

2012: $E = 125.69(12) + 1351.9 = \$2860.18$ billion



The government's projections are close to the predictions in part (c). They are most likely going to be right because the model is a good fit for the actual data.

49. The model for population because population tends to change at a consistent rate, whereas snowfall can be quite different from year to year. You should use more than three data points to find an accurate model.

50. (a) iv; The slope is 0.06 and represents the sales tax for each dollar spent.

(b) iii; The slope is 12 and it represents the amount charged per hour.

(c) i; The slope is -50 and it represents the amount the value of the refrigerator decreases each year.

(d) ii; The slope is 34.99 and it represents the cost per day to rent a car.

51. Yes. When you start you have zero wrong moves $(x = 0)$ and 800 points $(y = 800)$. So, 800 is the y-intercept. Then you lose 50 points for each wrong move. This is a slope of -50.

52. No; When you start with \$12 and save \$40 per week, the graph would have a y-intercept of 12 and a slope of 40. Graph (iii) has a y-intercept of 40 and a slope of 12.

53. A known rate of change corresponds to the slope of a linear model, so determine whether the rate of change of y with respect to x is constant. The data show a 10-unit increase in y for each 1-unit increase in x, so the rate of change is constant and the data is linear.

54. Answers will vary.

Section 2.4 Functions

Skills Warm Up

1. $2(-3)^3 + 4(-3) - 7 = 2(-27) - 12 - 7 = -73$

2. $4(-1)^2 - 5(-1) + 4 = 4 + 5 + 4 = 13$

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

4. $(x - 2)^2 - 4(x - 2) - (x^2 - 4)$
$= x^2 - 4x + 4 - 4x + 8 - x^2 + 4$
$= -8x + 16$
$= -8(x - 2)$

5. $2x + 5y - 7 = 0$
$5y = 7 - 2x$
$y = \frac{7}{5} - \frac{2}{5}x$

6. $y^2 = x^2$
$y = \pm x$

7. $x^2 - 4 \ge 0$
$x^2 \ge 4$
$x \le -2, x \ge 2$

8. $9 - x^2 \ge 0$
$9 \ge x^2$
$-3 \le x \le 3$

9. $x^2 + 2x + 1 \ge 0$
All real numbers

10. $x^2 - 3x + 2 \ge 0$
$(x - 2)(x - 1) \ge 0$
$x \le 1, x \ge 2$

1. Because each element of A is matched with exactly one element of B, $\{(a, 1), (b, 1), (c, 1)\}$ represents a function from A to B.

2. Because each element of A is matched with exactly one element of B, $\{(a, 1), (b, 2), (c, 4)\}$ represents a function from A to B.

3. Because $b \in A$ is not matched with an element of B, $\{(a, 1), (c, 3)\}$ does not represent a function from A to B.

4. Because $(a, 1)$ and $(a, 2)$ are both in $\{(a, 1), (a, 2), (b, 2), (c, 4)\}$ this set does not represent a function from A to B.

5. Because each element of A is matched with exactly one element of B, $\{(0, 1), (1, -2,), (2, 0), (3, 2)\}$, represents a function from A to B.

6. Because $(1, -2)$ and $(1, 1)$ are both in $\{(0, -1), (2, 2), (1, -2), (3, 0), (1, 1)\}$, this set does not represent a function from to A to B.

7. Because each element of A is matched with exactly one element of B, $\{(0, 0), (1, 0), (2, 0), (3, 0)\}$ represents a function from A to B.

8. Because $2 \in A$ is not matched with an element of B, $\{(0, 2), (3, 0), (1, 1)\}$ does not represent a function from A to B.

9. Because $(c, 2)$ and $(c, 3)$ are both in $\{(a, 1), (c, 2), (c, 3), (b, 3)\}$, this set does not represent a function from A to B.

10. Because $b \in A$ is not matched with an element of B, $\{(a, 3), (c, 1)\}$ does not represent a function from A to B.

11. Because the elements of A are the outputs rather than the inputs, $\{(0, a), (2, c), (3, b)\}$ does not represent a function from A to B.

12. Because each element of A is matched with exactly one element of B, $\{(a, 0), (c, 1), (b, 3)\}$ represents a function from A to B.

13. Because each element of A is matched with exactly one element of B, $\{(a, 1), (b, 2), (c, 3)\}$ represents a function from A to B.

14. Because each element of A is matched with exactly one element of B, $\{(c, 0), (b, 0), (a, 3)\}$ represents a function from A to B.

15. $x^2 + y^2 = 4 \Rightarrow y = \pm\sqrt{4 - x^2}$

Thus, y *is not* a function of x.

16. $x = y^2 \Rightarrow y = \pm\sqrt{x}$

Thus, y *is not* a function of x.

17. $x^2 + y = 4 \Rightarrow y = 4 - x^2$

Thus, y *is* a function of x.

18. $y = \sqrt{x + 5}$

y *is* a function of x.

19. $2x + 3y = 4 \Rightarrow y = \frac{1}{3}(4 - 2x)$

Thus, y *is* a function of x.

20. $5x - 7 = 3y \Rightarrow y = \frac{1}{3}(5x - 7)$

So, y *is* a function of x.

21. $y^2 = x^2 - 1 \Rightarrow y = \pm\sqrt{x^2 - 1}$

Thus, y *is not* a function of x.

22. $x + y^2 = 4 \Rightarrow y = \pm\sqrt{4 - x}$

Thus, y *is not* a function of x.

23. $x^2y - x^2 + 4y = 0$

$$y(x^2 + 4) = x^2$$

$$y = \frac{x^2}{x^2 + 4}$$

Thus, y *is* a function of x.

24. $xy - y - x - 2 = 0$

$$y(x - 1) = x + 2$$

$$y = \frac{x + 2}{x - 1}$$

Thus, y *is* a function of x.

25. $f(x) = 6 - 4x$

(a) $f(3) = 6 - 4(3) = -6$

(b) $f(-7) = 6 - 4(-7) = 34$

(c) $f(t) = 6 - 4(t) = 6 - 4t$

(d) $f(c + 1) = 6 - 4(c + 1) = 2 - 4c$

26. $f(s) = \dfrac{1}{s + 1}$

(a) $f(4) = \dfrac{1}{(4) + 1} = \dfrac{1}{5}$

(b) $f(0) = \dfrac{1}{(0) + 1} = 1$

(c) $f(4x) = \dfrac{1}{(4x) + 1} = \dfrac{1}{4x + 1}$

(d) $f(x + 1) = \dfrac{1}{(x + 1) + 1} = \dfrac{1}{x + 2}$

27. $g(x) = \dfrac{1}{x^2 - 2x}$

(a) $g(1) = \dfrac{1}{(1)^2 - 2(1)} = -1$

(b) $g(-3) = \dfrac{1}{(-3)^2 - 2(-3)} = \dfrac{1}{15}$

(c) $g(t) = \dfrac{1}{(t)^2 - 2(t)} = \dfrac{1}{t^2 - 2t}$

(d) $g(t + 1) = \dfrac{1}{(t + 1)^2 - 2(t + 1)} = \dfrac{1}{t^2 - 1}$

28. $f(t) = \sqrt{25 - t^2}$

(a) $f(3) = \sqrt{25 - (3)^2} = 4$

(b) $f(5) = \sqrt{25 - (5)^2} = 0$

(c) $f(x + 5) = \sqrt{25 - (x + 5)^2} = \sqrt{-x^2 - 10x}$

(d) $f(2x) = \sqrt{25 - (2x)^2} = \sqrt{25 - 4x^2}$

29. $f(x) = 2x - 3$

(a) $f(1) = 2(1) - 3 = -1$

(b) $f(-3) = 2(-3) - 3 = -9$

(c) $f(x - 1) = 2(x - 1) - 3 = 2x - 5$

(d) $f\left(\frac{1}{4}\right) = 2\left(\frac{1}{4}\right) - 3 = -\frac{5}{2}$

30. $g(y) = 7 - 3y$

(a) $g(0) = 7 - 3(0) = 7$

(b) $g\left(\frac{7}{3}\right) = 7 - 3\left(\frac{7}{3}\right) = 0$

(c) $g(s) = 7 - 3s$

(d) $g(s + 2) = 7 - 3(s + 2) = 1 - 3s$

31. $h(t) = t^2 - 2t$

(a) $h(2) = 2^2 - 2(2) = 0$

(b) $h(-1) = (-1)^2 - 2(-1) = 3$

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

(d) $h(1.5) = (1.5)^2 - 2(1.5) = -0.75$

32. $k(b) = 2b^2 + 7b + 3$

(a) $k(0) = 2(0)^2 + 7(0) + 3 = 3$

(b) $k\left(-\frac{1}{2}\right) = 2\left(-\frac{1}{2}\right)^2 + 7\left(-\frac{1}{2}\right) + 3 = 0$

(c) $k(a) = 2a^2 + 7a + 3$

(d) $k(x + 2) = 2(x + 2)^2 + 7(x + 2) + 3$
$= 2x^2 + 15x + 25$

33. $V(r) = \frac{4}{3}\pi r^3$

(a) $V(3) = \frac{4}{3}\pi(3)^3 = 36\pi$

(b) $V(0) = \frac{4}{3}\pi(0)^3 = 0$

(c) $V\left(\frac{3}{2}\right) = \frac{4}{3}\pi\left(\frac{3}{2}\right)^3 = \frac{9\pi}{2}$

(d) $V(2r) = \frac{4}{3}\pi(2r)^3 = \frac{32\pi r^3}{3}$

34. $A(s) = \frac{\sqrt{3}s^2}{4}$

(a) $A(1) = \frac{\sqrt{3}(1)^2}{4} = \frac{\sqrt{3}}{4}$

(b) $A(0) = \frac{\sqrt{3}(0)^2}{4} = 0$

(c) $A(2x) = \frac{\sqrt{3}(2x)^2}{4} = x^2\sqrt{3}$

(d) $A(3) = \frac{\sqrt{3}(3)^2}{4} = \frac{9\sqrt{3}}{4}$

35. $f(y) = 3 - \sqrt{y}$

(a) $f(4) = 3 - \sqrt{4} = 1$

(b) $f(100) = 3 - \sqrt{100} = -7$

(c) $f(4x^2) = 3 - \sqrt{4x^2} = 3 - 2|x|$

(d) $f(0.25) = 3 - \sqrt{0.25} = 2.5$

36. $f(x) = \sqrt{x + 3} - 2$

(a) $f(-3) = \sqrt{-3 + 3} - 2 = -2$

(b) $f(1) = \sqrt{1 + 3} - 2 = 0$

(c) $f(x - 3) = \sqrt{x - 3 + 3} - 2 = \sqrt{x} - 2$

(d) $f(x + 4) = \sqrt{x + 4 + 3} - 2 = \sqrt{x + 7} - 2$

37. $c(x) = \dfrac{1}{x^2 - 16}$

(a) $c(4) = \dfrac{1}{4^2 - 16}$ is undefined.

(b) $c(0) = \dfrac{1}{0^2 - 16} = -\dfrac{1}{16}$

(c) $c(y + 2) = \dfrac{1}{(y + 2)^2 - 16}$

$= \dfrac{1}{y^2 + 4y - 12},\ y \neq -6,\ 2$

(d) $c(y - 2) = \dfrac{1}{(y - 2)^2 - 16}$

$= \dfrac{1}{y^2 - 4y - 12},\ y \neq -2,\ 6$

38. $q(t) = \dfrac{2t^2 + 3}{t^2}$

(a) $q(2) = \dfrac{2(2)^2 + 3}{(2)^2} = \dfrac{11}{4}$

(b) $q(0) = \dfrac{2(0)^2 + 3}{(0)^2}$ is undefined.

(c) $q(x) = \dfrac{2x^2 + 3}{x^2}$

(d) $q(-x) = \dfrac{2(-x)^2 + 3}{(-x)^2} = \dfrac{2x^2 + 3}{x^2}$

39. $f(x) = \dfrac{|x|}{x}$

(a) $f(2) = \dfrac{|2|}{2} = 1$

(b) $f(-2) = \dfrac{|-2|}{-2} = -1$

(c) $f(x^2) = \dfrac{|x^2|}{x^2} = 1$

(d) $f(x - 1) = \dfrac{|x - 1|}{x - 1}$

40. $f(x) = |x| + 4$

(a) $f(2) = |2| + 4 = 6$

(b) $f(-2) = |-2| + 4 = 6$

(c) $f(x^2) = |x^2| + 4 = x^2 + 4$

(d) $f(x + 2) = |x + 2| + 4$

41. $f(x) = \begin{cases} 3x - 1, & x < 0 \\ 2x + 3, & x \geq 0 \end{cases}$

(a) $f(-1) = 3(-1) - 1 = -4$

(b) $f(0) = 2(0) + 3 = 3$

(c) $f(-2) = 3(-2) - 1 = -7$

(d) $f(2) = 2(2) + 3 = 7$

42. $g(x) = \begin{cases} \frac{1}{4}x + 2, & x \leq 4 \\ 8 - x, & x > 4 \end{cases}$

(a) $g(-2) = \frac{1}{4}(-2) + 2 = -\frac{1}{2} + 2 = \frac{3}{2}$

(b) $g(0) = \frac{1}{4}(0) + 2 = 2$

(c) $g(4) = \frac{1}{4}(4) + 2 = 3$

(d) $g(6) = 8 - 6 = 2$

43. $h(t) = \begin{cases} t^2 - 2, & t < 2 \\ 3, & t \geq 2 \end{cases}$

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

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

(c) $h(2) = 3$

(d) $h(5) = 3$

44. $f(x) = \begin{cases} x^2 + 1, & x \leq 1 \\ 2x - 3, & x > 1 \end{cases}$

(a) $f(-2) = (-2)^2 + 1 = 5$

(b) $f(1) = (1)^2 + 1 = 2$

(c) $f\left(\frac{3}{2}\right) = 2\left(\frac{3}{2}\right) - 3 = 0$

(d) $f(0) = 0^2 + 1 = 1$

45. $15 - 3x = 0$

$3x = 15$

$x = 5$

46. $\dfrac{2x - 5}{3} = 0$

$2x - 5 = 0$

$2x = 5$

$x = \frac{5}{2}$

47. $x^2 - 9 = 0$

$x^2 = 9$

$x = \pm 3$

48. $2x^2 - 11x + 5 = 0$
$(2x - 1)(x - 5) = 0$
$x = \frac{1}{2}, 5$

49. $x^3 - x = 0$
$x(x^2 - 1) = 0$
$x = 0 \quad x^2 - 1 = 0$
$x^2 = 1$
$x = \pm 1$

50. $x^3 - 3x^2 - 4x + 12 = 0$
$x^2(x - 3) - 4(x - 3) = 0$
$(x^2 - 4)(x - 3) = 0$
$(x - 2)(x + 2)(x - 3) = 0$
$x = \pm 2, 3$

51. $\frac{3}{x - 1} + \frac{4}{x - 2} = 0$
$3(x - 2) + 4(x - 1) = 0$
$7x - 10 = 0$
$x = \frac{10}{7}$

52. $3 + \frac{2}{x - 1} = 0$
$3 = -\frac{2}{x - 1}$
$3(x - 1) = -2$
$x - 1 = -\frac{2}{3}$
$x = \frac{1}{3}$

53. $\{0, 3, 5, 8, 9\}$

54. $\{10, 20, 30, 40, 50\}$

55. $\{-2, -1, 0, 1, 2\}$

56. $\{-5.7, -3.9, -2.9, -1.5\}$

57. All real numbers x or $(-\infty, \infty)$

58. All real numbers x or $(-\infty, \infty)$

59. All real numbers $t \neq 0$ or $(-\infty, 0) \cup (0, \infty)$

60. All real numbers $y \neq -5$ or $(-\infty, -5) \cup (-5, \infty)$

61. All real numbers y or $(-\infty, \infty)$

62. All real numbers t or $(-\infty, \infty)$

63. $1 - x^2 \geq 0$
$x^2 \leq 1$
$-1 \leq x \leq 1$
So the domain is $[-1, 1]$.

64. $x + 1 \geq 0$
$x \geq -1$
So the domain is $[-1, \infty)$.

65. All real numbers $x \neq 0$ and $x \neq -2$ or $(-\infty, -2) \cup (-2, 0) \cup (0, \infty)$

66. $x^2 - 2x \neq 0$
$x(x - 2) \neq 0$
All real numbers $x \neq 0$ and $x \neq 2$ or $(-\infty, 0) \cup (0, 2) \cup (2, \infty)$

67. $x + 1 \geq 0$ and $x - 2 \neq 0$
$x \geq -1 \qquad x \neq 2$
So the domain is $[-1, 2) \cup (2, \infty)$.

68. $s - 1 \geq 0$ and $s - 4 \neq 0$
$s \geq 1 \qquad s \neq 4$
So the domain is $[1, 4) \cup (4, \infty)$.

69. $x > 0$
The domain is $(0, \infty)$ or all real numbers greater than zero.

70. $x^2 - 9 > 0$
$(x - 3)(x + 3) > 0$
$x > 3$ or $x < -3$
Domain: $(-\infty, -3) \cup (3, \infty)$

71. $f(x) = x^2$
$\{(-2, 4), (-1, 1), (0, 0), (1, 1), (2, 4)\}$

72. $f(x) = \frac{2x}{x^2 + 1}$
$\{(-2, -\frac{4}{5}), (-1, -1), (0, 0), (1, 1), (2, \frac{4}{5})\}$

73. $f(x) = \sqrt{x+2}$

$\{(-2, 0), (-1, 1), (0, \sqrt{2}), (1, \sqrt{3}), (2, 2)\}$

74. $f(x) = |x+1|$

$\{(-2, 1), (-1, 0), (0, 1), (1, 2), (2, 3)\}$

75. The domain of $f(x) = \sqrt{x-2}$ is all real numbers $x \geq 2$ or $[2, \infty)$ since an even root of a negative number is not a real number.

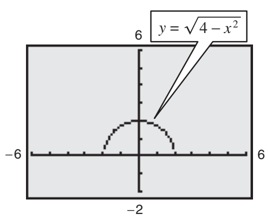
The domain of $g(x) = \sqrt[3]{x-2}$ is all real numbers or $(-\infty, \infty)$. The functions *f* and *g* have different domains because an odd root of a negative number is a real number but an even root of a negative number is not a real number.

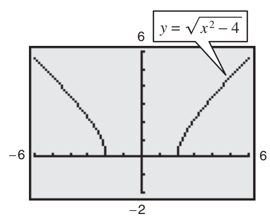
76. The student is incorrect. Since $x + 1$ must be greater than or equal to zero, $x \geq -1$. The domain is all real numbers.

$x \geq -1$ and $x \neq 3$ or $[-1, 3) \cup (3, \infty)$

77. There will be *n* ordered pairs because set *A* contains *n* elements and each element in the domain must be matched with exactly one element in the range.

78.





Domain:
$-2 \leq x \leq 2$

Domain:
$x \leq -2$ and $x \geq 2$

Yes, for $x = -2$ and $x = 2$.

79. (a) $V = x(18 - 2x)^2 = 4x(9 - x)^2$

(b) Because $V > 0$, the domain is $0 < x < 9$.

(c) $V = 4[18 - 2(4)]^2 = 4(10)^2 = 400 \text{ in.}^3$

80. $h^2 + 2000^2 = d^2$

$h^2 = d^2 - 2000^2$

$h = \sqrt{d^2 - 2000^2}$

Domain: $d^2 - 2000^2 \geq 0$

$d^2 \geq 2000^2$

$d \geq 2000$

81. $y = -\frac{1}{10}(30)^2 + 3(30) + 6 = 6$

Yes, at a distance of 30 feet, the height of the ball will be 6 feet. So, the teammate will be able to catch the ball without backing up.

82. $h = -0.42(4)^2 + 2.52(4) = 3.36$

Yes, when the salmon reaches the waterfall 4 feet away, its height will be 3.36 feet above the stream. Because the waterfall is 3 feet high, the salmon will clear the waterfall.

83. 2000: $A = -3.4(10) + 979 = 945$ million acres

2009: $A = -3.4(19) + 979 = 914.4$ million acres

84. (a) $C = 11.75x + 112{,}000$

(b) $R = 21.95x$

(c) $P = R - C$

$P = 21.95x - (11.75x + 112{,}000)$

$P = 10.2x - 112{,}000$

85. (a) $C = 57{,}000 + 2.05x$

(b) $\overline{C} = \dfrac{57{,}000 + 2.05x}{x}$

(c)

x	100	1000	10,000	100,000
$\overline{C}$	572.05	59.05	7.75	2.62

(d) Answers will vary. Sample answer: The average cost per unit decreases as *x* gets larger.

86. (a) 2003: $N = 556.50(3)^2 - 1096.5(3) + 4280$
$= 5999$ migrants

2004: $N = -1481.9(4) + 16{,}793$
$= 10{,}865$ migrants

2010: $N = -1481.9(10) + 16{,}793$
$= 1974$ migrants

(b) $N(0) = 556.5(0)^2 - 1096.5(0) + 4280 = 4280$

$N(1) = 556.5(1)^2 - 1096.5(1) + 4280 = 3740$

$N(2) = 556.5(2)^2 - 1096.5(2) + 4280 = 4313$

$N(3) = 556.5(3)^2 - 1096.5(3) + 4280 = 5999$

$N(4) = -1481.9(4) + 16{,}793 = 10{,}865.4 \approx 10{,}865$

$N(5) = -1481.9(5) + 16{,}793 = 9383.5 \approx 9384$

$N(6) = -1481.9(6) + 16{,}793 = 7901.6 \approx 7902$

$N(7) = -1481.9(7) + 16{,}798 = 6419.7 \approx 6420$

$N(8) = -1481.9(8) + 16{,}798 = 4937.8 \approx 4938$

$N(9) = -1481.9(9) + 16{,}798 = 3455.9 \approx 3456$

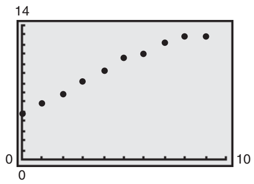
$N(10) = -1481.9(10) + 16{,}798 = 1974$

Total number of migrants:

$4280 + 3740 + 4313 + 5999 + 10{,}865 + 9384 + 7902 + 6420 + 4938 + 3456 + 1974 = 63{,}271$

From 2000 to 2009, the total number of migrants interdicted was about 63,271.

87. (a)



(b) Linear model: $P = 0.965t + 5.11$

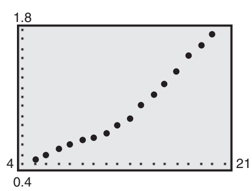
Quadratic model: $P = -0.0456t^2 + 1.375t + 4.56$

(c)

Year	P (Actual)	P (Linear)	P (Quadratic)
2000	4.80	5.11	4.56
2001	5.89	6.08	5.89
2002	6.81	7.04	7.13
2003	8.10	8.01	8.27
2004	9.30	8.97	9.33
2005	10.55	9.94	10.30
2006	11.13	10.90	11.17
2007	12.09	11.87	11.95
2008	12.95	12.83	12.64
2009	12.91	13.80	13.24

The quadratic model is a better fit because its values for P tend to be closer to the actual values than those of the linear model.

88. (a)

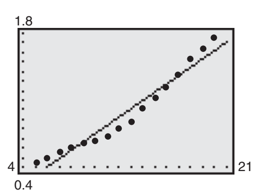


(b) Linear model: $D = 0.0873t - 0.125$

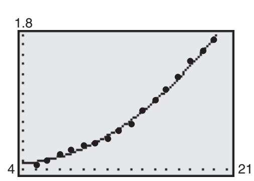
Quadratic model:

$D = 0.00470t^2 - 0.0301t + 0.509$

(c) Linear model:



Quadratic model:



(d) The quadratic model is a better fit because its values for D tend to be closer to the actual values than those of the linear model.

(e) 2011: $D(21) = 0.0047(21)^2 - 0.0301(21) + 0.509 \approx \$1.95$

2015: $D(25) = 0.0047(25)^2 - 0.0301(25) + 0.509 \approx \$2.69$

Yes, the predictions support those of Coca-Cola.

89. (a) $r(t) = 0.75t$

(b) $A = 0.5625\pi t^2$

Time, t	1	2	3
Radius, r (in feet)	0.75	1.5	2.25
Area, r (in square feet)	1.767	7.069	15.904

Time, t	4	5
Radius, r (in feet)	3	3.75
Area, r (in square feet)	28.274	44.179

(c) $\dfrac{A(2)}{A(1)} = \dfrac{7.069}{1.767} = 4.000$

$\dfrac{A(4)}{A(2)} = \dfrac{28.274}{7.069} = 4.000$

$A(8) = 113.097$

90. (a) The height h is a function of t because for each value of t there is a corresponding value of h for $0 \le t \le 2.6$.

(b) After 0.5 seconds, the cork is about 20 feet high.

After 1.25 seconds, the cork is about 28 feet high.

(c) The domain of h is $0 \le t \le 2.6$.

(d) The time t is not a function of h because some values of h correspond to more than one value of t.

91. (a) Correct; Each price has exactly one tax amount.

(b) Incorrect; For any given value of education there is not exactly one specific value of intelligence.

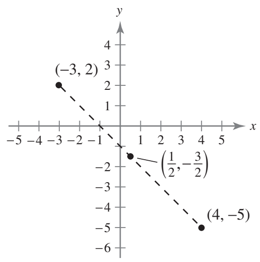
92. (a) Incorrect; For any given size of a home, there is not exactly one specific market value.

(b) Correct; Assuming all environmental factors are the same, each baseball dropped from the same initial height will hit the ground with exactly the same speed.

93. Answers will vary.

Chapter 2 Quiz Yourself

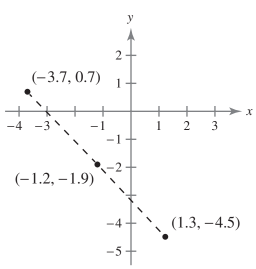
1. (a)



(b) $d = \sqrt{\left(4 - (-3)\right)^2 + \left(-5 - 2\right)^2}$
$= \sqrt{(7)^2 + (-7)^2}$
$= \sqrt{49 + 49}$
$= \sqrt{98}$
$= 7\sqrt{2}$

(c) $\left(\dfrac{-3 + 4}{2}, \dfrac{2 + (-5)}{2}\right) = \left(\dfrac{1}{2}, -\dfrac{3}{2}\right)$

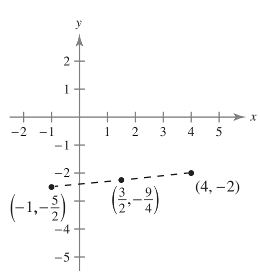
2. (a)



(b) $d = \sqrt{(-3.7 - 1.3)^2 + (0.7 + 4.5)^2}$
$= \sqrt{(5)^2 + (5.2)^2}$
$= \sqrt{52.04}$
≈ 7.214

(c) $\left[\dfrac{1.3 + (-3.7)}{2}, \dfrac{-4.5 + 0.7}{2}\right] = (-1.2, -1.9)$

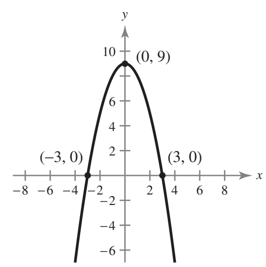
3. (a)



(b) $d = \sqrt{\left(4 - (-1)\right)^2 + \left(-2 - \dfrac{-5}{2}\right)^2}$
$= \sqrt{5^2 + \left(\dfrac{1}{2}\right)^2}$
$= \sqrt{25 + \dfrac{1}{4}}$
$= \sqrt{\dfrac{101}{4}}$
$= \dfrac{\sqrt{101}}{2}$
≈ 5.025

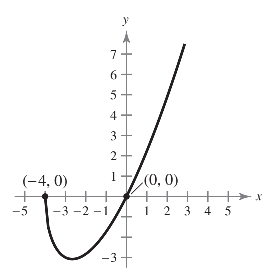
(c) $\left[\dfrac{4 + (-1)}{2}, \dfrac{-2 + \left(-\dfrac{5}{2}\right)}{2}\right] = \left(\dfrac{3}{2}, -\dfrac{9}{4}\right)$

4.



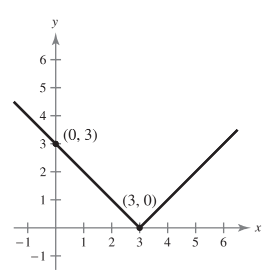
Intercepts: (±3, 0), (0, 9)
Symmetry: *y*-axis

5.



Intercepts: (–4, 0), (0, 0)
Symmetry: None

6.



Intercepts: (3, 0), (0, 3)
Symmetry: None

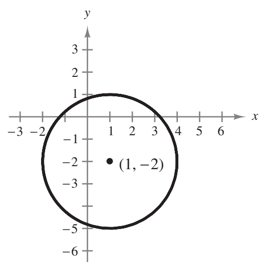
7. First use the Distance Formula to find the radius.

$$r = \sqrt{(4-0)^2 + (5-3)^2}$$
$$r = \sqrt{16+4}$$
$$r = \sqrt{20} = 2\sqrt{5}$$

So, the equation of the circle in standard form is:

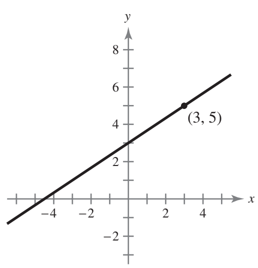
$$(x-4)^2 + (y-5)^2 = 20$$

8.
$$x^2 + y^2 - 2x + 4y - 4 = 0$$
$$(x^2 - 2x + 1) + (y^2 + 4y + 4) = 4 + 1 + 4$$
$$(x-1)^2 + (y+2)^2 = 9$$

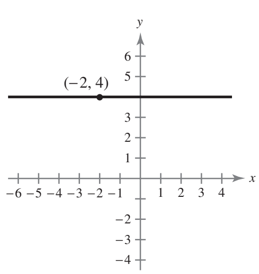


9.
$$y - 5 = \tfrac{2}{3}(x-3)$$
$$y = \tfrac{2}{3}x + 3$$

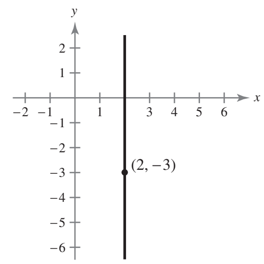
or $2x - 3y + 9 = 0$



10.
$$y = 4$$
$$y - 4 = 0$$

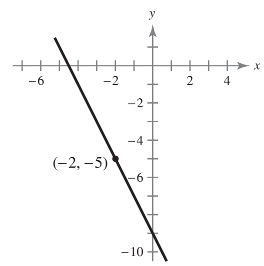


11.
$$x = 2$$
$$x - 2 = 0$$



12.
$$y - (-5) = -2[x - (-2)]$$
$$y = -2x + 9$$

or $2x + y + 9 = 0$



13. Let $t = 0$ represent 2010 and $t = 2$ represent 2012.

Ordered pairs: $(0, 233{,}134)$ and $(2, 244{,}288)$

Using the point-slope form of a line:

$$P - 233{,}134 = \left(\frac{244{,}288 - 233{,}134}{2-0}\right)(t-0)$$
$$P - 233{,}134 = 5577t$$
$$P = 5577t + 233{,}134$$

When $t = 5$:

$$P = 5577(5) + 233{,}134 = 261{,}019$$

In 2015, the population of the city will be about 261,019 people.

14. $x^2 + y = 3$ can be rewritten as

$y = 3 - x^2$.

$y = 3 - x^2$ represents y as a function of x because each element in the domain corresponds to exactly one element in the range.

15. Yes; Each element of A is matched with exactly one element of B.

16. No; The element 8 in A has no corresponding value in B.

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

(a) $f(0) = 3(2) - 4 = 2$

(b) $f(-3) = 3(-3+2) - 4 = 3(-1) - 4 = -7$

18. $g(t) = 2t^3 - t^2$

(a) $g(1) = 2(1)^3 - (1)^2 = 2 - 1 = 1$

(b) $g(-2) = 2(-2)^3 - (-2)^2 = 2(-8) - 4 = -20$

19. $x - 4 \geq 0$

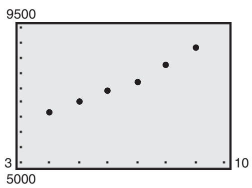
$x \geq 4$

20. $x + 2 \neq 0$

$x \neq -2$

All real numbers $x \neq -2$

21.



Linear model: $y = 428.5t + 4873$

Quadratic model: $y = 35.29t^2 - 30.2t + 6261$

22. Linear model:

When $t = 10$: $y = 428.5(10) + 4873 = 9158$

When $t = 11$: $y = 428.5(11) + 4873 = 9586.5$

Federal costs for school lunch programs will be \$9158 million in 2010 and \$9586.5 million in 2011.

Quadratic model:

When $t = 10$:

$y = 35.29(10)^2 - 30.2(10) + 6261 = 9488$

When $t = 11$:

$y = 35.29(11)^2 - 30.2(11) + 6261 = 10{,}198.89$

Federal costs for school lunch programs will be \$9488 million in 2010 and \$10,198.89 million in 2011.

23. $C = 2\pi r \Rightarrow r = \dfrac{C}{2\pi}$

Because the area of a circle is given by $A = \pi r^2$,

$A = \pi\left(\dfrac{C}{2\pi}\right)^2$.

$A = \dfrac{C^2}{4\pi}$ is the area of a circle as a function of its circumference.

Section 2.5 Graphs of Functions

Skills Warm Up

1. $f(2) = -(2)^3 + 5(2) = -8 + 10 = 2$

2. $f(6) = 6^2 - 6(6) = 0$

3. $f(-x) = -\dfrac{3}{x}$

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

5. $x^3 - 16x = 0$

$x(x^2 - 16) = 0$

$x = 0 \quad x = \pm 4$

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

$(2x - 1)(x - 1) = 0$

$x = \frac{1}{2} \quad x = 1$

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

$x - 4 \neq 0$

All real numbers $x \neq 4$

8. $f(x) = \dfrac{2x}{(x - 4)(x - 5)}$

$x - 4 \neq 0 \quad x - 5 \neq 0$

$x \neq 4 \quad x \neq 5$

All real numbers $x \neq 4$, $x \neq 5$

9. $5 - 3t \geq 0$

$t \leq \frac{5}{3}$

10. All real numbers

1. $f(x) = \sqrt{x - 1}$

Domain: $[1, \infty)$

Range: $[0, \infty)$

$f(1) = \sqrt{1 - 1} = 0$

2. $f(x) = \sqrt{x^2 - 4}$

Domain: $(-\infty, -2] \cup [2, \infty)$

Range: $[0, \infty)$

$f(-2) = \sqrt{(-2)^2 - 4} = 0$

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

Domain: $(-\infty, \infty)$

Range: $(-\infty, 4]$

$f(0) = 4 - 0^2 = 4$

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

Domain: $(-\infty, \infty)$

Range: $[0, \infty)$

$f(2) = |2 - 2| = 0$

5. $f(x) = x^3 - 1$

Domain: $(-\infty, \infty)$

Range: $(-\infty, \infty)$

$f(0) = 0^3 - 1 = -1$

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

Domain: $(-\infty, 0) \cup (0, \infty)$

Range: $\{-1, 1\}$

$f(5) = \frac{|5|}{5} = 1$

7. $f(x) = \sqrt{25 - x^2}$

Domain: $[-5, 5]$

Range: $[0, 5]$

$f(0) = \sqrt{25 - 0^2} = 5$

8. $f(x) = \sqrt{x^2 - 9}$

Domain: $(-\infty, -3] \cup [3, \infty)$

Range: $[0, \infty)$

$f(3) = \sqrt{3^2 - 9} = 0$

9. $y = x^2$

A vertical line intersects the graph just once, so y is a function of x.

10. $x^2 = xy - 1$

A vertical line intersects the graph just once, so y is a function of x.

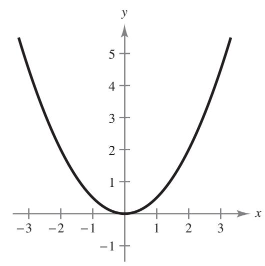
11. $x^2 + y^2 = 9$

Some vertical lines intersect the graph more than once, so y is not a function of x.

12. $x - y^2 = 0$

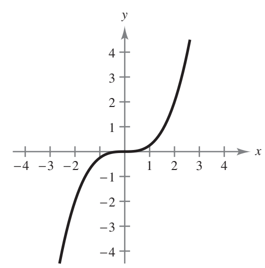
Some vertical lines intersect the graph more than once, so y is not a function of x.

13. $y = \frac{1}{2}x^2$



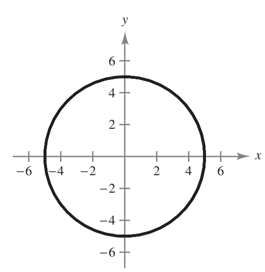
A vertical line intersects the graph just once, so y is a function of x.

14. $y = \frac{1}{4}x^3$



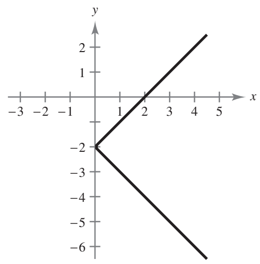
A vertical line intersects the graph just once, so y is a function of x.

15. $x^2 + y^2 = 25$



Some vertical lines intersect the graph more than once, so y is not a function of x.

16. $x = |y + 2|$



Some vertical lines intersect the graph more than once, so y is not a function of x.

17. $f(x) = 2x$

Increasing on $(-\infty, \infty)$

No change in the graph's behavior

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

Decreasing on $(-\infty, 1)$

Increasing on $(1, \infty)$

The graph's behavior changes at the point $(1, -1)$.

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

Increasing on $(-\infty, 0)$ and $(2, \infty)$

Decreasing on $(0, 2)$

The graph's behavior changes at the points (0, 0) and $(2, -4)$.

20. $f(x) = \sqrt{x^2 - 4}$

Decreasing on $(-\infty, -2)$

Increasing on $(2, \infty)$

The graph's behavior changes at the points (–2, 0) and (2, 0).

21. $f(x) = 3x^4 - 6x^2$

Decreasing on $(-\infty, -1)$ and $(0, 1)$

Increasing on $(-1, 0)$ and $(1, \infty)$

The graph's behavior changes at the points $(-1, -3)$, $(0, 0)$, and $(1, -3)$.

22. $f(x) = x^{2/3}$

Decreasing on $(-\infty, 0)$

Increasing on $(0, \infty)$

The graph's behavior changes at the point $(0, 0)$.

23. $f(x) = x\sqrt{x + 3}$

Decreasing on (–3, –2)

Increasing on $(-2, \infty)$

The graph's behavior changes at the point $(-2, -2)$.

24. $f(x) = |x + 1| + |x - 1|$

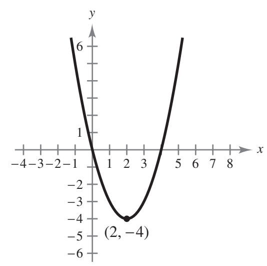
Decreasing on $(-\infty, -1)$

Constant on $(-1, 1)$

Increasing on $(1, \infty)$

The graph's behavior changes at the points $(-1, 2)$ and $(1, 2)$.

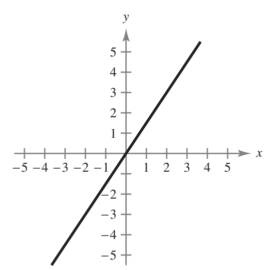
25. $f(x) = x^2 - 4x$



Increasing on $(2, \infty)$, decreasing on $(-\infty, 2)$

The behavior changes at $(2, -4)$.

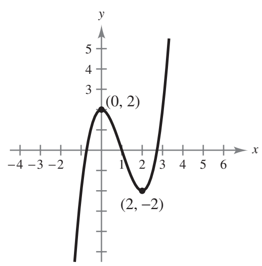
26. $f(x) = \frac{3}{2}x$



Increasing on the entire real line $(-\infty, \infty)$.

There is no behavior change.

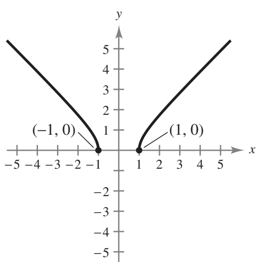
27. $f(x) = x^3 - 3x^2 + 2$



Increasing on $(-\infty, 0)$ and $(2, \infty)$, decreasing on $(0, 2)$

The behavior changes at $(0, 2)$ and $(2, -2)$.

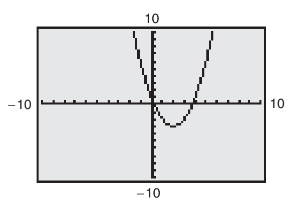
28. $f(x) = \sqrt{x^2 - 1}$



Increasing on $(1, \infty)$ and decreasing on $(-\infty, -1)$

The behavior changes at $(-1, 0)$ and $(1, 0)$.

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

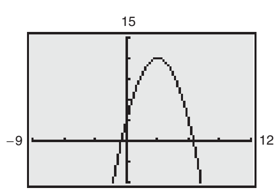


Decreasing on $(-\infty, 2)$

Increasing on $(2, \infty)$

Relative minimum: $(2, -3)$

30. $f(x) = -x^2 + 6x + 3$

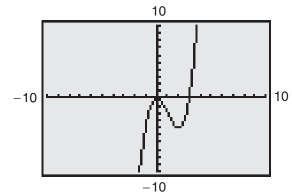


Increasing on $(-\infty, 3)$

Decreasing on $(3, \infty)$

Relative maximum: $(3, 12)$

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



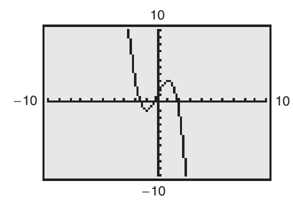
Increasing on $(-\infty, 0), (2, \infty)$

Decreasing on $(0, 2)$

Relative maximum: $(0, 0)$

Relative minimum: $(2, -4)$

32. $f(x) = -x^3 + 3x + 1$



Increasing on $(-1, 1)$

Decreasing on $(-\infty, -1), (1, \infty)$

Relative maximum: $(1, 3)$

Relative minimum: $(-1, -1)$

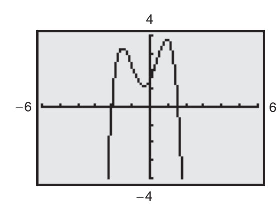
33. $f(x) = \frac{1}{4}(-4x^4 - 5x^3 + 10x^2 + 8x + 6)$

Relative maxima: $(-1.54, 3.29), (0.95, 3.77)$

Relative minimum: $(-0.34, 1.14)$

Increasing: $(-\infty, -1.54), (-0.34, 0.95)$

Decreasing: $(-1.54, -0.34), (0.95, \infty)$



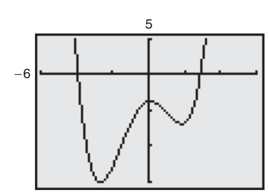
34. $f(x) = \frac{1}{4}(x^4 + x^3 - 10x^2 + 2x - 15)$

Relative maximum: $(0.10, -3.72)$

Relative minima: $(-2.68, -14.96), (1.83, -6.87)$

Increasing on
$(-2.68, 0.10), (1.83, \infty)$

Decreasing on
$(-\infty, -2.68), (0.10, 1.83)$



35. (a) $f(2) = \llbracket 2 \rrbracket = 2$

(b) $f(2.5) = \llbracket 2.5 \rrbracket = 2$

(c) $f(-2.5) = \llbracket -2.5 \rrbracket = -3$

(d) $f(-4) = \llbracket -4 \rrbracket = -4$

36. (a) $f(3) = \llbracket -3 \rrbracket = -3$

(b) $f(6.1) = \llbracket -6.1 \rrbracket = -7$

(c) $f(-5.9) = \llbracket 5.9 \rrbracket = 5$

(d) $f(-9) = \llbracket 9 \rrbracket = 9$

37. (a) $f(4) = \llbracket 4 - 1.8 \rrbracket = \llbracket 2.2 \rrbracket = 2$

(b) $f(3.7) = \llbracket 3.7 - 1.8 \rrbracket = \llbracket 1.9 \rrbracket = 1$

(c) $f(-5.8) = \llbracket -5.8 - 1.8 \rrbracket = \llbracket -7.6 \rrbracket = -8$

(d) $f(-6.3) = \llbracket -6.3 - 1.8 \rrbracket = \llbracket -8.1 \rrbracket = -9$

38. (a) $f(2.9) = \llbracket 2.9 + 0.3 \rrbracket = \llbracket 3.2 \rrbracket = 3$

(b) $f(4.6) = \llbracket 4.6 + 0.3 \rrbracket = \llbracket 4.9 \rrbracket = 4$

(c) $f(-2.3) = \llbracket -2.3 + 0.3 \rrbracket = \llbracket -2 \rrbracket = -2$

(d) $f(-4.2) = \llbracket -4.2 + 0.3 \rrbracket = \llbracket -3.9 \rrbracket = -4$

39.
$$\begin{aligned} f(-x) &= (-x)^6 - 2(-x)^2 + 3 \\ &= x^6 - 2x^2 + 3 \\ &= f(x) \end{aligned}$$

f is even.

40. $f(-t) = (-t)^2 + 3(-t) - 10 = t^2 - 3t - 10$

f is neither even nor odd.

41. $g(-x) = (-x)^3 - 5(-x) = -x^3 + 5x = -g(x)$

g is odd.

42. $h(-x) = (-x)^3 + 3 = -x^3 + 3$

h is neither even nor odd.

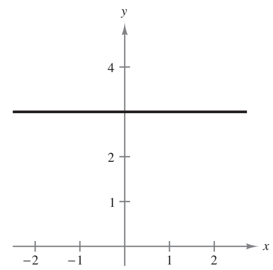
43. $f(-x) = -x\sqrt{4 - (-x)^2} = -x\sqrt{4 - x^2}$

f is odd.

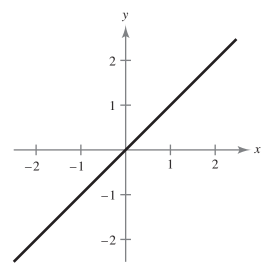
44. $g(-s) = 4(-s)^{2/3} = 4s^{2/3} = g(s)$

g is even.

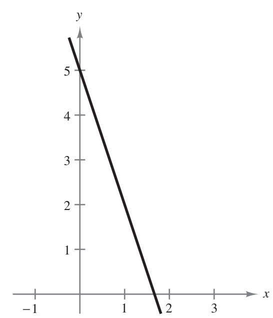
45. $f(x) = 3$, even



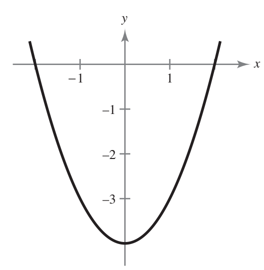
46. $g(x) = x$, odd



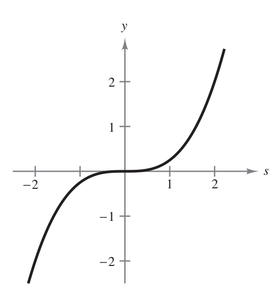
47. $f(x) = 5 - 3x$, neither even nor odd



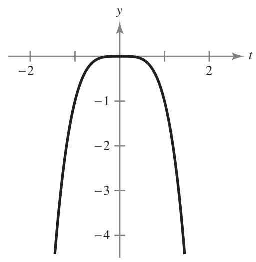
48. $h(x) = x^2 - 4$, even



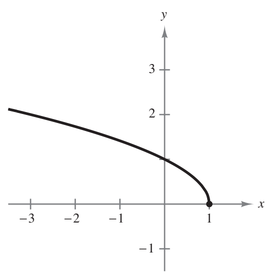
49. $g(s) = \dfrac{s^3}{4}$, odd



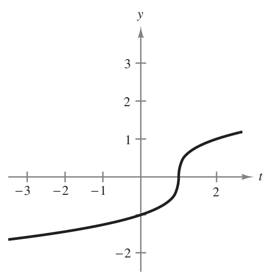
50. $f(t) = -t^4$, even



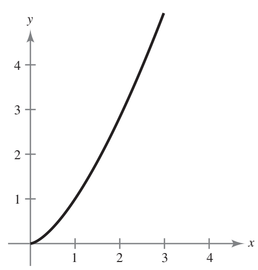
51. $f(x) = \sqrt{1 - x}$, neither even nor odd



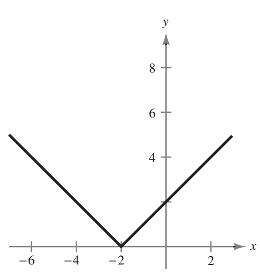
52. $g(t) = \sqrt[3]{t - 1}$, neither even nor odd



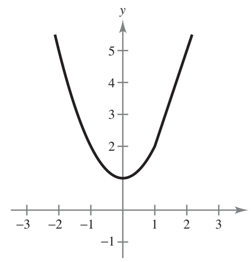
53. $f(x) = x^{3/2}$, neither even nor odd



54. $f(x) = |x + 2|$, neither even nor odd

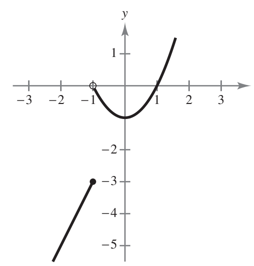


55.



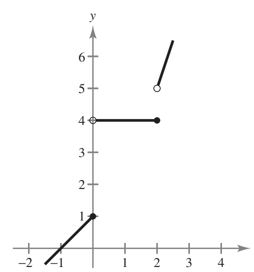
Neither even nor odd

56.



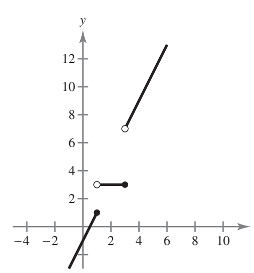
Neither even nor odd

57.



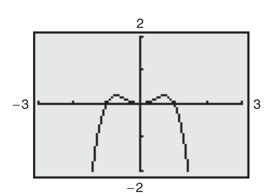
Neither even nor odd

58.



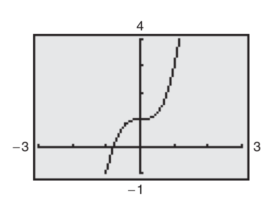
Neither even nor odd

59.

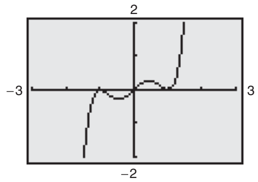


Even

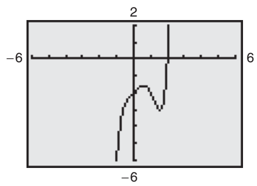
60.



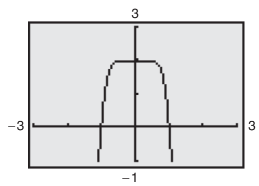
Neither

61. 

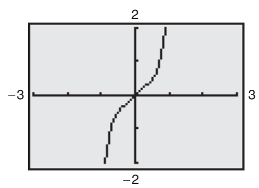
Odd

62. 

Neither

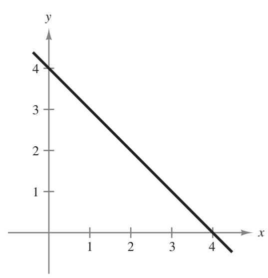
63. 

Even

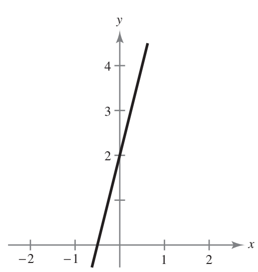
64. 

Odd

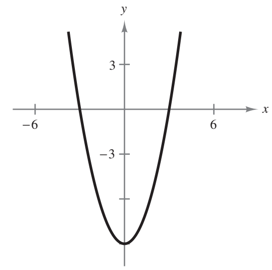
65. $f(x) = 4 - x$



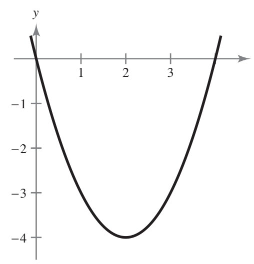
66. $f(x) = 4x + 2$



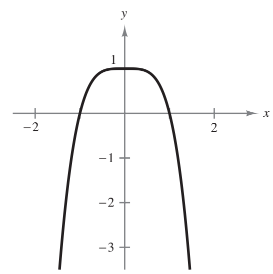
67. $f(x) = x^2 - 9$



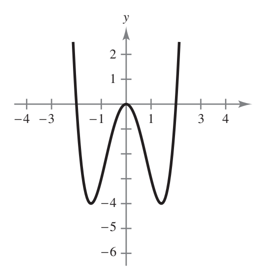
68. $f(x) = x^2 - 4x$



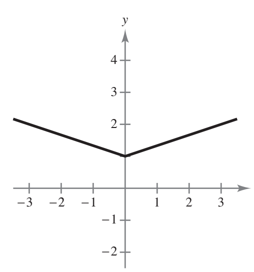
69. $f(x) = 1 - x^4$



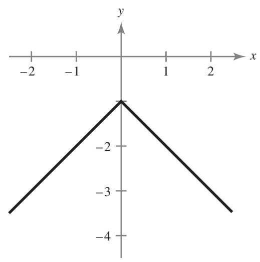
70. $f(x) = x^4 - 4x^2$



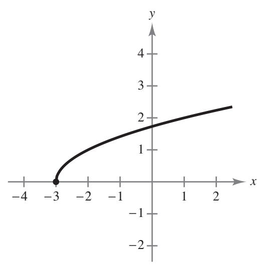
71. $f(x) = \frac{1}{3}(3 + |x|)$



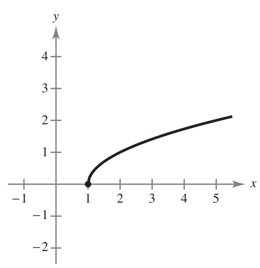
72. $f(x) = -1(1 + |x|)$



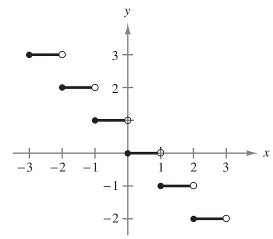
73. $f(x) = \sqrt{x + 3}$



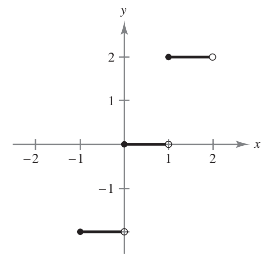
74. $f(x) = \sqrt{x - 1}$



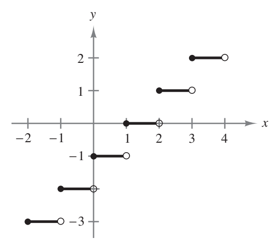
75. $f(x) = -[\![x]\!]$



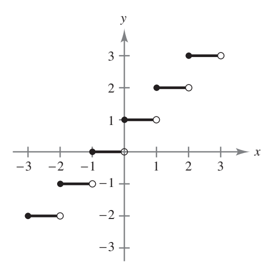
76. $f(x) = 2[\![x]\!]$



77. $f(x) = [\![x - 1]\!]$



78. $f(x) = [\![x + 1]\!]$



79. (a) From the graph, the maximum occurred at $t = 10$. The maximum price of gold in 2010 was

$$P = 0.038214(10)^4 - 0.48703(10)^3 + 11.0120(10)^2 - 6.018(10) + 276.49 = 1212.62.$$

(b) The price did not decrease during 2000–2010.
The price only increased during 2000–2010.

(c) The slope of the graph seems to increase quite rapidly in future years. The price of gold probably will not increase that quickly.

80. (a) From the graph, the maximum occurred at $t = 17$.

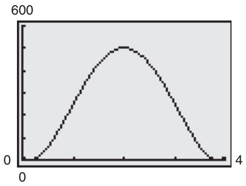
$$S = -1.28418(17)^4 + 67.9435(17)^3 - 1316.592(17)^2 + 11{,}169.74(17) - 34{,}707.3$$

In 2007, sales were about $1234 billion.

(b) Sales were decreasing in 2008 and 2009.
Sales were increasing from 1999 to 2007.

(c) No, sales of petroleum and coal products may increase after 2009.

81. (a)



Increasing: 0 seconds to 2 seconds

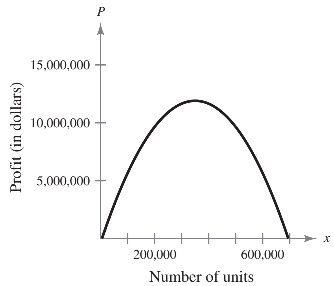
Decreasing: 2 seconds to 4 seconds

(b) Maximum change in volume ≈ 501.9 milliliters

82. $P = R - C = xp - C$

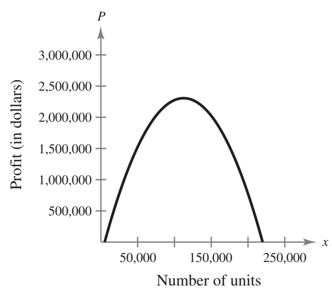
$= x(100 - 0.0001x) - (350{,}000 + 30x)$

$= -0.0001x^2 + 70x - 350{,}000, \quad x \geq 0$



The number of units that would produce a maximum profit is about 350,000.

83.



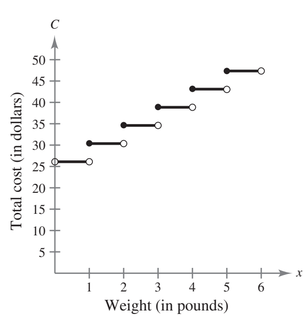
Approximately 112,500 units

84. (a) The maximum book value per share was about \$18.

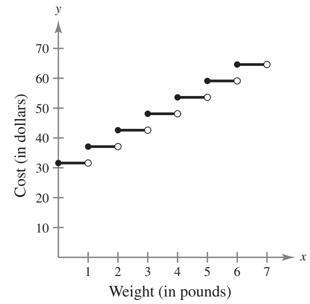
(b) The minimum book value per share was about \$4.

(c) B will be at a maximum in 2011.

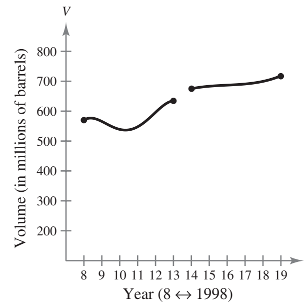
85.



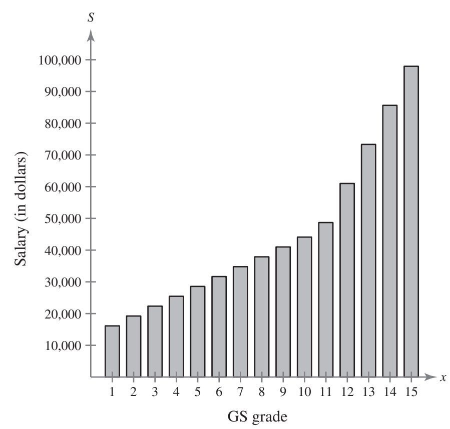
86.



87.



88.



89. (a) $y = 425.71t + 705.54$

Domain: $(0, 4)$

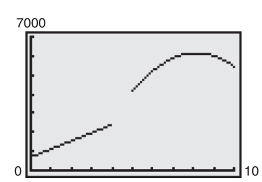
Range: $(705.54, 2408.38)$

(b) $y = -202.950t^2 + 3304.67t - 7311.8$

Domain: $(5, 9)$

Range: $(4137.8, 6140.3)$

(c) $y = \begin{cases} 425.71t + 705.54, & 0 \leq t \leq 4 \\ -202.950t^2 + 3304.67t - 7311.8, & 5 \leq t \leq 9 \end{cases}$



(d) The revenues increased from 2000 to 2008 and decreased from 2008 to 2009.

90. (a) Even. The graph is a reflection in the x-axis.
(b) Even. The graph is a reflection in the y-axis.
(c) Even. The graph is a vertical translation of f.
(d) Neither. The graph is a horizontal translation of f.

91. $\left(-\frac{3}{2}, 4\right)$
(a) If f is even, another point is $\left(\frac{3}{2}, 4\right)$.
(b) If f is odd, another point is $\left(\frac{3}{2}, -4\right)$.

92. $\left(-\frac{5}{3}, -7\right)$
(a) If f is even, another point is $\left(\frac{5}{3}, -7\right)$.
(b) If f is odd, another point is $\left(\frac{5}{3}, 7\right)$.

93. $(4, 9)$
(a) If f is even, another point is $(-4, 9)$.
(b) If f is odd, another point is $(-4, -9)$.

94. $(5, -1)$
(a) If f is even, another point is $(-5, -1)$.
(b) If f is odd, another point is $(5, -1)$.

Section 2.6 Transformations of Functions

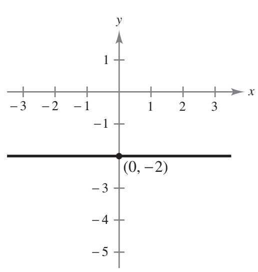
Skills Warm Up

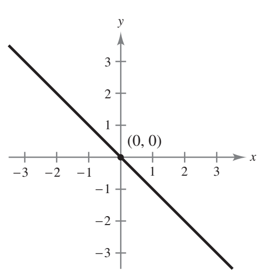
1. $f(3) = 3^2 - 4(3) + 15 = 9 - 12 + 15 = 12$

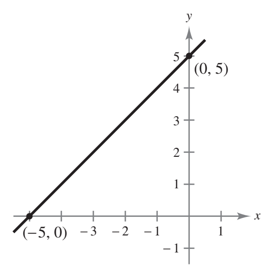
2. $f(-x) = \dfrac{2(-x)}{(-x - 3)} = \dfrac{-2x}{-x - 3}$

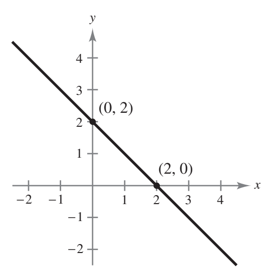
3. $-x^3 + 10x = 0$
$-x(x^2 - 10) = 0$
$x = 0, x = \pm\sqrt{10}$

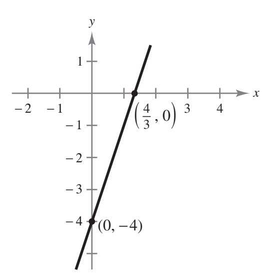
4. $3x^2 + 2x - 8 = 0$
$(3x - 4)(x + 2) = 0$
$x = \frac{4}{3}, x = -2$

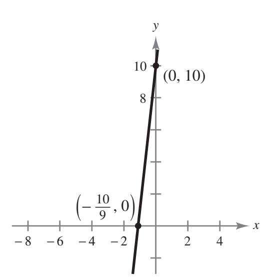
5.


6.


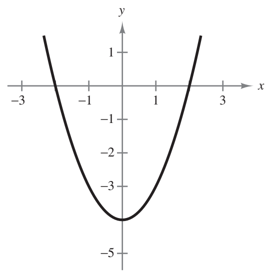
7.


8.


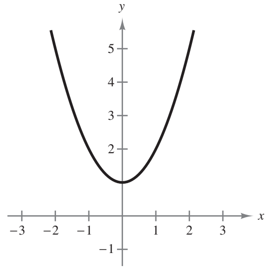
9.


10.


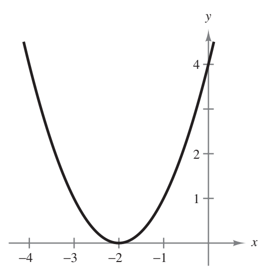
1. Shifted 4 units downward



2. Shifted 1 unit upward

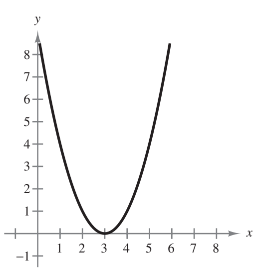


3. Shifted 2 units to the left



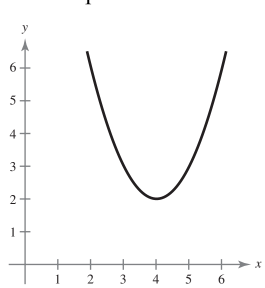
4. $g(x) = (x - 3)^2$

Horizontal shift 3 units to the right



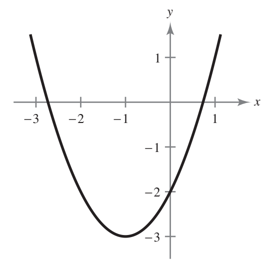
5. $g(x) = (x - 4)^2 + 2 = f(x - 4) + 2$

Horizontal shift 4 units to the right and vertical shift 2 units upward



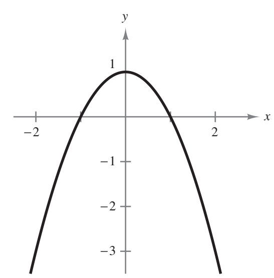
6. $g(x) = (x + 1)^2 - 3 = f(x + 1) - 3$

Horizontal shift 1 unit to the left and vertical shift 3 units downward



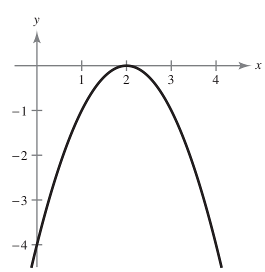
7. $g(x) = -x^2 + 1 = -f(x) + 1$

A reflection in the x-axis and a vertical shift 1 unit upward



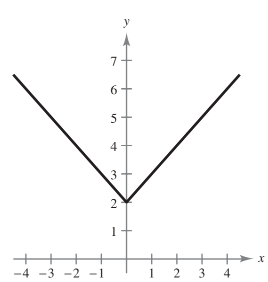
8. $g(x) = -(x - 2)^2 = -f(x - 2)$

Horizontal shift 2 units to the right and a reflection in the x-axis



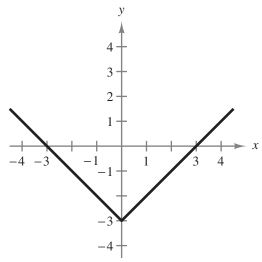
9. $g(x) = |x| + 2 = f(x) + 2$

Vertical shift 2 units upward



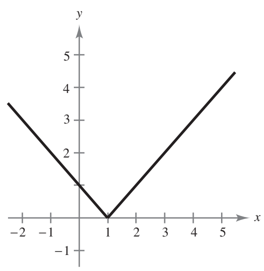
10. $g(x) = |x| - 3$

Vertical shift down 3 units



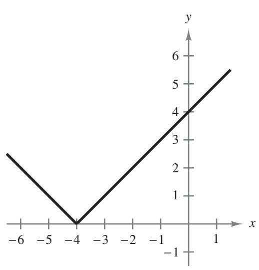
11. $g(x) = |x - 1| = f(x - 1)$

Horizontal shift 1 unit to the right



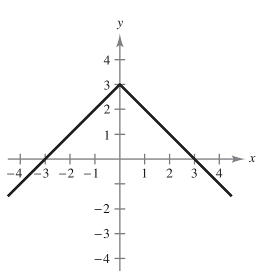
12. $g(x) = |x + 4|$

Horizontal shift 4 units to the left



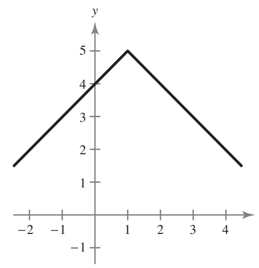
13. $g(x) = -|x| + 3 = -f(x) + 3$

A reflection in the x-axis and a vertical shift 3 units upward



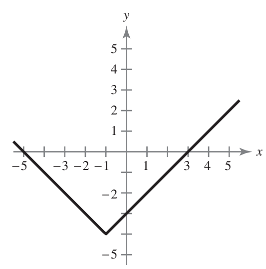
14. $g(x) = 5 - |x - 1|$

Reflected about the x-axis and shifted 1 unit to the right and 5 units upward



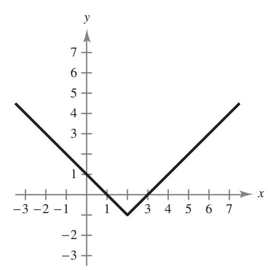
15. $g(x) = |x + 1| - 4 = f(x + 1) - 4$

Horizontal shift 1 unit to the left and vertical shift 4 units downward



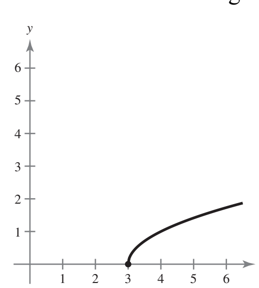
16. $g(x) = |x - 2| - 1 = f(x - 2) - 1$

Horizontal shift 2 units to the right and vertical shift 1 unit downward



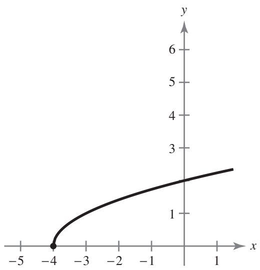
17. $g(x) = \sqrt{x - 3}$

Shifted 3 units to the right



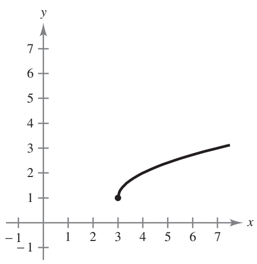
18. $g(x) = \sqrt{x + 4}$

Shifted 4 units to the left



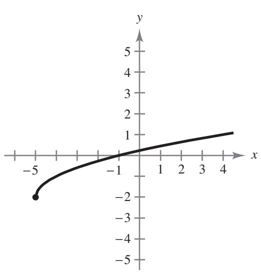
19. $y = \sqrt{x - 3} + 1 = f(x - 3) + 1$

Horizontal shift of 3 units to the right and a vertical shift 1 unit upward



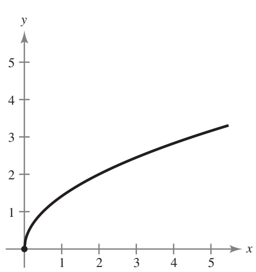
20. $y = \sqrt{x + 5} - 2 = f(x + 5) - 2$

Horizontal shift 5 units to the left and a vertical shift 2 units downward



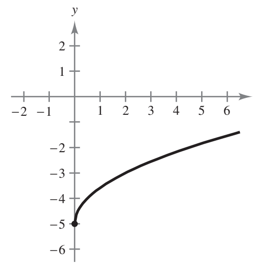
21. $y = \sqrt{2x} = \sqrt{2}\sqrt{x} = \sqrt{2}f(x)$

Vertical stretch by a factor of $\sqrt{2}$



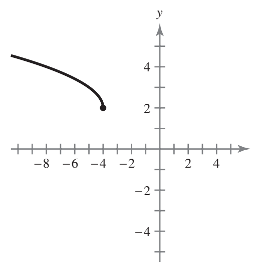
22. $y = \sqrt{2x} - 5 = \sqrt{2}\sqrt{x} - 5 = \sqrt{2}f(x) - 5$

Vertical stretch by a factor of $\sqrt{2}$ and a vertical shift 5 units downward



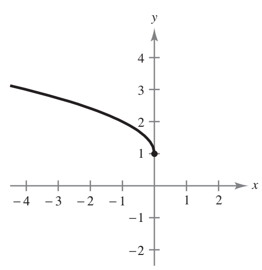
23. $g(x) = 2 + \sqrt{-x - 4} = f[(-1)(x + 4)] + 2$

The graph is reflected about the y-axis and shifted 4 units to the left and 2 units upward.



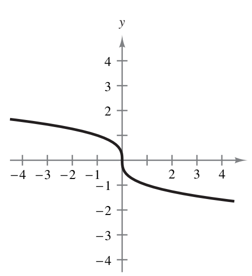
24. $y = \sqrt{-x} + 1 = f(-x) + 1$

Reflection about the y-axis and a vertical shift 1 unit upward



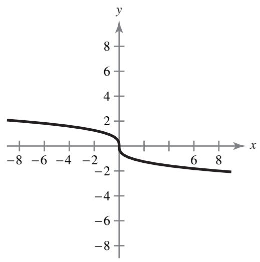
25. $y = \sqrt[3]{-x}$

Reflection about the y-axis



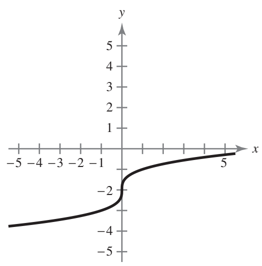
26. $y = -\sqrt[3]{x}$

Reflection about the x-axis



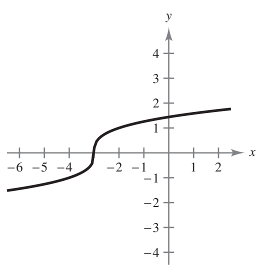
27. $y = \sqrt[3]{x} - 2$

The graph is shifted 2 units downward.



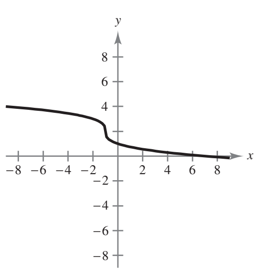
28. $y = \sqrt[3]{x + 3}$

The graph is shifted 3 units to the left.



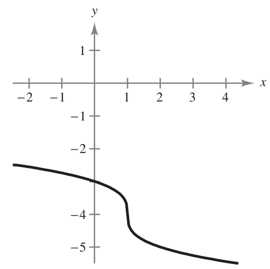
29. $y = 2 - \sqrt[3]{x + 1} = 2 - f(x + 1)$

Reflection about the x-axis, horizontal shift 1 unit to the left, and a vertical shift 2 units upward



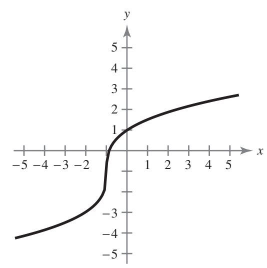
30. $y = -\sqrt[3]{x - 1} - 4 = -f(x - 1) - 4$

Reflection about the x-axis, horizontal shift 1 unit to the right, and a vertical shift 4 units downward



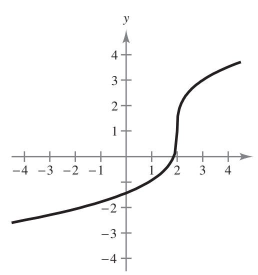
31. $y = 2\sqrt[3]{x + 1} - 1 = 2f(x + 1) - 1$

Vertical stretch by a factor of 2, horizontal shift 1 unit to the left, and a vertical shift 1 unit downward



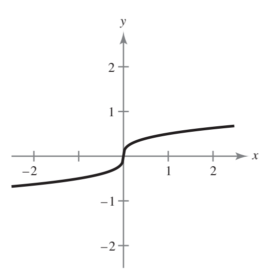
32. $y = 2\sqrt[3]{x - 2} + 1 = 2f(x - 2) + 1$

Vertical stretch by a factor of 2, horizontal shift 2 units to the right, and a vertical shift 1 unit upward



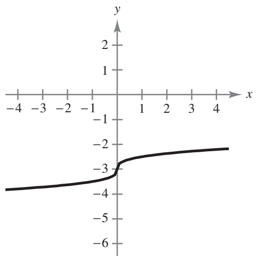
33. $y = \frac{1}{2}\sqrt[3]{x} = \frac{1}{2}f(x)$

Vertical shrink by a factor of $\frac{1}{2}$



34. $y = \frac{1}{2}\sqrt[3]{x} - 3 = \frac{1}{2}f(x) - 3$

Vertical shrink by a factor of $\frac{1}{2}$ and a vertical shift 3 units downward



35. Common function: $y = x^3$

Transformation: horizontal shift 2 units to the right

Equation: $y = (x - 2)^3$

36. Common function: $y = x$

Transformation: multiplied by $\frac{1}{2}$, shrinking

Equation: $y = \frac{1}{2}x$

37. Common function: $y = x^2$

Transformation: reflection about the x-axis

Equation: $y = -x^2$

38. Common function: $y = c$

Transformation: c is 7.

Equation: $y = 7$

39. Common function: $y = \sqrt{x}$

Transformation: reflection about the x-axis and a vertical shift 1 unit upward

Equation: $y = -\sqrt{x} + 1$

40. Common function: $y = |x|$

Transformation: horizontal shift 2 units to the left

Equation: $y = |x + 2|$

41. Common function: $y = x$

Transformation: vertically stretched by a factor of 2

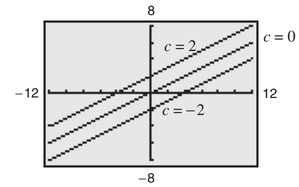
Equation: $y = 2x$

42. Common function: $y = c$

Transformation: shifted downward 3 units

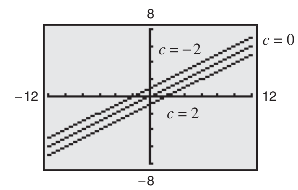
Equation: $y = -3$

43. (a) $f(x) = \frac{1}{2}x + c$



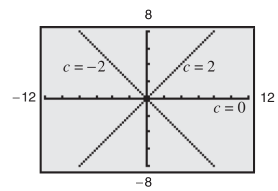
Vertical shift of 2 units

(b) $f(x) = \frac{1}{2}(x - c)$



Horizontal shift of 2 units

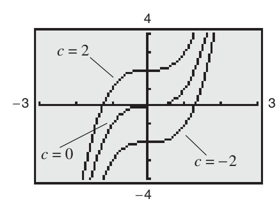
(c) $f(x) = \frac{1}{2}(cx)$



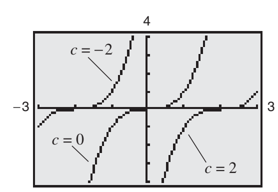
Slope of the function changes

44. (a) $f(x) = x^3 + c$

Vertical shift of 2 units

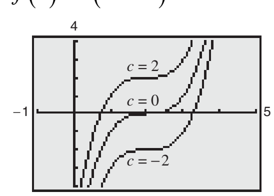


(b) $f(x) = (x - c)^3$



Horizontal shift of 2 units

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



Vertical shift of 2 units and translated 2 units to the right

45. (a) $g(x) = f(x - 1) + 1$

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

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

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

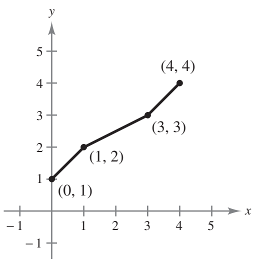
46. (a) $y = -f(x)$

$y = -x^3$

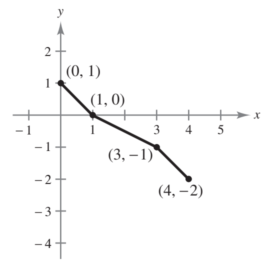
(b) $y = f(x + 1) - 1$

$y = (x + 1)^3 - 1$

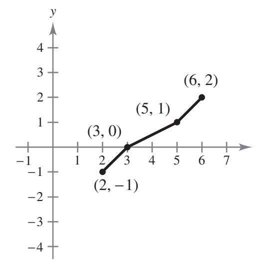
47. (a) Vertical shift 2 units upward



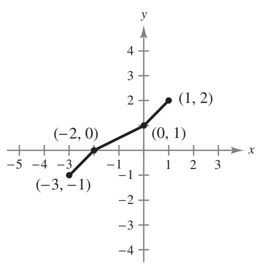
(b) Reflection in the x-axis



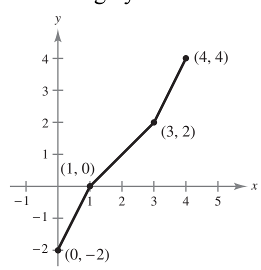
(c) Horizontal shift 2 units to the right



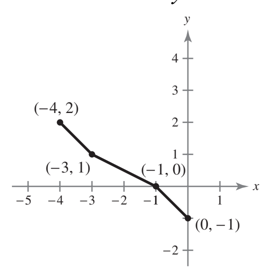
(d) Horizontal shift 3 units to the left



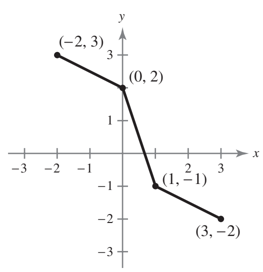
(e) Stretching by 2



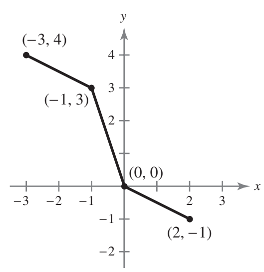
(f) Reflection in the y-axis



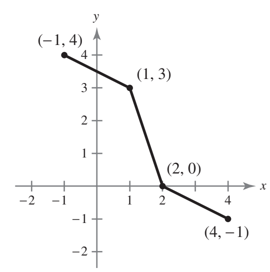
48. (a) Vertical shift 1 unit downward



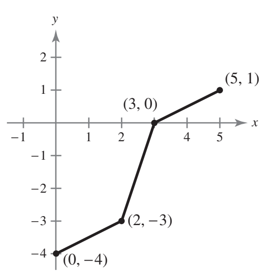
(b) Horizontal shift 1 unit to the left



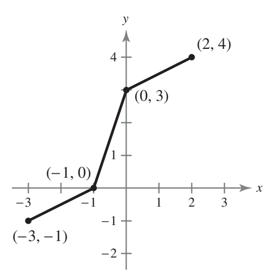
(c) Horizontal shift 1 unit to the right



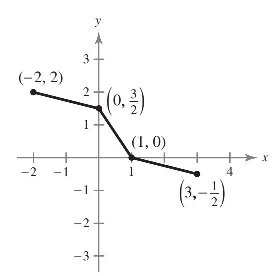
(d) Reflection about the x-axis and a horizontal shift 2 units to the right



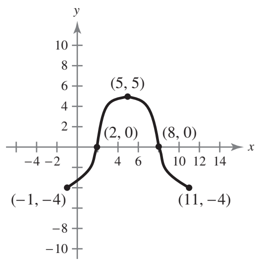
(e) Reflection about the y-axis



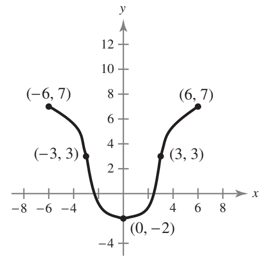
(f) Shrinking by $\frac{1}{2}$



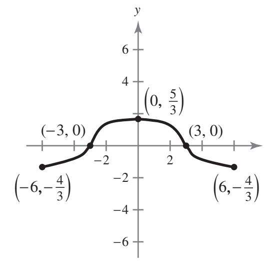
49. (a) Horizontal shift 5 units to the right



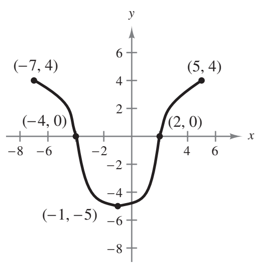
(b) Reflection about the x-axis and a vertical shift 3 units upward



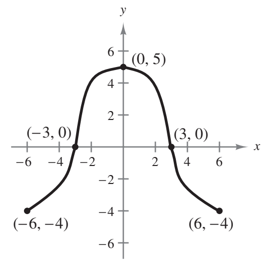
(c) Shrinking by $\frac{1}{3}$



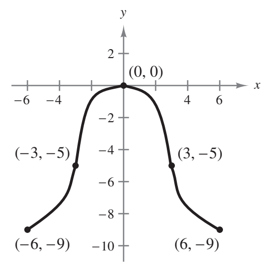
(d) Reflection about the x-axis and a horizontal shift of 1 unit to the left



(e) Reflection about the y-axis



(f) Vertical shift 5 units downward



50. (a) ii
(b) iv
(c) i
(d) iii

51. $y = x^3 - 2$

52. $y = (x + 3)^3$

53. $y = 4x^3$

54. $y = \frac{1}{3}x^3$

55. $h(x) = \sqrt{x - 4} - 3$

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

57. $h(x) = \frac{1}{2}\sqrt{x - 3}$

58. $h(x) = -2\sqrt{x} + 3$

59. The graph is shifted 2 units upward, so $g(x) = x^3 - 3x^2 + 2.$

60. The graph is reflected in the x-axis and shifted 1 unit upward so $g(x) = -f(x) + 1 = -x^3 + 3x^2 + 1.$

61. The graph is shifted 1 unit to the left, so $g(x) = (x + 1)^3 - 3(x + 1)^2 = x^3 - 3x - 2.$

62. The graph is shifted horizontally 2 units to the right and shifted vertically 1 unit upward. So, $g(x) = f(x - 2) + 1 = (x - 2)^3 - 3(x - 2)^2 + 1.$

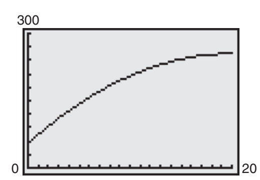
63. Shift: horizontally 1 unit to the right and vertically 2 units downward

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

64. Shift: horizontal by 3 units to the left and vertically 2 units downward

$h(x) = f(x + 3) - 2 = \sqrt[3]{x + 3} - 2$

65. (a)



(b) $P(x) = 80 + 20x - 0.5x^2 - 25$

$P(x) = 55 + 20x - 0.5x^2, 0 \le x \le 20$

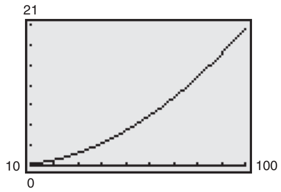
Vertical shift 25 units downward. Note the shift is 25 units since both x and P are measured in hundreds of dollars.

(c) $P\left(\frac{x}{100}\right) = 80 + \frac{x}{5} - 0.00005x^2,$

$0 \le x \le 2000$ (x in dollars)

Horizontal stretch

66. (a)



(b) $H\left(\frac{x}{1.6}\right) = 0.002\left(\frac{x}{1.6}\right)^2 + 0.005\left(\frac{x}{1.6}\right) - 0.029$

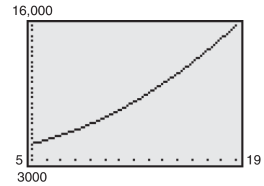
$H\left(\frac{x}{1.6}\right) = 0.00078x^2 + 0.003x - 0.029,$

$16 \le x \le 60,$ x in kilometers

Horizontal stretch

67. (a) The graph is stretched by a factor of 34 and shifted 3705 units upward.

(b)



(c) $34t^2 + 3705 = 13{,}000$

$34t^2 = 9295$

$t^2 = \frac{9295}{34}$

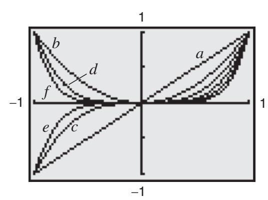
$t = \sqrt{\frac{9295}{34}} \approx 16.5$

So, the amount of debt exceeded $13 trillion in 2007.

(d) $M(t) = 34(t + 10)^2 + 3705$

To make a horizontal shift 10 years backward (10 units to the left), add 10 to t.

68. The graphs of a, c, and e are odd and increasing for all real numbers. The graphs of b, d, and f are even and decreasing for all x less than zero and increasing for all x greater than zero.



69. $y = x^7$ will be an odd function and its graph will be similar in shape to the graphs of $y = x^3$ and $y = x^5$.

$y = x^8$ will be an even function and its graph will be similar in shape to the graphs of $y = x^2$, $y = x^4$, and $y = x^6$.

Section 2.7 The Algebra of Functions

Skills Warm Up

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

2. $\frac{2}{x+3} - \frac{2}{x-3} = \frac{2(x-3)}{(x+3)(x-3)} - \frac{2(x+3)}{(x+3)(x-3)}$

$= \frac{2x - 6 - 2x - 6}{(x+3)(x-3)}$

$= -\frac{12}{(x+3)(x-3)}$

3. $\frac{3}{x-2} - \frac{2}{x(x-2)} = \frac{3x-2}{x(x-2)}$

4. $\frac{x}{x-5} + \frac{1}{3} = \frac{3x}{3(x-5)} + \frac{x-5}{3(x-5)} = \frac{4x-5}{3(x-5)}$

5. $(x-1)\left(\frac{1}{\sqrt{x^2-1}}\right) = \frac{x-1}{\sqrt{x^2-1}} \cdot \frac{\sqrt{x^2-1}}{\sqrt{x^2-1}}$

$= \frac{(x-1)\left(\sqrt{x^2-1}\right)}{x^2-1}$

$= \frac{(x-1)\left(\sqrt{x^2-1}\right)}{(x-1)(x+1)}$

$= \frac{\sqrt{x^2-1}}{x+1}, \quad x \ne 1$

6. $\left(\frac{x}{x^2-4}\right)\left(\frac{x^2-x-2}{x^2}\right)$

$= \left(\frac{x}{(x+2)(x-2)}\right)\left(\frac{(x-2)(x+1)}{x^2}\right)$

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

Skills Warm Up —*continued*—

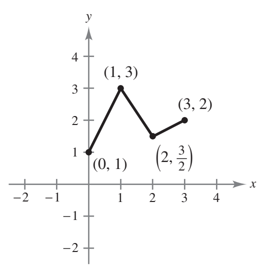
7. $(x^2 - 4) \div \left(\frac{x+2}{5}\right) = (x+2)(x-2)\left(\frac{5}{x+2}\right)$
$= 5(x-2)$

8. $\left(\frac{x}{x^2+3x-10}\right) \div \left(\frac{x^2+3x}{x^2+6x+5}\right)$
$= \left(\frac{x}{(x+5)(x-2)}\right)\left(\frac{(x+5)(x+1)}{x(x+3)}\right)$
$= \frac{x+1}{(x-2)(x+3)},\ x \neq -5, -1, 0$

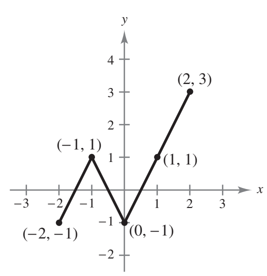
9. $\frac{\left(\frac{1}{x}\right)+5}{3-\left(\frac{1}{x}\right)} = \frac{\frac{1+5x}{x}}{\frac{3x-1}{x}}$
$= \left(\frac{1+5x}{x}\right)\left(\frac{x}{3x-1}\right)$
$= \frac{1+5x}{3x-1},\ x \neq 0$

10. $\frac{\frac{x}{4}-\frac{4}{x}}{x-4} = \frac{\frac{x^2}{4x}-\frac{16}{4x}}{x-4}$
$= \left(\frac{x^2-16}{4x}\right)\left(\frac{1}{x-4}\right)$
$= \left(\frac{(x+4)(x-4)}{4x}\right)\left(\frac{1}{x-4}\right)$
$= \frac{x+4}{4x},\ x \neq 4$

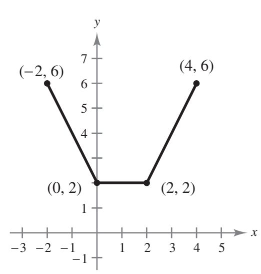
1.



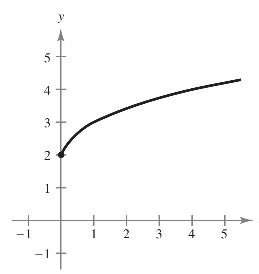
2.



3.



4.



5. (a) $(f+g)(x) = f(x) + g(x)$
$= (x+1) + (x-1)$
$= 2x$

(b) $(f-g)(x) = f(x) - g(x)$
$= (x+1) - (x-1)$
$= 2$

(c) $(fg)(x) = f(x) \cdot g(x)$
$= (x+1)(x-1)$
$= x^2 - 1$

(d) $\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{x+1}{x-1}$

Domain: $(-\infty, 1) \cup (1, \infty)$

6. (a) $(f+g)(x) = f(x) + g(x)$
$= (2x-3) + (1-x)$
$= x - 2$

(b) $(f-g)(x) = f(x) - g(x)$
$= (2x-3) - (1-x)$
$= 3x - 4$

(c) $(fg)(x) = f(x) \cdot g(x)$
$= (2x-3)(1-x)$
$= -2x^2 + 5x - 3$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{2x-3}{1-x}$

Domain: $(-\infty, 1) \cup (1, \infty)$

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

(b) $(f-g)(x) = f(x) - g(x)$
$= 3x - 1 - (1 - x^2)$
$= x^2 + 3x - 2$

(c) $(fg)(x) = f(x)\, g(x)$
$= (3x-1)(1-x^2)$
$= -3x^3 + x^2 + 3x - 1$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{3x-1}{1-x^2}$

Domain: $(-\infty, -1) \cup (-1, 1) \cup (1, \infty)$

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

(b) $(f-g)(x) = f(x) - g(x)$
$= (2x+3) - (x^2 - 1)$
$= -x^2 + 2x + 4$

(c) $(fg)(x) = f(x) \cdot g(x)$
$= (2x+3)(x^2-1)$
$= 2x^3 + 3x^2 - 2x - 3$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{2x+3}{x^2-1}$

Domain: $(-\infty, -1) \cup (-1, 1) \cup (1, \infty)$

9. (a) $(f+g)(x) = f(x) + g(x) = (x^2+5) + \sqrt{1-x}$

(b) $(f-g)(x) = f(x) - g(x) = (x^2+5) - \sqrt{1-x}$

(c) $(fg)(x) = f(x) \cdot g(x) = (x^2+5)\sqrt{1-x}$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{x^2+5}{\sqrt{1-x}}$

Domain: $(-\infty, 1)$

10. (a) $(f+g)(x) = f(x) + g(x)$
$= x^2 - 4 + \sqrt{x-3}$

(b) $(f-g)(x) = f(x) - g(x)$
$= x^2 - 4 - \sqrt{x-3}$

(c) $(fg)(x) = f(x)\, g(x)$
$= (x^2-4)(\sqrt{x-3})$
$= x^2\sqrt{x-3} - 4\sqrt{x-3}$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)}$
$= \dfrac{x^2-4}{\sqrt{x-3}}$

Domain: $(3, \infty)$

11. (a) $(f+g)(x) = f(x) + g(x) = \dfrac{1}{x} + \dfrac{1}{x^2} = \dfrac{x+1}{x^2}$

(b) $(f-g)(x) = f(x) - g(x) = \dfrac{1}{x} - \dfrac{1}{x^2} = \dfrac{x-1}{x^2}$

(c) $(fg)(x) = f(x) \cdot g(x) = \dfrac{1}{x}\left(\dfrac{1}{x^2}\right) = \dfrac{1}{x^3}$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{\frac{1}{x}}{\frac{1}{x^2}} = \dfrac{x^2}{x} = x,\ x \neq 0$

Domain: $(-\infty, 0) \cup (0, \infty)$

12. (a) $(f+g)(x) = f(x) + g(x) = \dfrac{1}{x} + \dfrac{2}{x^3} = \dfrac{x^2+2}{x^3}$

(b) $(f-g)(x) = f(x) - g(x) = \dfrac{1}{x} - \dfrac{2}{x^3} = \dfrac{x^2-2}{x^3}$

(c) $(fg)(x) = f(x)\, g(x) = \left(\dfrac{1}{x}\right)\left(\dfrac{2}{x^3}\right) = \dfrac{2}{x^4}$

(d) $\left(\dfrac{f}{g}\right)(x) = \dfrac{f(x)}{g(x)} = \dfrac{\frac{1}{x}}{\frac{2}{x^3}} = \dfrac{x^2}{2}$

Domain: $(-\infty, 0) \cup (0, \infty)$

13. $(f+g)(x) = 2x + 1 + x^2 - 2$
$= x^2 + 2x - 1$
$(f+g)(3) = 3^2 + 2(3) - 1$
$= 9 + 6 - 1$
$= 14$

14. $(f-g)(x) = 2x + 1 - (x^2 - 2) = -x^2 + 2x + 3$
$(f-g)(-2) = -(-2)^2 + 2(-2) + 3$
$= -4 - 4 + 3$
$= -5$

15. $(f-g)(2t) = -(2t)^2 + 2(2t) + 3 = -4t^2 + 4t + 3$

16. $(f+g)(3t) = f(3t) + g(3t)$
$= \left[2(3t) + 1\right] + \left[(3t)^2 - 2\right]$
$= 6t + 1 + 9t^2 - 2$
$= 9t^2 + 6t - 1$

17. $(fg)(x) = (2x+1)(x^2 - 2)$
$= 2x^3 + x^2 - 4x - 2$
$(fg)(-2) = 2(-2)^3 + (-2)^2 - 4(-2) - 2$
$= 2(-8) + 4 + 8 - 2$
$= -6$

18. $(fg)(-6) = 2(-6)^3 + (-6)^2 - 4(-6) - 2$
$= 2(-216) + 36 + 24 - 2$
$= -374$

19. $\left(\frac{f}{g}\right)(x) = \frac{2x+1}{x^2 - 2}$
$\left(\frac{f}{g}\right)(5) = \frac{2(5)+1}{5^2 - 2} = \frac{11}{23}$

20. $\left(\frac{f}{g}\right)(0) = \frac{2(0)+1}{0^2 - 2} = -\frac{1}{2}$

21. $(f-g)(0) = -0^2 + 2(0) + 3 = 3$

22. $(f+g)(1) = 1^2 + 2(1) - 1 = 2$

23. $4f = 4(2x+1) = 8x + 4$
$2g = 2(x^2 - 2) = 2x^2 - 4$
$(4f)(2) - (2g)(4) = \left[8(2) + 4\right] - \left[2(4)^2 - 4\right]$
$= 20 - 28$
$= -8$

24. $2\left(2(5) + 1\right) + 3\left((-4)^2 - 2\right) = 2(11) + 3(14) = 64$

25. (a) $(f \circ g)(x) = f(g(x)) = f(2x+5) = 3(2x+5) = 6x + 15$

(b) $(g \circ f)(x) = g(f(x)) = g(3x) = 2(3x) + 5 = 6x + 5$

(c) $(f \circ f)(x) = f(f(x)) = f(3x) = 3(3x) = 9x$

26. (a) $(f \circ g)(x) = f(g(x)) = f(7 - x) = 2(7 - x) - 1 = 14 - 2x - 1 = -2x + 13$

(b) $(g \circ f)(x) = g(f(x)) = g(2x - 1) = 7 - (2x - 1) = 7 - 2x + 1 = -2x + 8$

(c) $(f \circ f)(x) = f(f(x)) = f(2x - 1) = 2(2x - 1) - 1 = 4x - 2 - 1 = 4x - 3$

27. (a) $(f \circ g)(x) = f(g(x)) = f(3x+1) = (3x+1)^2 = 9x^2 + 6x + 1$

(b) $(g \circ f)(x) = g(f(x)) = g(x^2) = 3x^2 + 1$

(c) $(f \circ f)(x) = f(f(x)) = f(x^2) = (x^2)^2 = x^4$

28. (a) $(f \circ g)(x) = f(g(x)) = f\left(\frac{1}{x}\right) = \left(\frac{1}{x}\right)^3 = \frac{1}{x^3}$

(b) $(g \circ f)(x) = g(f(x)) = g(x^3) = \frac{1}{x^3}$

(c) $(f \circ f)(x) = f(f(x)) = f(x^3) = (x^3)^3 = x^9$

29. (a) $(f \circ g)(x) = f(g(x)) = f(3x + 1) = \frac{1}{3}(3x + 1) - 3 = x - \frac{8}{3}$

(b) $(g \circ f)(x) = g(f(x)) = g\left(\frac{1}{3}x - 3\right) = 3\left(\frac{1}{3}x - 3\right) + 1 = x - 8$

30. (a) $(f \circ g)(x) = f(g(x)) = f(2x + 3) = \frac{1}{2}(2x + 3) + 1 = x + \frac{3}{2} + 1 = x + \frac{5}{2}$

(b) $(g \circ f)(x) = g(f(x)) = g\left(\frac{1}{2}x + 1\right) = 2\left(\frac{1}{2}x + 1\right) + 3 = x + 2 + 3 = x + 5$

31. (a) $(f \circ g)(x) = f(g(x)) = f(x^2 - 4) = \sqrt{x^2 - 4 + 4} = x$

(b) $(g \circ f)(x) = g(f(x)) = g\left(\sqrt{x + 4}\right) = \left(\sqrt{x + 4}\right)^2 - 4 = x + 4 - 4 = x$

32. (a) $(f \circ g)(x) = f(g(x)) = f(x^3 + 1) = \sqrt[3]{(x^3 + 1) - 1} = x$

(b) $(g \circ f)(x) = g(f(x)) = g\left(\sqrt[3]{x - 1}\right) = \left(\sqrt[3]{x - 1}\right)^3 + 1 = x$

33. (a) $(f \circ g)(x) = f(g(x)) = f\left(\sqrt{x}\right) = \left(x^{1/2}\right)^{1/2} = x^{1/4} = \sqrt[4]{x}$

(b) Since $f(x) = g(x)$, $(g \circ f)(x) = (f \circ g)(x) = \sqrt[4]{x}$.

34. (a) $(f \circ g)(x) = f(g(x)) = f(x^2) = \left(x^2\right)^2 = x^4$

(b) $(g \circ f)(x) = g(f(x)) = g(x^2) = \left(x^2\right)^2 = x^4$

35. (a) $(f \circ g)(x) = f(g(x)) = f(x + 6) = |x + 6|$

(b) $(g \circ f)(x) = g(f(x)) = g(|x|) = |x| + 6$

36. (a) $(f \circ g)(x) = f(g(x)) = f(|x|) = |x| - 4$

(b) $(g \circ f)(x) = g(f(x)) = g(x - 4) = |x - 4|$

37. (a) All real numbers, or $(-\infty, \infty)$

(b) $x \geq 0$, or $[0, \infty)$

(c) $(f \circ g)(x) = f(g(x)) = f\left(\sqrt{x}\right)$

$= \left(\sqrt{x}\right)^2 + 3 = x + 3$

$x \geq 0$, or $[0, \infty)$

38. (a) All real numbers, or $(-\infty, \infty)$

(b) All real numbers, or $(-\infty, \infty)$

(c) All real numbers, or $(-\infty, \infty)$

39. (a) All real numbers $x \neq 0$, or $(-\infty, 0) \cup (0, \infty)$

(b) All real numbers, or $(-\infty, \infty)$

(c) $(f \circ g)(x) = f(g(x)) = f(x - 2) = \dfrac{1}{(x - 2)^2}$

All real numbers $x \neq 2$, or $(-\infty, 2) \cup (2, \infty)$

40. (a) All real numbers $x \neq \pm 2$, or $(-\infty, -2) \cup (-2, 2) \cup (2, \infty)$

(b) All real numbers, or $(-\infty, \infty)$

(c) $(f \circ g)(x) = f(g(x)) = f(x + 3)$

$= \dfrac{5}{(x + 3)^2 - 4} = \dfrac{5}{x^2 + 6x + 5}$

$= \dfrac{5}{(x + 5)(x + 1)}$

All real numbers $x \neq -5, -1$, or $(-\infty, -5) \cup (-5, -1) \cup (-1, \infty)$

41. (a) $(f + g)(3) = f(3) + g(3) = 2 + 1 = 3$

(b) $\left(\dfrac{f}{g}\right)(2) = \dfrac{f(2)}{g(2)} = \dfrac{0}{2} = 0$

42. (a) $(f - g)(1) = f(1) - g(1) = 2 - 3 = -1$

(b) $(fg)(4) = f(4)g(4) = 4(0) = 0$

43. (a) $(f \circ g)(2) = f(g(2)) = f(2) = 0$

(b) $(g \circ f)(2) = g(f(2)) = g(0) = 4$

44. (a) $(f \circ g)(0) = f(g(0)) = f(4) = 4$

(b) $(g \circ f)(3) = g(f(3)) = g(2) = 2$

45. $f(x) = x^2$, $g(x) = 2x + 1$ (Answers will vary.)

46. $f(x) = x^3$, $g(x) = 1 - x$ (Answers will vary.)

47. $f(x) = \sqrt[3]{x},\ g(x) = x^2 - 4$ (Answers will vary.)

48. $f(x) = \sqrt{x},\ g(x) = 9 - x$ (Answers will vary.)

49. $f(x) = \dfrac{1}{x},\ g(x) = x + 2$ (Answers will vary.)

50. $f(x) = \dfrac{4}{x^2},\ g(x) = 5x + 2$ or $f(x) = x^2,$

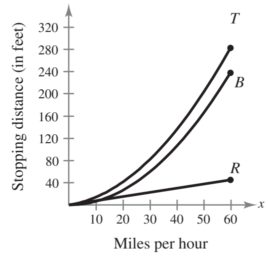
$g(x) = \dfrac{2}{5x + 2}$

(Answers will vary.)

51. $f(x) = x^2 + 2x, g(x) = x + 4$ (Answers will vary.)

52. $f(x) = x^{3/2}, g(x) = x + 3$ (Answers will vary.)

53. $T = R + B = \frac{3}{4}x + \frac{1}{15}x^2, 0 \le x \le 60$



54. $(C \circ x)(t) = 70(40t) + 800 = 2800t + 800$

$C \circ x$ represents the cost of producing x units in t hours.

55. $(C \circ x)(t) = 50(30t) + 495 = 1500t + 495$

$C \circ x$ represents the cost of producing x units in t hours.

56. (a) The company's total yearly profits increased slightly from 2005 through 2012.

(b) Total yearly profit $= P_1 + P_2 = (18.97 - 0.55t) + (15.85 + 0.67t) = 34.82 + 0.12t$

The function is linear with positive slope, so profits increased from 2005 to 2012. The slope is close to zero, so profits increased only slightly.

57. (a) Total yearly sales decreased from 2005 to 2012.

(b) Total yearly sales $= R_1 + R_2 = (525 - 15.2t) + (392 + 8.5t) = 917 - 6.7t$

The function is linear with a negative slope, so yearly sales decreased for increasing values of t.

58. (a) $y_1 = 4.93t + 31.4, \quad 3 \le t \le 12$

$y_2 = 3.78t + 21.0, \quad 3 \le t \le 12$

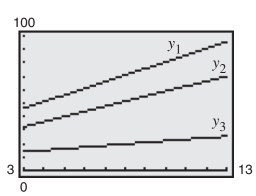
(b) $y_3 = y_1 - y_2 = (4.93t + 31.4) - (3.78t + 21.0)$

$= 1.15t + 10.4$

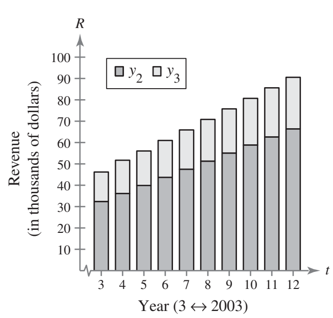
y_3 represents profit for a sports memorabilia store from 2003 to 2012.

When $t = 14$: $y_3 = 1.15(14) + 10.4 = 26.5$

In 2014, the profit for the store will be about $26,500.

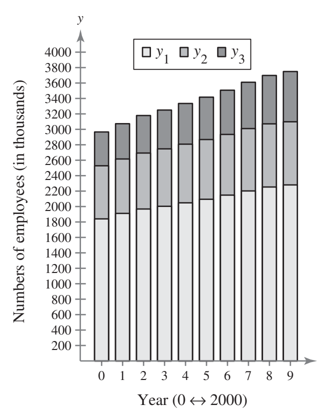


(c)



The heights of the bars represent the revenues, y_1, in thousands of dollars.

59. (a)

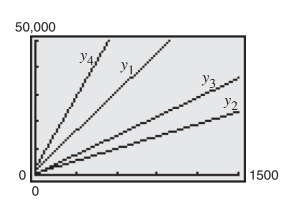


(b) $y_1 = 48.5t + 1856$

$y_2 = 15.2t + 694$

$y_3 = 23.7t + 434$

(c)



$y_4 = 87.4t + 2984$

When $t = 11$: $y_4 = 87.4(11) + 2984 = 3945.4$

When $t = 13$: $y_4 = 87.4(13) + 2984 = 4120.2$

In 2011, there were 3,945,400 employees.

In 2013, there were 4,120,200 employees.

60. (a) $N(T(t)) = 10(3t + 1)^2 - 20(3t + 1) + 600$
$= 90t^2 + 590$

(b) $N(T(2)) = 90(2)^2 + 590 = 950$

The number of bacteria will be 950.

(c) $90t^2 + 590 = 1500$
$90t^2 = 910$
$t^2 = \frac{910}{90}$
$t = \frac{\sqrt{91}}{3} \approx 3.1798$

The bacteria count will reach 1500 in about 3 hours.

61. $(A \circ r)(t) = A(r(t)) = \pi(0.6t)^2 = 0.36\pi t^2$
$A \circ r$ represents the area of the circle at time t.

62. (a) L_2

(b) L_1

(c) L_4; $(g \circ f)(p)$ represents subtracting \$5 after applying a 50% discount.

(d) L_3; $(f \circ g)(p)$ represents subtracting \$5 from the price and then taking a 50% discount.

63.

Year	2005	2006	2007	2008	2009
P/E	16.7	21.0	25.9	12.7	11.3

64.

Year	2005	2006	2007	2008	2009
P/E	20.4	17.1	17.8	14.2	12.5

65. $\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{\sqrt{x}}{\sqrt{9 - x^2}}$

Domain: all real numbers $0 \le x < 3$, or $[0, 3)$

$\left(\frac{g}{f}\right)(x) = \frac{g(x)}{f(x)} = \frac{\sqrt{9 - x^2}}{\sqrt{x}}$

Domain: all real numbers $0 < x \le 3$ or $(0, 3]$

The domains differ because if $x = 3$, $\left(\frac{f}{g}\right)(x)$ would be undefined (division by zero), and if $x = 0$, $\left(\frac{g}{f}\right)(x)$ would be undefined (division by zero).

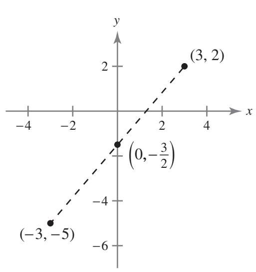
66. False. $(f \circ g)(x) = 6x + 1$ and $(g \circ f)(x) = 6x + 6$

67. True. The range of g must be a subset of the domain of f for $(f \circ g)(x)$ to be defined.

68. Answers will vary.

Review Exercises for Chapter 2

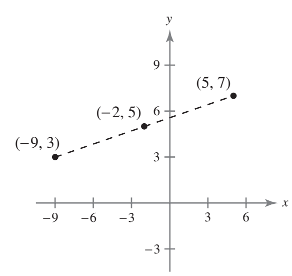
1. (a)



(b) $d = \sqrt{(3 - (-3))^2 + (2 - (-5))^2}$
$= \sqrt{6^2 + 7^2} = \sqrt{85} \approx 9.22$

(c) Midpoint: $\left(\frac{-3 + 3}{2}, \frac{-5 + 2}{2}\right) = \left(0, -\frac{3}{2}\right)$

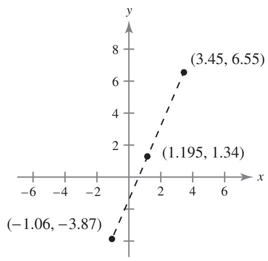
2. (a)



(b) $d = \sqrt{(5 - (-9))^2 + (7 - 3)^2}$
$= \sqrt{14^2 + 4^2} = \sqrt{212} = 2\sqrt{53} \approx 14.56$

(c) Midpoint: $\left(\frac{-9 + 5}{2}, \frac{3 + 7}{2}\right) = (-2, 5)$

3. (a)



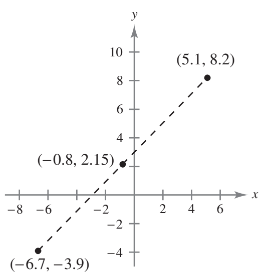
(b) $d = \sqrt{(3.45 + 1.06)^2 + (6.55 + 3.87)^2}$

$= \sqrt{128.9165} \approx 11.35$

(c) Midpoint:

$\left(\dfrac{-1.06 + 3.45}{2}, \dfrac{-3.87 + 6.55}{2}\right) = (1.195, 1.34)$

4. (a)



(b) $d = \sqrt{(5.1 + 6.7)^2 + (8.2 + 3.9)^2}$

$= \sqrt{285.65} \approx 16.90$

(c) Midpoint:

$\left(\dfrac{-6.7 + 5.1}{2}, \dfrac{-3.9 + 8.2}{2}\right) = (-0.8, 2.15)$

5. $\sqrt{(x - 10)^2 + (-5 - 10)^2} = 25$

$x^2 - 20x + 100 + 225 = 625$

$x^2 - 20x - 300 = 0$

$(x + 10)(x - 30) = 0$

$x = -10$ or $x = 30$

6. $\sqrt{(-15 - x)^2 + (10 + 5)^2} = 25$

$225 + 30x + x^2 + 225 = 625$

$x^2 + 30x - 175 = 0$

$(x + 35)(x - 5) = 0$

$x = -35$ or $x = 5$

7. (a) $0 \stackrel{?}{=} 2(5)^2 - 7(5) - 15$

$0 \stackrel{?}{=} 50 - 35 - 15$

$0 = 0$ ✓

(5, 0) is a solution.

(b) $7 \stackrel{?}{=} 2(-2)^2 - 7(-2) - 15$

$7 \stackrel{?}{=} 8 + 14 - 15$

$7 = 7$ ✓

$(-2, 7)$ is a solution.

8. (a) $5 \stackrel{?}{=} \sqrt{16 - 1^2}$

$5 \neq \sqrt{15}$ ✗

(1, 5) is not a solution.

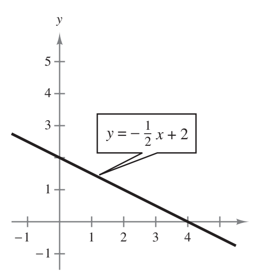
(b) $0 \stackrel{?}{=} \sqrt{16 - 4^2}$

$0 = \sqrt{0}$ ✓

(4, 0) is a solution.

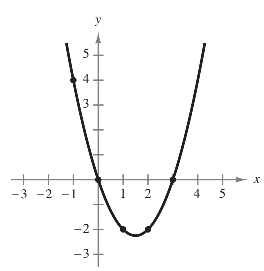
9. $y = -\frac{1}{2}x + 2$

x	-2	0	2	3	4
y	3	2	1	$\frac{1}{2}$	0



10. $y = x^2 - 3x$

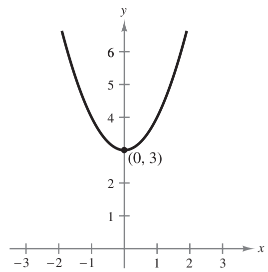
x	-1	0	1	2	3
y	4	0	-2	-2	0



11. $y = x^2 + 3$

y-intercept: $(0, 3)$

y-axis symmetry



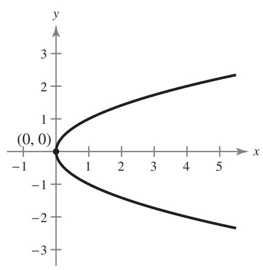
12. $y^2 = x$

x-axis symmetry:

$(-y)^2 = x$

$y^2 = x$

x- and y-intercepts: $(0, 0)$

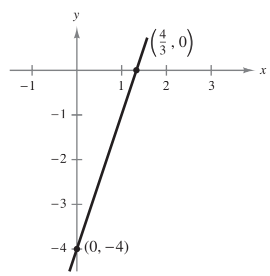


13. $y = 3x - 4$

x-intercept: $\left(\frac{4}{3}, 0\right)$

y-intercept: $(0, -4)$

Symmetry: none

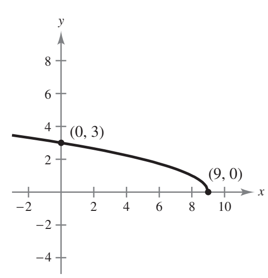


14. $y = \sqrt{9 - x}$

x-intercept: $(9, 0)$

y-intercept: $(0, 3)$

Symmetry: none

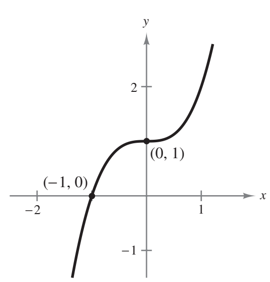


15. $y = x^3 + 1$

x-intercept: $(-1, 0)$

y-intercept: $(0, 1)$

Symmetry: none

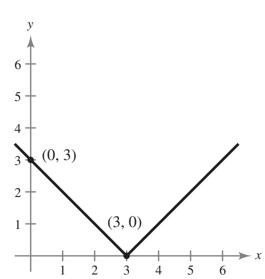


16. $y = |x - 3|$

x-intercept: $(3, 0)$

y-intercept: $(0, 3)$

Symmetry: none



17. $(x + 1)^2 + (y - 2)^2 = 6^2$

$(x + 1)^2 + (y - 2)^2 = 36$

18. $C = \left(\frac{-2 + 4}{2}, \frac{-3 + 5}{2}\right)$

$= (1, 1)$

$r = \sqrt{(1 + 3)^2 + (1 + 2)^2}$

$= \sqrt{16 + 9}$

$= 5$

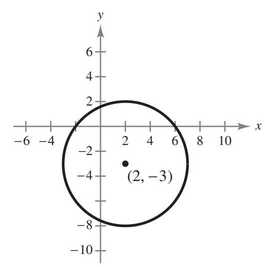
$(x - 1)^2 + (y - 1)^2 = 5^2$

$(x - 1)^2 + (y - 1)^2 = 25$

19. $x^2 + y^2 - 4x + 6y - 12 = 0$

$(x - 4x + 4) + (y^2 + 6y + 9) = 12 + 4 + 9$

$(x - 2)^2 + (y + 3)^2 = 25$

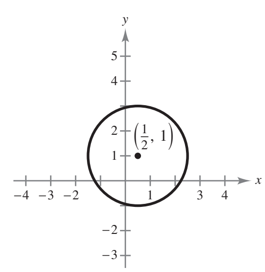


20. $4x^2 + 4y^2 - 4x - 8y - 11 = 0$

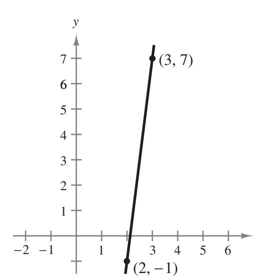
$x^2 + y^2 - x - 2y - \frac{11}{4} = 0$

$\left(x^2 - x + \frac{1}{4}\right) + \left(y^2 - 2y + 1\right) = \frac{11}{4} + \frac{1}{4} + 1$

$\left(x - \frac{1}{2}\right)^2 + (y - 1)^2 = 4$

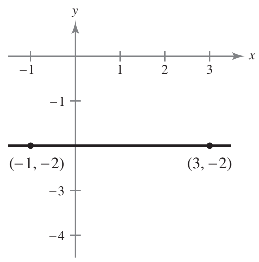


21. $m = \frac{-1 - 7}{2 - 3} = 8$



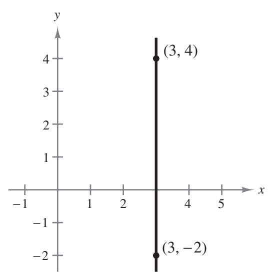
22. Since $m = 0$, the line is horizontal.

$y = -2 \Rightarrow y + 2 = 0$

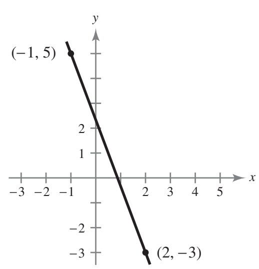


23. Since m is undefined, the line is vertical.

$x = 3 \Rightarrow x - 3 = 0$

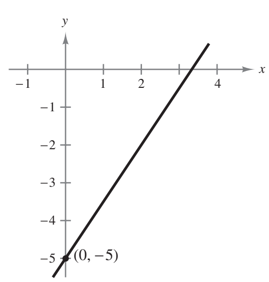


24. $m = \dfrac{-3 - 5}{2 + 1} = -\dfrac{8}{3}$



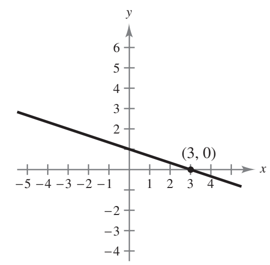
25. $y + 5 = \frac{3}{2}(x - 0)$

$y = \frac{3}{2}x - 5 \Rightarrow 3x - 2y - 10 = 0$



26. $y - 0 = -\frac{1}{3}(x - 3)$

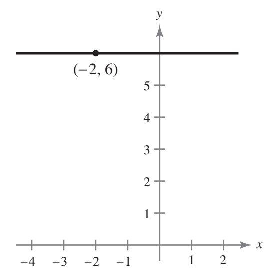
$y = -\frac{1}{3}x + 1$



27. $y - 6 = 0(x + 2)$

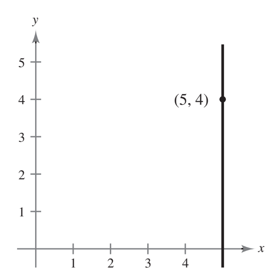
$y - 6 = 0$

$y = 6$



28. Since m is undefined, the line is vertical.

$x = 5 \Rightarrow x - 5 = 0$



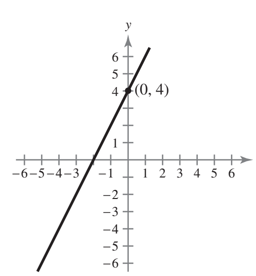
29. $8x - 4y + 16 = 0$

$-4y = -8x - 16$

$y = 2x + 4$

Slope: $m = 2$

y-intercept: $(0, 4)$

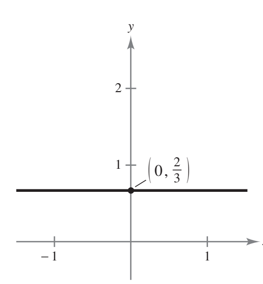


30. $3y - 2 = 0$

$y = \frac{2}{3}$

Slope: $m = 0$

y-intercept: $\left(0, \frac{2}{3}\right)$



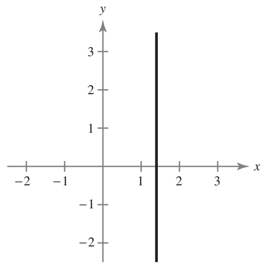
31. $17 - 5x = 10$

$-5x = -7$

$x = \frac{7}{5}$

Slope: undefined

y-intercept: none



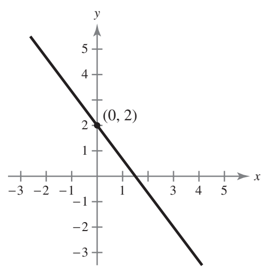
32. $16x + 12y - 24 = 0$

$12y = -16x + 24$

$y = -\frac{4}{3}x + 2$

Slope: $-\frac{4}{3}$

y-intercept: $(0, 2)$



33. L_1: $(0, 3), (-2, 1)$

$m_1 = \dfrac{1 - 3}{-2 - 0} = 1$

L_2: $(-8, -3), (4, 9)$

$m_2 = \dfrac{9 + 3}{4 + 8} = 1$

Since $m_1 = m_2$, the lines are parallel.

34. L_1: $(-1, 0), (5, 5)$

$m_1 = \dfrac{5 - 0}{5 - (-1)} = \dfrac{5}{6}$

L_2: $(2, 1), (8, 6)$

$m_2 = \dfrac{6 - 1}{8 - 2} = \dfrac{5}{6}$

Since $m_1 = m_2$, the lines are parallel.

35. L_1: $(3, 6), (-1, -5)$

$m_1 = \dfrac{-5 - 6}{-1 - 3} = \dfrac{11}{4}$

L_2: $(-2, 3), (4, 7)$

$m_2 = \dfrac{7 - 3}{4 + 2} = \dfrac{4}{6} = \dfrac{2}{3}$

The lines are neither parallel nor perpendicular.

36. L_1: $(-1, 2), (-1, 4)$

$m_1 = \dfrac{4 - 2}{-1 + 1} = \dfrac{2}{0}$ undefined

L_2: $(7, 3), (4, 7)$

$m_2 = \dfrac{7 - 3}{4 - 7} = -\dfrac{4}{3}$

Vertical line

The lines are neither parallel nor perpendicular.

37. $y = \dfrac{1}{2}x - 1$

$m_1 = \dfrac{1}{2}$

(a) $m_2 = \dfrac{1}{2}, (4, 3)$

$y - 3 = \dfrac{1}{2}(x - 4)$

$y - 3 = \dfrac{1}{2}x - 2$

$y = \dfrac{1}{2}x + 1$

(b) $m_2 = -\dfrac{1}{\frac{1}{2}} = -2$

$y - 3 = -2(x - 4)$

$y - 3 = -2x + 8$

$y = -2x + 11$

38. $y = -2x + 3$

$m_1 = -2$

(a) $m_2 = -2, (1, -4)$

$y - (-4) = -2(x - 1)$

$y + 4 = -2x + 2$

$y = -2x - 2$

(b) $m_2 = -\dfrac{1}{-2} = \dfrac{1}{2}$

$y - (-4) = \dfrac{1}{2}(x - 1)$

$y + 4 = \dfrac{1}{2}x - \dfrac{1}{2}$

$y = \dfrac{1}{2}x - \dfrac{9}{2}$

or

$x - 2y - 9 = 0$

39. $5x - 4y = 8$

$y = \frac{5}{4}x - 2$

$m_1 = \frac{5}{4}$

(a) $m_2 = \frac{5}{4}, (3, -2)$

$y + 2 = \frac{5}{4}(x - 3)$

$4y + 8 = 5x - 15$

$0 = 5x - 4y - 23$

(b) $m_2 = -\frac{4}{5}, (3, -2)$

$y + 2 = -\frac{4}{5}(x - 3)$

$5y + 10 = -4x + 12$

$4x + 5y - 2 = 0$

40. $2x + 3y = 5$

$y = -\frac{2}{3}x + \frac{5}{3}$

$m_1 = -\frac{2}{3}$

(a) $m_2 = -\frac{2}{3}, (-8, 3)$

$y - 3 = -\frac{2}{3}(x + 8)$

$3y - 9 = -2x - 16$

$2x + 3y + 7 = 0$

(b) $m_2 = \frac{3}{2}, (-8, 3)$

$y - 3 = \frac{3}{2}(x + 8)$

$2y - 6 = 3x + 24$

$0 = 3x - 2y + 30$

41. (a) $y = -2$

(b) $x = -1$

42. (a) $x = 0$

(b) $y = 5$

43. $y = kx$

$7 = k(3)$

$\frac{7}{3} = k$

$y = \frac{7}{3}x$

44. $y = kx$

$7.5 = k(5)$

$1.5 = k$

$y = 1.5x$

45. $y = kx$

$3480 = k(10)$

$348 = k$

$y = 348x$

46. $y = kx$

$1.95 = k(14)$

$\frac{39}{280} = k$

$y = \frac{39}{280}x$

47. $A = \frac{30}{6}r = 5r$

48. $y = \frac{7}{14}z = \frac{1}{2}z$

49. $a = \frac{15}{20}b = \frac{3}{4}b$

50. $m = kn$

$12 = 36k$

$\frac{1}{3} = k$

$m = \frac{1}{3}n$

51. $y = \dfrac{1260}{150{,}000}x$

Model: $y = 0.0084x$

When $x = 175{,}000$: $y = 0.0084(175{,}000) = 1470$

The property tax on a $175,000 home is $1470.

52. $M = kF$

$305 = k(1000)$

$k = \frac{61}{200}$

$M = \frac{61}{200}F$

Feet	20	50	100	120
Meters	6.1	15.25	30.5	36.6

53. $\dfrac{3{,}150{,}000 - 2{,}950{,}000}{3 - 2} = 200{,}000$

$y - 2{,}950{,}000 = 200{,}000(x - 2)$

$y = 200{,}000x + 2{,}550{,}000$

When $x = 4$:

$y = 200{,}000(4) + 2{,}550{,}000 = 3{,}350{,}000$

In the fourth quarter, sales will be $3,350,000.

54. $V = 4.75t + 75$

When $t = 13$: $V = 4.75(13) + 75 = 136.75$

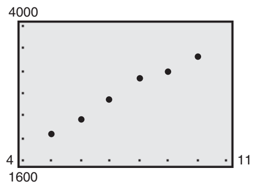
In 2013, the dollar value of the product will be $136.75.

55. Amount lost: $135{,}000 - 5500 = 129{,}500 \div 10$

$= 12{,}950$ lost per year

Model: $y = -12{,}950t + 135{,}000, 0 \le t \le 10$

56. (a)



Yes, the data appear to be approximately linear.

(b) $S = 279.83t + 701.8$

(c) When $t = 11$: $S = 279.83(11) + 701.8 = 3779.93$

In 2011, sales will be about \$3780 million.

(d) The prediction in part (c) is close to that of Intuit Corporation. Answers will vary.

57. $3x + y = 12$

$y = -3x + 12$

y is a function of x.

58. $y^2 = x^2 - 9$

$y = \pm\sqrt{x^2 - 9}$

y is not a function of x because it fails the vertical line test for y as a function of x.

59. $y^2 = x + 3$

No, y is not a function of x because a value of x will be matched with two different values of y.

60.

$$x^2 + y^2 - 6x + 8y = 0$$
$$(x^2 - 6x + 9) + (y^2 + 8y + 16) = 9 + 16$$
$$(x - 3)^2 + (y + 4)^2 = 25$$
$$(y + 4)^2 = 25 - (x - 3)^2$$
$$y + 4 = \pm\sqrt{25 - (x - 3)^2}$$
$$y = -4 \pm \sqrt{25 - (x - 3)^2}$$

y is not a function of x. $x^2 + y^2 - 6x + 8y = 0$ is a circle and fails the vertical line test for y as a function of x.

61. Because each element of A is paired with only one element of B, $\{(1, -3), (2, -7), (3, -3)\}$ represents a function from A to B.

62. Because -9 is not an element of B, $\{(1, -4), (2, -3), (3, -9)\}$ does not represent a function from A to B.

63. (a) $f(5) = \sqrt{5 + 4} - 5 = \sqrt{9} - 5 = -2$

(b) $f(0) = \sqrt{0 + 4} - 5 = 2 - 5 = -3$

(c) $f(-4) = \sqrt{-4 + 4} - 5 = -5$

(d) $f(x + 3) = \sqrt{x + 3 + 4} - 5 = \sqrt{x + 7} - 5$

64. (a) $f(0) = 2(0) - 1 = -1$

(b) $f(1) = 2(1) - 1 = 2 - 1 = 1$

(c) $f(3) = 3^2 + 2 = 9 + 2 = 11$

(d) $f(-4) = 2(-4) - 1 = -8 - 1 = -9$

65. All real numbers x

66. All real numbers t

67. $x \geq -5$

68. All real numbers t

69. $1 \leq t < 4,\ t > 4$

70. $x^2 - 4 \neq 0$

$x^2 \neq 4$

$x \neq \pm 2$

The domain is all real numbers except $x = \pm 2$.

71. The domain of $h(x)$ is all real numbers except $x = 0$ because division by zero is undefined. The domain of $k(x)$ is all real numbers except $x = -2$ and $x = 2$ because if $x = -2$ or $x = 2$, then $x^2 - 4$ would equal zero and division by zero is undefined. Using a graphing utility and the table feature, $h(0)$ results in an error and $k(-2)$ and $k(2)$ also result in an error.

72. (a) $V = x(20 - 2x)^2$

$V = 4x^3 - 80x^2 + 400x$

(b) Because the length, width, and height of the box must be positive:

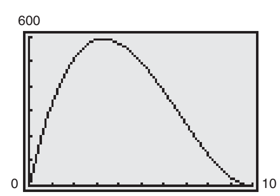
$x > 0$ and $20 - 2x > 0$

$-2x > -20$

$x < 10$

So, the domain is $0 < x < 10$.

(c)



(d) When $x = 3$: $V = 4(3)^3 - 80(3)^2 + 400(3) = 588$

When the height is 3 inches, the volume of the box is 588 cubic inches.

73. (a) $B = 6500\left(1 + \dfrac{0.0575}{4}\right)^{4t}$

(b) The domain is $t \geq 0$.

74. (a) $V(1) = -32(1) + 80 = 48$ feet per second

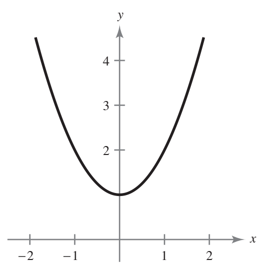
(b) $0 = -32t + 80$

$32t = 80$

$t = 2.5$ seconds

(c) $V(3) = -32(3) + 80 = -16$ feet per second

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



(a) Domain: all real numbers or $(-\infty, \infty)$

Range: $[1, \infty)$

(b) Increasing on $(0, \infty)$

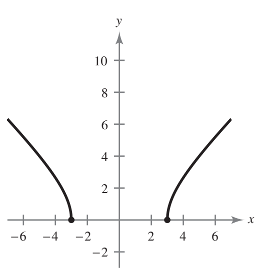
Decreasing on $(-\infty, 0)$

(c) $f(-x) = (-x)^2 + 1 = x^2 + 1 = f(x)$

Even

(d) Relative minimum at (0, 1)

76. $f(x) = \sqrt{x^2 - 9}$



(a) Domain: $(-\infty, -3] \cup [3, \infty)$

Range: $[0, \infty)$

(b) Increasing on $(3, \infty)$

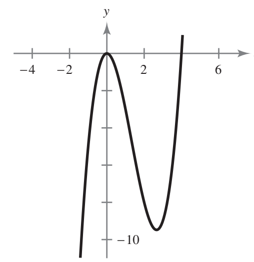
Decreasing on $(-\infty, -3)$

(c) $f(-x) = \sqrt{(-x)^2 - 9} = \sqrt{x^2 - 9} = f(x)$

Even

(d) Relative minimum at (–3, 0) and (3, 0)

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



(a) Domain: All real numbers or $(-\infty, \infty)$

Range: All real numbers or $(-\infty, \infty)$

(b) Increasing on $(-\infty, 0)$ and $\left(\frac{8}{3}, \infty\right)$

Decreasing on $\left(0, \frac{8}{3}\right)$

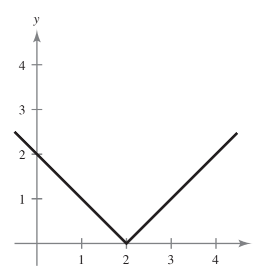
(c) $f(-x) = (-x)^3 - 4(-x)^2 = -x^3 - 4x^2$

Neither odd nor even

(d) Relative maximum at (0, 0)

Relative minimum at $\left(\frac{8}{3}, -\frac{256}{27}\right)$

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



(a) Domain: All real numbers or $(-\infty, \infty)$

Range: $[0, \infty)$

(b) Increasing on $(2, \infty)$

Decreasing on $(-\infty, 2)$

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

Neither odd nor even

(d) Relative minimum at (2, 0)

79. $y = \frac{1}{2}x^2$

This is a function because a vertical line intersects the graph only once.

80. Yes, $y = \frac{1}{4}x^3$ is a function because a vertical line intersects the graph only once.

81. $x - y^2 = 1$

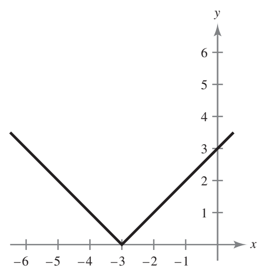
This is not a function because a vertical line intersects the graph twice.

82. No, $x^2 + y^2 = 25$ is not a function because some vertical lines intersect the graph twice.

83. $f(x) = |x + 3|$

x-intercept: $(-3, 0)$

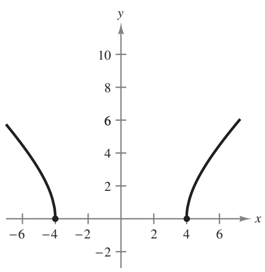
y-intercept: $(0, 3)$



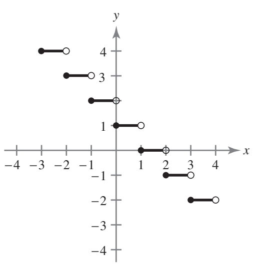
84. $g(x) = \sqrt{x^2 - 16}$

Domain: $(-\infty, -4] \cup [4, \infty)$

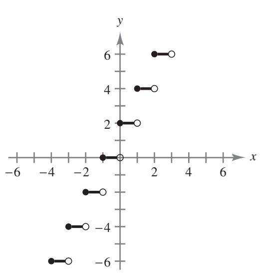
x-intercepts: $(\pm 4, 0)$



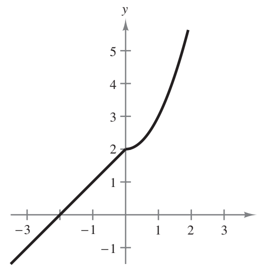
85. $h(x) = -[\![x]\!] + 1$



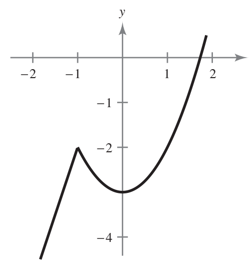
86. $f(x) = 2[\![x]\!] + 2$



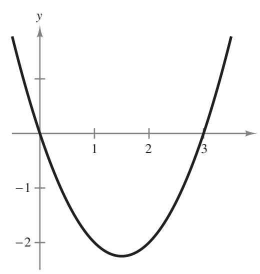
87. $g(x) = \begin{cases} x + 2, & x < 0 \\ 2, & x = 0 \\ x^2 + 2, & x > 0 \end{cases}$



88. $g(x) = \begin{cases} 3x + 1, & x < -1 \\ x^2 - 3, & x \geq -1 \end{cases}$

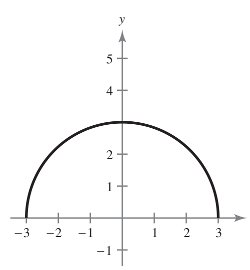


89. $h(x) = x^2 - 3x = x(x - 3)$



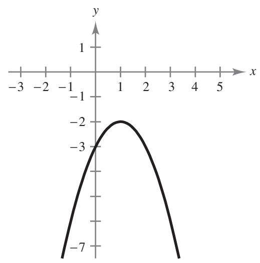
90. $f(x) = \sqrt{9 - x^2}$

Domain: $[-3, 3]$



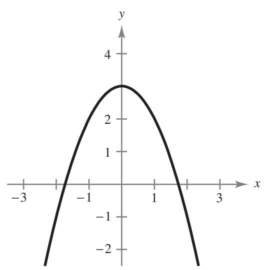
91. $g(x) = -f(x - 1) - 2$

Reflection in the x-axis, horizontal shift 1 unit to the right, and a vertical shift 2 units downward



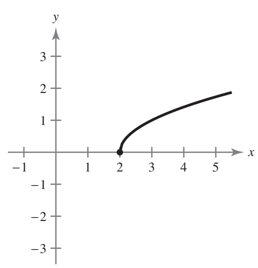
92. $g(x) = -f(x) + 3$

Reflection about the x-axis and a vertical shift 3 units upwards



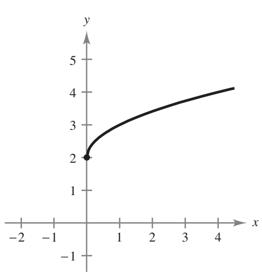
93. $g(x) = f(x - 2)$

Horizontal shift of 2 units to the right



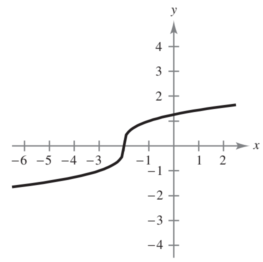
94. $g(x) = f(x) + 2$

Vertical shift 2 units upward



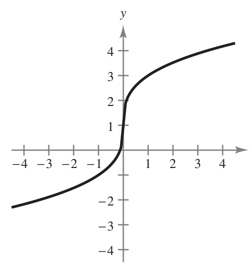
95. $y = f(x + 2)$

Horizontal shift 2 units to the left



96. $g(x) = 2f(x) + 1$

Vertically stretched by a factor of 2 and shifted 1 unit upward



97. Common function: $y = \sqrt{x}$

Transformation: horizontal shift 3 units to the right and then reflected about the y-axis

Equation: $y = \sqrt{-(x - 3)} = \sqrt{-x + 3}$ or $\sqrt{3 - x}$

98. Common function: $y = x^2$

Transformation: shifted down 1 unit

Equation: $y = x^2 - 1$

99.
$$(f + g)(x) = (3x - 1) + (x^2 + 2x) = x^2 + 5x - 1$$
$$(f - g)(x) = (3x - 1) - (x^2 + 2x) = -x^2 + x - 1$$
$$(fg)(x) = (3x - 1)(x^2 + 2x) = 3x^3 - x^2 + 6x^2 - 2x = 3x^3 + 5x^2 - 2x$$
$$\left(\frac{f}{g}\right)(x) = \frac{3x + 1}{x^2 + 2x},\ x \neq 0,\ x \neq -2$$

Domain of $\left(\frac{f}{g}\right)(x)$: all real numbers except $x = 0$ and $x = -2$

100. $(f + g)(x) = 3x + \sqrt{x^2 + 1}$

$(f - g)(x) = 3x - \sqrt{x^2 + 1}$

$(fg)(x) = 3x\sqrt{x^2 + 1}$

$\left(\frac{f}{g}\right)(x) = \frac{3x}{\sqrt{x^2 + 1}}$

Domain of $\left(\frac{f}{g}\right)(x)$: all real numbers x

101. $(f + g)(x) = x^2 + 3x + 2x - 5 = x^2 + 5x - 5$

$(f + g)(2) = 2^2 + 5(2) - 5 = 4 + 10 - 5 = 9$

102. $(f - g)(x) = x^2 + 3x - (2x - 5) = x^2 + x + 5$

$(f - g)(-1) = (-1)^2 - 1 + 5 = 5$

103. $(fg)(x) = (x^2 + 3x)(2x - 5)$

$= 2x^3 - 5x^2 + 6x^2 - 15x$

$= 2x^3 + x^2 - 15x$

$(fg)(3) = 2(3)^3 + 3^2 - 15(3)$

$= 54 + 9 - 45$

$= 18$

104. $\left(\frac{f}{g}\right)(x) = \frac{x^2 + 3x}{2x - 5}$

$\left(\frac{f}{g}\right)(0) = \frac{0 + 0}{0 - 5} = 0$

105. $f(x) = x^2,\ g(x) = x + 3$

(a) $(f \circ g)(x) = f(g(x))$

$= f(x + 3)$

$= (x + 3)^2$

$= x^2 + 6x + 9$

Domain: $(-\infty, \infty)$

(b) $(g \circ f)(x) = g(f(x)) = g(x^2) = x^2 + 3$

Domain: $(-\infty, \infty)$

106. $f(x) = 2x - 5,\ g(x) = x^2 + 2$

(a) $(f \circ g)(x) = f(g(x))$

$= f(x^2 + 2)$

$= 2(x^2 + 2) - 5$

$= 2x^2 - 1$

Domain: $(-\infty, \infty)$

(b) $(g \circ f)(x) = g(f(x)) = g(2x - 5)$

$= (2x - 5)^2 + 2 = 4x^2 - 20x + 27$

Domain: $(-\infty, \infty)$

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

(a) $(f \circ g)(x) = f(g(x)) = f(3x + x^2)$

$= \frac{1}{3x + x^2},\quad x \neq 0, x \neq -3$

Domain: $(-\infty, -3) \cup (-3, 0) \cup (0, \infty)$

(b) $(g \circ f)(x) = g(f(x)) = g\left(\frac{1}{x}\right)$

$= 3\left(\frac{1}{x}\right) + \left(\frac{1}{x}\right)^2 = \left(\frac{3}{x}\right) + \left(\frac{1}{x}\right)^2$

$= \frac{3x + 1}{x^2},\ x \neq 0$

Domain: $(-\infty, 0) \cup (0, \infty)$

108. $f(x) = \frac{1}{x^2},\ g(x) = x^3$

(a) $(f \circ g)(x) = \frac{1}{(x^3)^2} = \frac{1}{x^6},\ x \neq 0$

Domain: $(-\infty, 0) \cup (0, \infty)$

(b) $(g \circ f)(x) = \left(\frac{1}{x^2}\right)^3 = \frac{1}{x^6},\ x \neq 0$

Domain: $(-\infty, 0) \cup (0, \infty)$

109. $f(x) = x^2, g(x) = 6x - 5$; Answers will vary.

110. $f(x) = \sqrt[3]{x},\ g(x) = x + 2$; Answers will vary.

111. $f(x) = \frac{1}{x^2}, g(x) = x - 1$; Answers will vary.

112. $f(x) = x^3 + 2x, g(x) = x - 3$; Answers will vary.

113. (a) $r = \frac{x}{2}$

(b) $A = \pi r^2$

(c) $(A \circ r)(x) = \frac{\pi x^2}{4}$

$(A \circ r)(x)$ is the area of the base of the tank in terms of x, where x is the length of a side of the square base.

114. $f(x) = x - 500{,}000,\ g(x) = 0.04x$

$f(g(x)) = f(0.04x) = 0.04x - 500{,}000$

$g(f(x)) = g(x - 500{,}000) = 0.04(x - 500{,}000)$

The function $g(f(x)) = 0.04x - 20{,}000$ represents the bonus because f first calculates the amount over \$500,000 and then g finds 4% of the result.

115. $(N \circ T)(t) = 8(2t + 2)^2 - 14(2t + 2) + 200$

$= 8(4t^2 + 8t + 4) - 28t - 28 + 200$

$= 32t^2 + 64t + 32 - 28t - 28 + 200$

$= 32t^2 + 36t + 204$

$(N \circ T)(t)$ represents the number of bacteria in the food at time t.

Chapter 2 Test Yourself

1. $d = \sqrt{(5 - (-3))^2 + (-2 - 2)^2}$

$= \sqrt{(8)^2 + (-4)^2}$

$= \sqrt{80}$

$= 4\sqrt{5}$

≈ 8.94

Midpoint: $\left(\dfrac{-3 + 5}{2}, \dfrac{2 + (-2)}{2}\right) = \left(\dfrac{2}{2}, \dfrac{0}{2}\right) = (1, 0)$

2. $d = \sqrt{(-2.37 - 3.25)^2 + (1.62 - 7.05)^2}$

$= \sqrt{(-5.62)^2 + (-5.43)^2}$

$= \sqrt{61.0693} \approx 7.81$

Midpoint:

$\left(\dfrac{3.25 + (-2.37)}{2}, \dfrac{7.05 + 1.62}{2}\right) = \left(\dfrac{0.88}{2}, \dfrac{8.67}{2}\right)$

$= (0.44, 4.335)$

3. x-intercepts: $0 = (x + 5)(x - 3) \Rightarrow x = -5, 3$

$(-5, 0), (3, 0)$

y-intercept: $y = (0 + 5)(0 - 3) = -15$

$(0, -15)$

4. $(-y) = \dfrac{x}{x^2 - 4} \Rightarrow y = -\dfrac{x}{x^2 - 4}$ No x-axis symmetry

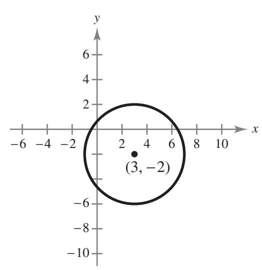
$y = \dfrac{(-x)}{(-x)^2 - 4} \Rightarrow y = -\dfrac{x}{x^2 - 4}$ No y-axis symmetry

$(-y) = \dfrac{(-x)}{(-x)^2 - 4} \Rightarrow y = \dfrac{x}{x^2 - 4}$ Origin symmetry

5. $x^2 + y^2 - 6x + 4y - 3 = 0$

$(x - 6x + 9) + (y^2 + 4y + 4) = 3 + 9 + 4$

$(x - 3)^2 + (y + 2)^2 = 16$



6. $y - 5 = \frac{2}{3}(x + 3)$

$y - 5 = \frac{2}{3}x + 2$

$y = \frac{2}{3}x + 7$

$2x - 3y + 7 = 0$

7. $2x - 3y = 5$

$-3y = -2x + 5$

$y = \frac{2}{3}x - \frac{5}{3}$

Each value of x yields only one y-value, so it is a function of x. True.

8. $A = \{3, 4, 5\}, B = \{-1, -2, -3\}$

$C = \{(3, -9), (4, -2), (5, -3)\}$

Because -9 is not an element of B, C does **not** represent a function from A to B. False.

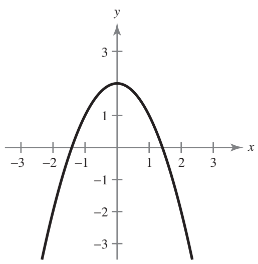
9. (a) Domain: $(-\infty, \infty)$
Range: $(-\infty, 2]$

(b) Increasing on $(-\infty, 0)$
Decreasing on $(0, \infty)$

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

The function is even.

(d) Relative maximum at $(0, 2)$

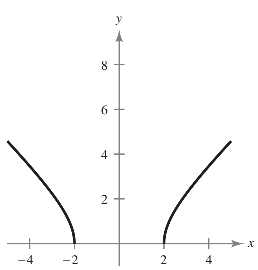


10. (a) Domain: $(-\infty, -2] \cup [2, \infty)$
Range: $[0, \infty)$

(b) Increasing on $(2, \infty)$
Decreasing on $(-\infty, -2)$

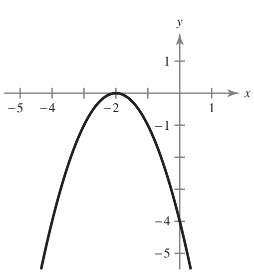
(c) $f(-x) = \sqrt{(-x)^2 - 4}$
$= \sqrt{x^2 - 4}$
$= f(x)$

The function is even.

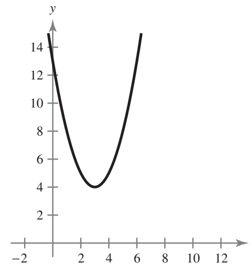


(d) Relative minimum at $(-2, 0)$ and $(2, 0)$

11. Reflected about the x-axis and shifted 2 units to the left.



12. Shifted 3 units to the right and 4 units upward



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

14. $(fg)(x) = f(x)g(x)$
$= (x^2 + 1)(2x - 2)$
$= 2x^3 - 2x^2 + 2x - 2$

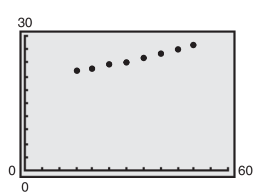
15. $(f \circ g)(x) = f(g(x))$
$= f(2x - 2)$
$= (2x - 2)^2 + 1$
$= 4x^2 - 8x + 5$

16. $(g \circ f)(x) = g(f(x))$
$= g(x^2 + 1)$
$= 2(x^2 + 1) - 2$
$= 2x^2$

17. When the equipment is new, $t = 0$, so $(0, 30{,}000)$ represents the value when the equipment is new and $(5, 3500)$ represents the value after 5 years.

$$V - 30{,}000 = \left(\frac{3500 - 30{,}000}{5 - 0}\right)(t - 0)$$
$$V - 30{,}000 = -5300t$$
$$V = 30{,}000 - 5300t$$

18.



Linear model: $P = 0.17t + 19.3$