

Chapter 2: Relations, Functions and Graphs

Technology Highlight

1. $y = \pm 4.8$; $y = \pm 3.6$, Answers will vary.

2. $(x-3)^2 + y^2 = 16$

Center (3,0), $r = 4$

If $x = 0$, $(0-3)^2 + y^2 = 16$

$9 + y^2 = 16$

$y^2 = 7$

$y = \pm\sqrt{7}$

y -intercepts: $(0, \pm\sqrt{7})$; $(0, \pm 2.6457513)$

2.1 Exercises

1. First, second

2. independent, output

3. Radius, center

4. (0,0), five, central

5. Answers will vary.

6. Answers will vary.

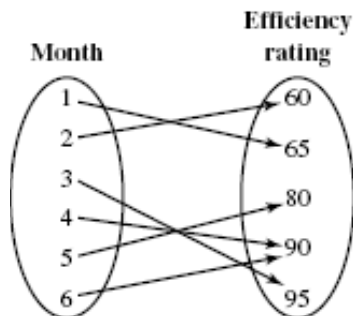
7.



Domain = {1, 2, 3, 4, 5}

Range = {2.75, 3.00, 3.25, 3.50, 3.75}

8.



Domain = {1, 2, 3, 4, 5, 6}

Range = {60, 65, 80, 90, 95}

9. $D = \{1, 3, 5, 7, 9\}$

$R = \{2, 4, 6, 8, 10\}$

10. $D = \{-2, -3, -1, 4, 2\}$

$R = \{4, -5, 3, -3\}$

11. $D = \{4, -1, 2, -3\}$

$R = \{0, 5, 4, 2, 3\}$

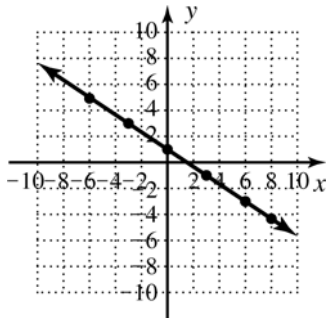
12. $D = \{-1, 0, 2, -3\}$

$R = \{1, 4, -5, 3\}$

2.1 Exercises

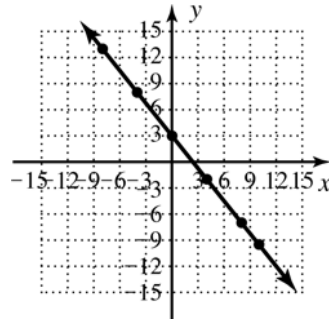
13. $y = -\frac{2}{3}x + 1$

x	y
-6	$-\frac{2}{3}(-6) + 1 = 4 + 1 = 5$
-3	$-\frac{2}{3}(-3) + 1 = 2 + 1 = 3$
0	$-\frac{2}{3}(0) + 1 = 0 + 1 = 1$
3	$-\frac{2}{3}(3) + 1 = -2 + 1 = -1$
6	$-\frac{2}{3}(6) + 1 = -4 + 1 = -3$
8	$-\frac{2}{3}(8) + 1 = -\frac{16}{3} + 1 = -\frac{13}{3}$



14. $y = -\frac{5}{4}x + 3$

x	y
-8	$-\frac{5}{4}(-8) + 3 = 10 + 3 = 13$
-4	$-\frac{5}{4}(-4) + 3 = 5 + 3 = 8$
0	$-\frac{5}{4}(0) + 3 = 0 + 3 = 3$
4	$-\frac{5}{4}(4) + 3 = -5 + 3 = -2$
8	$-\frac{5}{4}(8) + 3 = -10 + 3 = -7$
10	$-\frac{5}{4}(10) + 3 = -\frac{25}{2} + 3 = -\frac{19}{2}$



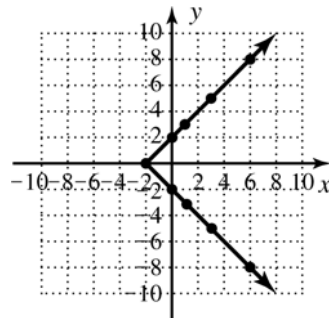
15. $x + 2 = |y|$

x	y
-2	0
0	2, -2
1	3, -3
3	5, -5
6	8, -8
7	9, -9

$$\begin{aligned} -2 + 2 &= |y| & 0 + 2 &= |y| \\ 0 &= |y| & 2 &= |y| \\ 0 &= y; & \pm 2 &= y; \end{aligned}$$

$$\begin{aligned} 1 + 2 &= |y| & 3 + 2 &= |y| \\ 3 &= |y| & 5 &= |y| \\ \pm 3 &= y; & \pm 5 &= y; \end{aligned}$$

$$\begin{aligned} 6 + 2 &= |y| & 7 + 2 &= |y| \\ 8 &= |y| & 9 &= |y| \\ \pm 8 &= y; & \pm 9 &= y; \end{aligned}$$

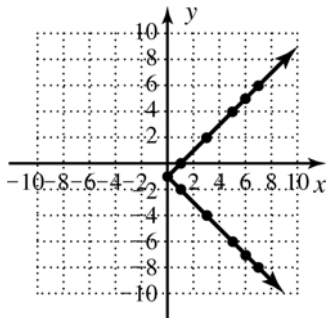


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16. $|y+1| = x$

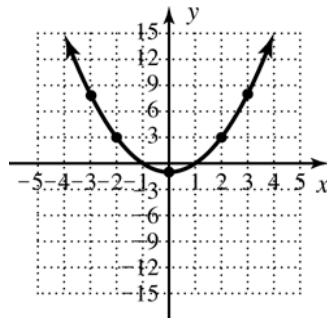
x	y
0	-1
1	0, -2
3	2, -4
5	4, -6
6	5, -7
7	6, -8

$$\begin{aligned}
 |y+1| &= 0 & |y+1| &= 1 \\
 y+1 &= 0 & y+1 &= \pm 1 \\
 y &= -1; & y &= -1 \pm 1; \\
 & & y &= 0 \\
 & & y &= -2 \\
 |y+1| &= 3 & |y+1| &= 5 \\
 y+1 &= \pm 3 & y+1 &= \pm 5 \\
 y &= -1 \pm 3 & y &= -1 \pm 5 \\
 y &= 2 & y &= 4 \\
 y &= -4; & y &= -6; \\
 |y+1| &= 6 & |y+1| &= 7 \\
 y+1 &= \pm 6 & y+1 &= \pm 7 \\
 y &= -1 \pm 6 & y &= -1 \pm 7 \\
 y &= 5 & y &= 6 \\
 y &= -7; & y &= -8
 \end{aligned}$$



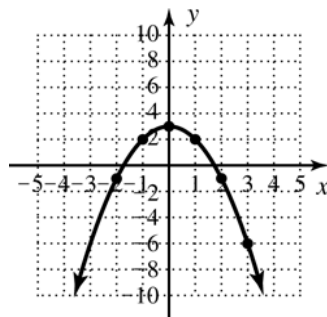
17. $y = x^2 - 1$

x	y
-3	$(-3)^2 - 1 = 9 - 1 = 8$
-2	$(-2)^2 - 1 = 4 - 1 = 3$
0	$(0)^2 - 1 = 0 - 1 = -1$
2	$(2)^2 - 1 = 4 - 1 = 3$
3	$(3)^2 - 1 = 9 - 1 = 8$
4	$(4)^2 - 1 = 16 - 1 = 15$



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

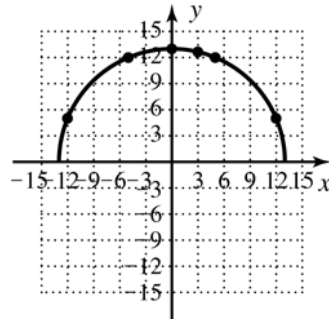
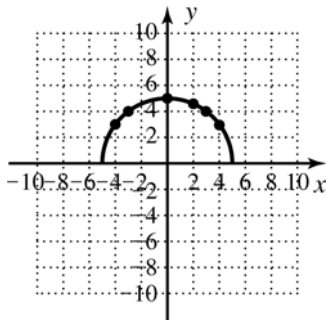
x	y
-2	$-(-2)^2 + 3 = -4 + 3 = -1$
-1	$-(-1)^2 + 3 = -1 + 3 = 2$
0	$-(0)^2 + 3 = 0 + 3 = 3$
1	$-(1)^2 + 3 = -1 + 3 = 2$
2	$-(2)^2 + 3 = -4 + 3 = -1$
3	$-(3)^2 + 3 = -9 + 3 = -6$



2.1 Exercises

19. $y = \sqrt{25 - x^2}$

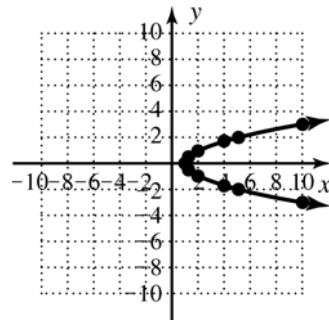
x	y
-4	$\sqrt{25 - (-4)^2} = \sqrt{25 - 16} = \sqrt{9} = 3$
-3	$\sqrt{25 - (-3)^2} = \sqrt{25 - 9} = \sqrt{16} = 4$
0	$\sqrt{25 - (0)^2} = \sqrt{25} = 5$
2	$\sqrt{25 - (2)^2} = \sqrt{25 - 4} = \sqrt{21}$
3	$\sqrt{25 - (3)^2} = \sqrt{25 - 9} = \sqrt{16} = 4$
4	$\sqrt{25 - (4)^2} = \sqrt{25 - 16} = \sqrt{9} = 3$



21. $x - 1 = y^2$

$y = \pm\sqrt{x-1}$

x	y
10	$\sqrt{(10)-1} = \sqrt{9} = \pm 3$
5	$\sqrt{(5)-1} = \sqrt{4} = \pm 2$
4	$\sqrt{(4)-1} = \pm\sqrt{3}$
2	$\sqrt{(2)-1} = \sqrt{1} = \pm 1$
1.25	$\sqrt{(1.25)-1} = \sqrt{0.25} = \pm 0.5$
1	$\sqrt{(1)-1} = \sqrt{0} = 0$



20. $y = \sqrt{169 - x^2}$

x	y
-12	$\sqrt{169 - (-12)^2} = \sqrt{169 - 144} = \sqrt{25} = 5$
-5	$\sqrt{169 - (-5)^2} = \sqrt{169 - 25} = \sqrt{144} = 12$
0	$\sqrt{169 - (0)^2} = \sqrt{169} = 13$
3	$\sqrt{169 - (3)^2} = \sqrt{169 - 9} = \sqrt{160} = 4\sqrt{10}$
5	$\sqrt{169 - (5)^2} = \sqrt{169 - 25} = \sqrt{144} = 12$
12	$\sqrt{169 - (12)^2} = \sqrt{169 - 144} = \sqrt{25} = 5$

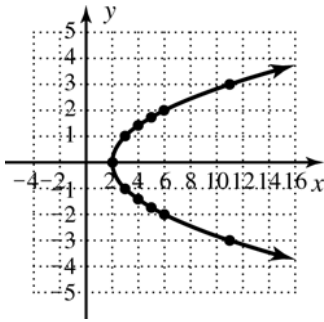
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22. $y^2 + 2 = x$

$$y^2 = x - 2$$

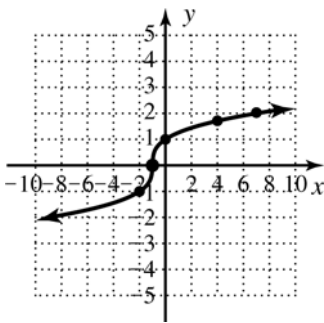
$$y = \pm\sqrt{x-2}$$

x	y
2	$\sqrt{(2)-2} = \sqrt{0} = 0$
3	$\sqrt{(3)-2} = \sqrt{1} = \pm 1$
4	$\sqrt{(4)-2} = \pm\sqrt{2}$
5	$\sqrt{(5)-2} = \pm\sqrt{3}$
6	$\sqrt{(6)-2} = \sqrt{4} = \pm 2$
11	$\sqrt{(11)-2} = \sqrt{9} = \pm 3$



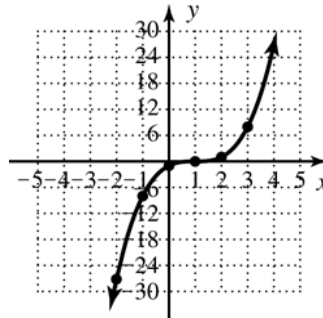
23. $y = \sqrt[3]{x+1}$

x	y
-9	$\sqrt[3]{(-9)+1} = \sqrt[3]{-8} = -2$
-2	$\sqrt[3]{(-2)+1} = \sqrt[3]{-1} = -1$
-1	$\sqrt[3]{(-1)+1} = \sqrt[3]{0} = 0$
0	$\sqrt[3]{(0)+1} = \sqrt[3]{1} = 1$
4	$\sqrt[3]{(4)+1} = \sqrt[3]{5}$
7	$\sqrt[3]{(7)+1} = \sqrt[3]{8} = 2$



24. $y = (x-1)^3$

x	y
-2	$[(-2)-1]^3 = (-3)^3 = -27$
-1	$[(-1)-1]^3 = (-2)^3 = -8$
0	$[(0)-1]^3 = (-1)^3 = -1$
1	$[(1)-1]^3 = (0)^3 = 0$
2	$[(2)-1]^3 = (1)^3 = 1$
3	$[(3)-1]^3 = (2)^3 = 8$



25. $M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$

$$M = \left(\frac{1+5}{2}, \frac{8+(-6)}{2} \right)$$

$$M = \left(\frac{6}{2}, \frac{2}{2} \right)$$

$$M = (3, 1)$$

26. $M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$

$$M = \left(\frac{5+6}{2}, \frac{6+(-8)}{2} \right)$$

$$M = \left(\frac{11}{2}, \frac{-2}{2} \right)$$

$$M = \left(\frac{11}{2}, -1 \right)$$

2.1 Exercises

$$27. \quad M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-4.5 + 3.1}{2}, \frac{9.2 + (-9.8)}{2} \right)$$

$$M = \left(\frac{-1.4}{2}, \frac{-0.6}{2} \right)$$

$$M = (-0.7, -0.3)$$

$$28. \quad M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{5.2 + 6.3}{2}, \frac{7.1 + (-7.1)}{2} \right)$$

$$M = \left(\frac{11.5}{2}, \frac{0}{2} \right)$$

$$M = (5.75, 0)$$

$$29. \quad M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{\frac{1}{5} + \left(\frac{-1}{10}\right)}{2}, \frac{\frac{-2}{3} + \frac{3}{4}}{2} \right)$$

$$M = \left(\frac{\frac{1}{10}}{2}, \frac{\frac{1}{12}}{2} \right)$$

$$M = \left(\frac{1}{20}, \frac{1}{24} \right)$$

$$30. \quad M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-\frac{3}{4} + \frac{3}{8}}{2}, \frac{-\frac{1}{3} + \frac{5}{6}}{2} \right)$$

$$M = \left(\frac{-\frac{3}{8}}{2}, \frac{\frac{1}{2}}{2} \right)$$

$$M = \left(-\frac{3}{16}, \frac{1}{4} \right)$$

$$31. \quad (-5, -4) (5, 2)$$

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-5 + 5}{2}, \frac{-4 + 2}{2} \right)$$

$$M = \left(\frac{0}{2}, \frac{-2}{2} \right)$$

$$M = (0, -1)$$

$$32. \quad (-5, 4) (3, -2)$$

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-5 + 3}{2}, \frac{4 + (-2)}{2} \right)$$

$$M = \left(\frac{-2}{2}, \frac{2}{2} \right)$$

$$M = (-1, 1)$$

$$33. \quad (-4, -4) (2, 4)$$

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-4 + 2}{2}, \frac{-4 + 4}{2} \right)$$

$$M = \left(\frac{-2}{2}, \frac{0}{2} \right)$$

$$M = (-1, 0)$$

The center of the circle is $(-1, 0)$.

$$34. \quad (-5, 3) (1, -1)$$

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

$$M = \left(\frac{-5 + 1}{2}, \frac{3 + (-1)}{2} \right)$$

$$M = \left(\frac{-4}{2}, \frac{2}{2} \right)$$

$$M = (-2, 1)$$

The center of the circle is $(-2, 1)$.

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35. $(-5, -4) (5, 2)$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

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

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

$$d = \sqrt{100 + 36}$$

$$d = \sqrt{136}$$

$$d = 2\sqrt{34}$$

36. $(-5, 4) (3, -2)$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$d = \sqrt{(3 - (-5))^2 + (-2 - 4)^2}$$

$$d = \sqrt{8^2 + (-6)^2}$$

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

$$d = \sqrt{100}$$

$$d = 10$$

37. $(-4, -4) (2, 4)$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

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

$$d = \sqrt{6^2 + 8^2}$$

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

$$d = \sqrt{100}$$

$$d = 10$$

38. $(-5, 3) (1, -1)$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

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

$$d = \sqrt{6^2 + (-4)^2}$$

$$d = \sqrt{36 + 16}$$

$$d = \sqrt{52}$$

$$d = 2\sqrt{13}$$

39. $(5, 2) (0, -3)$

$$m = \frac{-3 - 2}{0 - 5} = \frac{-5}{-5} = 1;$$

$(0, -3) (4, -4)$

$$m = \frac{-4 - (-3)}{4 - 0} = \frac{-4 + 3}{4} = \frac{-1}{4};$$

$(5, 2) (4, -4)$

$$m = \frac{-4 - 2}{4 - 5} = \frac{-6}{-1} = 6$$

Not a right triangle. Lines are not perpendicular. Slopes: $1; \frac{-1}{4}; 6$

40. $(7, 0) (-1, 0)$

$$m = \frac{0 - 0}{-1 - 7} = 0;$$

$(7, 0) (7, 4)$

$$m = \frac{4 - 0}{7 - 7} \text{ Undefined}$$

Right triangle because these two lines are perpendicular. Slopes: $0; \text{undefined}$.

41. $(-4, 3) (-7, -1)$

$$m = \frac{-1 - 3}{-7 - (-4)} = \frac{-4}{-7 + 4} = \frac{-4}{-3} = \frac{4}{3};$$

$(-7, -1) (3, -2)$

$$m = \frac{-2 - (-1)}{3 - (-7)} = \frac{-2 + 1}{3 + 7} = \frac{-1}{10};$$

$(-4, 3) (3, -2)$

$$m = \frac{-2 - 3}{3 - (-4)} = \frac{-5}{7}$$

Not a right triangle. Lines are not perpendicular. Slopes: $\frac{4}{3}; \frac{-1}{10}; \frac{-5}{7}$

42. $(-3, 7) (2, 2)$

$$m = \frac{2 - 7}{2 - (-3)} = \frac{-5}{2 + 3} = \frac{-5}{5} = -1;$$

$(2, 2) (5, 5)$

$$m = \frac{5 - 2}{5 - 2} = \frac{3}{3} = 1$$

Right triangle because these two lines are perpendicular. Slopes: $-1; 1$

2.1 Exercises

43. $(-3, 2) (-1, 5)$

$$m = \frac{5-2}{-1-(-3)} = \frac{3}{-1+3} = \frac{3}{2};$$

$(-3, 2) (-6, 4)$

$$m = \frac{4-2}{-6-(-3)} = \frac{2}{-6+3} = -\frac{2}{3}$$

Right triangle because these two lines are perpendicular. Slopes: $\frac{3}{2}; -\frac{2}{3}$

44. $(0, 0) (-5, 2)$

$$m = \frac{2-0}{-5-0} = \frac{2}{-5} = -\frac{2}{5};$$

$(-5, 2) (2, -5)$

$$m = \frac{-5-2}{2-(-5)} = \frac{-7}{2+5} = \frac{-7}{7} = -1;$$

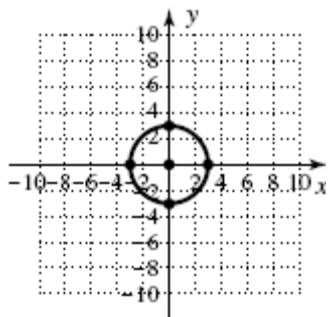
$(0, 0) (2, -5)$

$$m = \frac{-5-0}{2-0} = \frac{-5}{2}$$

Not a right triangle. Lines are not perpendicular. Slopes: $-\frac{2}{5}, -1, -\frac{5}{2}$

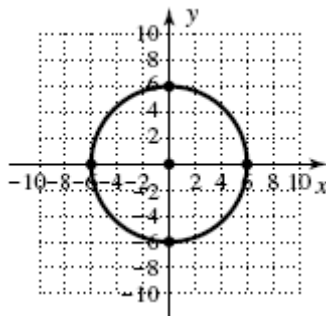
45. Center $(0,0)$, radius 3

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



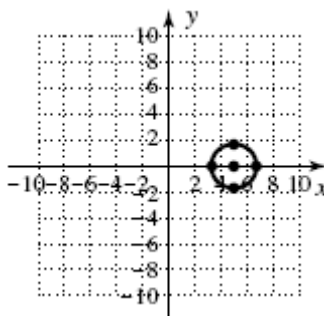
46. Center $(0,0)$, radius 6

$$x^2 + y^2 = 36$$



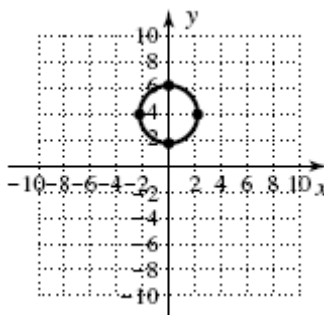
47. Center $(5,0)$, radius $\sqrt{3}$

$$(x-5)^2 + y^2 = 3$$



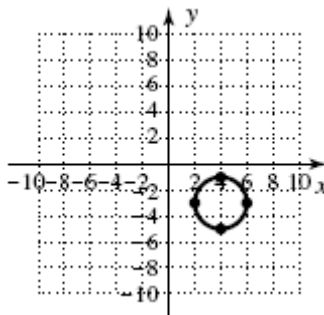
48. Center $(0,4)$, radius $\sqrt{5}$

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



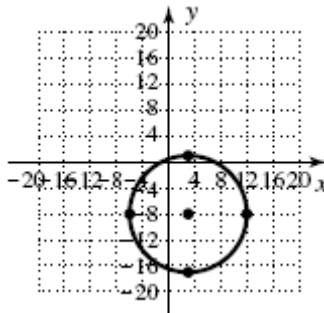
49. Center $(4, -3)$, radius 2

$$(x-4)^2 + (y+3)^2 = 4$$



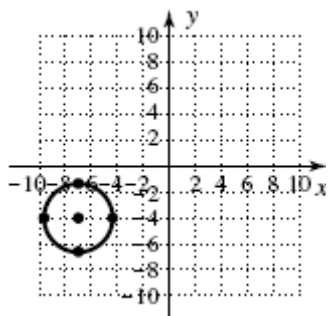
50. Center $(3, -8)$, radius 9

$$(x-3)^2 + (y+8)^2 = 81$$

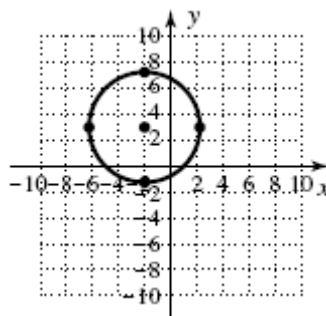


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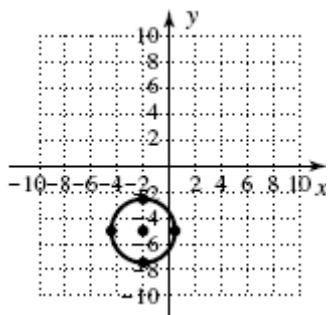
51. Center $(-7, -4)$, radius $\sqrt{7}$
 $(x+7)^2 + (y+4)^2 = 7$



54. Center $(-2, 3)$, radius $3\sqrt{2}$
 $(x+2)^2 + (y-3)^2 = 18$



52. Center $(-2, -5)$, radius $\sqrt{6}$
 $(x+2)^2 + (y+5)^2 = 6$

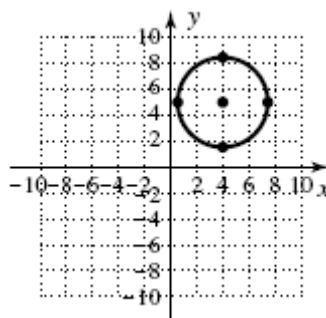


55. Center $(4, 5)$, diameter $4\sqrt{3}$
radius = $\frac{1}{2} \cdot \text{diameter}$

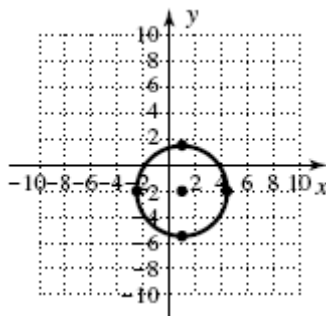
$$r = \frac{1}{2}(4\sqrt{3}) = 2\sqrt{3}$$

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

$$(x-4)^2 + (y-5)^2 = 12$$



53. Center $(1, -2)$, radius $2\sqrt{3}$
 $(x-1)^2 + (y+2)^2 = 12$

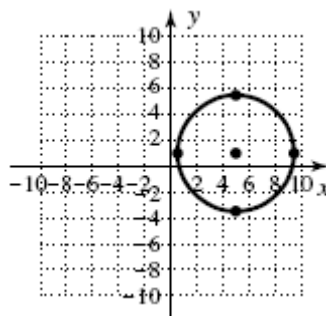


56. Center $(5, 1)$, diameter $4\sqrt{5}$
radius = $\frac{1}{2} \cdot \text{diameter}$

$$r = \frac{1}{2}(4\sqrt{5}) = 2\sqrt{5}$$

$$(x-5)^2 + (y-1)^2 = (2\sqrt{5})^2$$

$$(x-5)^2 + (y-1)^2 = 20$$



2.1 Exercises

57. Center at $(7,1)$,
graph contains the point $(1, -7)$

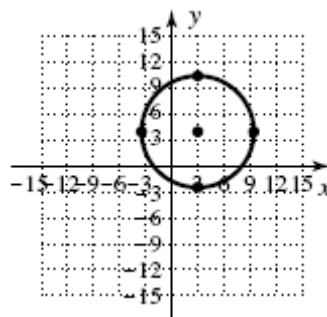
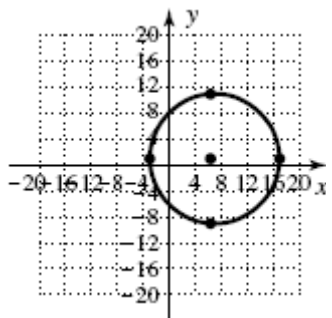
$$(x-7)^2 + (y-1)^2 = r^2;$$

$$(1-7)^2 + (-7-1)^2 = r^2$$

$$36 + 64 = r^2$$

$$100 = r^2;$$

$$(x-7)^2 + (y-1)^2 = 100$$



58. Center at $(-8,3)$,
graph contains the point $(-3,15)$

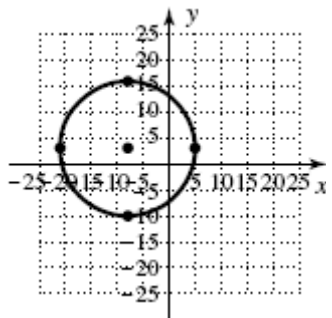
$$(x+8)^2 + (y-3)^2 = r^2;$$

$$(-3+8)^2 + (15-3)^2 = r^2$$

$$25 + 144 = r^2$$

$$169 = r^2;$$

$$(x+8)^2 + (y-3)^2 = 169$$



60. Center at $(-5,2)$,
graph contains the point $(-1,3)$

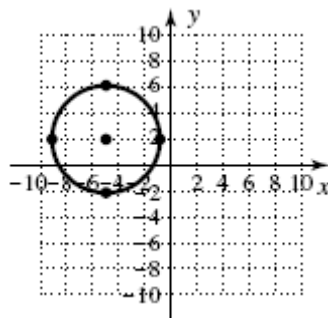
$$(x+5)^2 + (y-2)^2 = r^2;$$

$$(-1+5)^2 + (3-2)^2 = r^2$$

$$16 + 1 = r^2$$

$$17 = r^2;$$

$$(x+5)^2 + (y-2)^2 = 17$$



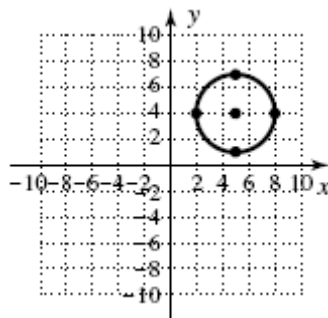
61. Diameter has endpoints $(5,1)$ and $(5,7)$;
midpoint of diameter = center of circle

$$\left(\frac{5+5}{2}, \frac{1+7}{2} \right) = (5,4);$$

radius = distance from center to endpoint

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

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



59. Center at $(3,4)$,
graph contains the point $(7,9)$

$$(x-3)^2 + (y-4)^2 = r^2;$$

$$(7-3)^2 + (9-4)^2 = r^2$$

$$16 + 25 = r^2$$

$$41 = r^2;$$

$$(x-3)^2 + (y-4)^2 = 41$$

Chapter 2: Relations, Functions and Graphs

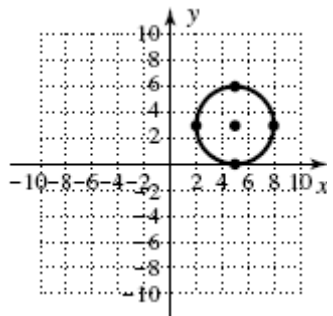
62. Diameter has endpoints (2,3) and (8,3);
midpoint of diameter = center of circle

$$\left(\frac{2+8}{2}, \frac{3+3}{2}\right) = (5,3);$$

radius = distance from center to endpt

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

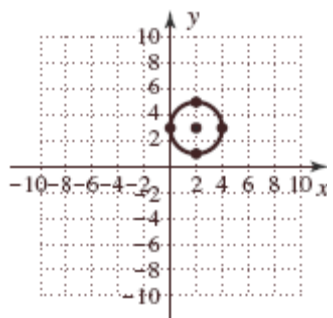
$$(x-5)^2 + (y-3)^2 = 9$$



63. Center: (2,3), $r = 2$

$$D: x \in [0, 4]$$

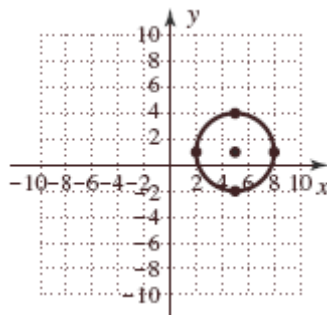
$$R: y \in [1, 5]$$



64. Center: (5,1), $r = 3$

$$D: x \in [2, 8]$$

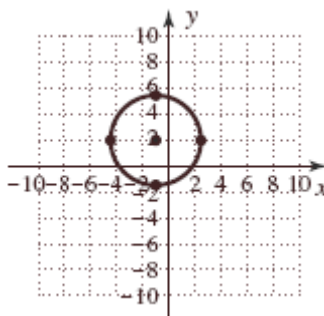
$$R: y \in [-2, 4]$$



65. Center: $(-1, 2)$, $r = 2\sqrt{3}$

$$D: x \in [-1 - 2\sqrt{3}, -1 + 2\sqrt{3}]$$

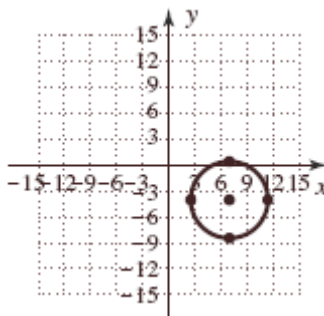
$$R: y \in [2 - 2\sqrt{3}, 2 + 2\sqrt{3}]$$



66. Center: $(7, -4)$, $r = 2\sqrt{5}$

$$D: x \in [7 - 2\sqrt{5}, 7 + 2\sqrt{5}]$$

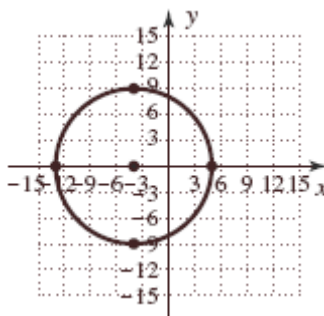
$$R: y \in [-4 - 2\sqrt{5}, -4 + 2\sqrt{5}]$$



67. Center: $(-4, 0)$, $r = 9$

$$D: x \in [-13, 5]$$

$$R: y \in [-9, 9]$$

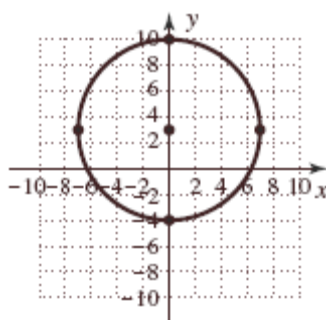


2.1 Exercises

68. Center: $(0,3)$, $r = 7$

$$D: x \in [-7, 7]$$

$$R: y \in [-4, 10]$$



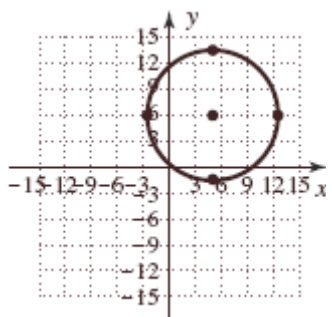
69. $x^2 + y^2 - 10x - 12y + 4 = 0$

$$x^2 - 10x + y^2 - 12y = -4$$

$$x^2 - 10x + 25 + y^2 - 12y + 36 = -4 + 25 + 36$$

$$(x-5)^2 + (y-6)^2 = 57$$

Center: $(5,6)$, Radius: $r = \sqrt{57}$



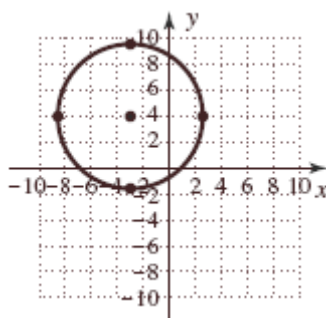
70. $x^2 + y^2 + 6x - 8y - 6 = 0$

$$x^2 + 6x + y^2 - 8y = 6$$

$$x^2 + 6x + 9 + y^2 - 8y + 16 = 6 + 9 + 16$$

$$(x+3)^2 + (y-4)^2 = 31$$

Center: $(-3,4)$, Radius: $r = \sqrt{31}$



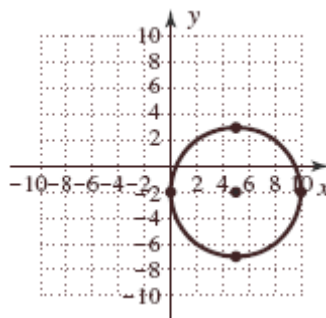
71. $x^2 + y^2 - 10x + 4y + 4 = 0$

$$x^2 - 10x + y^2 + 4y = -4$$

$$x^2 - 10x + 25 + y^2 + 4y + 4 = -4 + 25 + 4$$

$$(x-5)^2 + (y+2)^2 = 25$$

Center: $(5,-2)$, Radius: $r = 5$



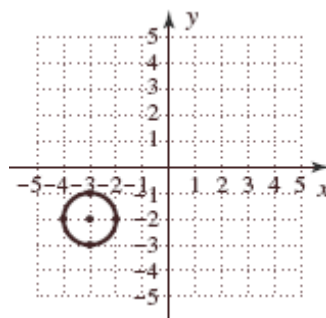
72. $x^2 + y^2 + 6x + 4y + 12 = 0$

$$x^2 + 6x + y^2 + 4y = -12$$

$$x^2 + 6x + 9 + y^2 + 4y + 4 = -12 + 9 + 4$$

$$(x+3)^2 + (y+2)^2 = 1$$

Center: $(-3,-2)$, Radius: $r = 1$



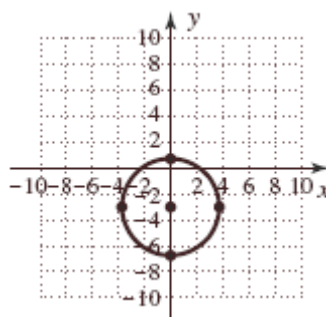
73. $x^2 + y^2 + 6y - 5 = 0$

$$x^2 + y^2 + 6y = 5$$

$$x^2 + y^2 + 6y + 9 = 5 + 9$$

$$x^2 + (y+3)^2 = 14$$

Center: $(0,-3)$, Radius: $r = \sqrt{14}$



Chapter 2: Relations, Functions and Graphs

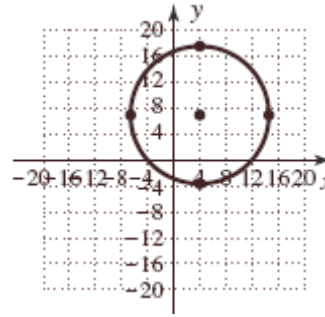
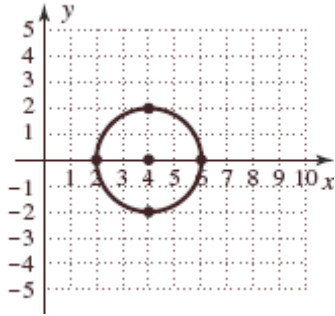
74. $x^2 + y^2 - 8x + 12 = 0$

$$x^2 - 8x + y^2 = -12$$

$$x^2 - 8x + 16 + y^2 = -12 + 16$$

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

Center: $(4,0)$, Radius: $r = 2$



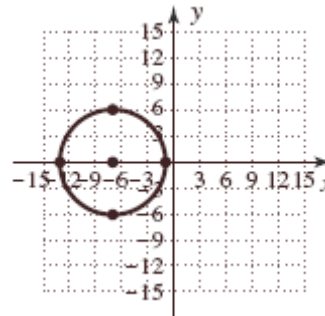
77. $x^2 + y^2 + 14x + 12 = 0$

$$x^2 + 14x + y^2 = -12$$

$$x^2 + 14x + 49 + y^2 = -12 + 49$$

$$(x+7)^2 + y^2 = 37$$

Center: $(-7,0)$, Radius: $r = \sqrt{37}$



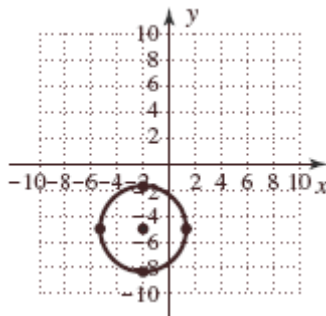
75. $x^2 + y^2 + 4x + 10y + 18 = 0$

$$x^2 + 4x + y^2 + 10y = -18$$

$$x^2 + 4x + 4 + y^2 + 10y + 25 = -18 + 4 + 25$$

$$(x+2)^2 + (y+5)^2 = 11$$

Center: $(-2,-5)$, Radius: $r = \sqrt{11}$



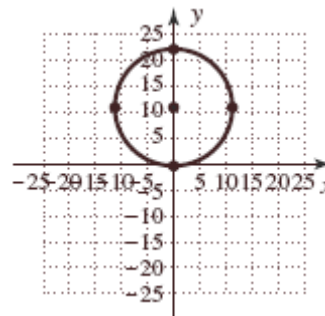
78. $x^2 + y^2 - 22y - 5 = 0$

$$x^2 + y^2 - 22y = 5$$

$$x^2 + y^2 - 22y + 121 = 5 + 121$$

$$x^2 + (y-11)^2 = 126$$

Center: $(0,11)$, Radius: $r = 3\sqrt{14}$



76. $x^2 + y^2 - 8x - 14y - 47 = 0$

$$x^2 - 8x + y^2 - 14y = 47$$

$$x^2 - 8x + 16 + y^2 - 14y + 49 = 47 + 16 + 49$$

$$(x-4)^2 + (y-7)^2 = 112$$

Center: $(4,7)$, Radius: $r = 4\sqrt{7}$

2.1 Exercises

79. $2x^2 + 2y^2 - 12x + 20y + 4 = 0$

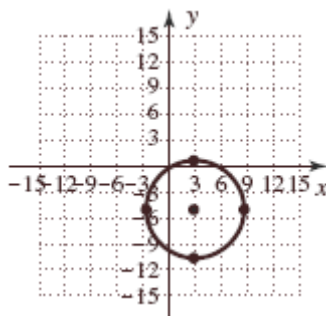
$$x^2 + y^2 - 6x + 10y + 2 = 0$$

$$x^2 - 6x + y^2 + 10y = -2$$

$$x^2 - 6x + 9 + y^2 + 10y + 25 = -2 + 9 + 25$$

$$(x-3)^2 + (y+5)^2 = 32$$

Center: $(3, -5)$, Radius: $r = 4\sqrt{2}$



80. $3x^2 + 3y^2 - 24x + 18y + 3 = 0$

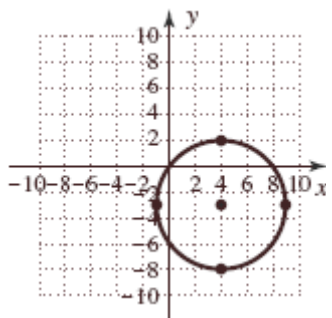
$$x^2 + y^2 - 8x + 6y + 1 = 0$$

$$x^2 - 8x + y^2 + 6y = -1$$

$$x^2 - 8x + 16 + y^2 + 6y + 9 = -1 + 16 + 9$$

$$(x-4)^2 + (y+3)^2 = 24$$

Center: $(4, -3)$, Radius: $r = \sqrt{24} = 2\sqrt{6}$



81. $s = 12.5t + 59$

a. Let $t = 1, s = 12.5(1) + 59 = 71.5$;

Let $t = 2, s = 12.5(2) + 59 = 84$;

Let $t = 3, s = 12.5(3) + 59 = 96.5$;

Let $t = 5, s = 12.5(5) + 59 = 121.5$;

Let $t = 7, s = 12.5(7) + 59 = 146.5$;

$(1, 71.5), (2, 84), (3, 96.5), (5, 121.5), (7, 146.5)$

b. Let $t = 8, s = 12.5(8) + 59 = 159$

Average amount spend in 2008 is \$159.

c. Let $s = 196$,

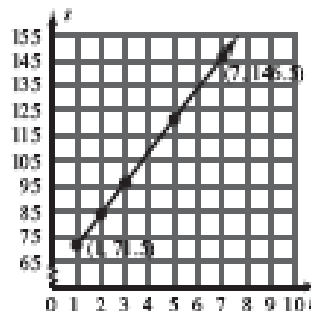
$$196 = 12.5t + 59$$

$$137 = 12.5t$$

$$10.96 = t$$

In 2011, annual spending surpasses \$196.

d.



82. $A = 2r^2$

$$A = 2(5)^2 = 50 \text{ units}^2$$

83. a. $(x-5)^2 + (y-12)^2 = 25^2$

$$(x-5)^2 + (y-12)^2 = 625$$

b. $d = \sqrt{(15-5)^2 + (36-12)^2}$

$$d = \sqrt{10^2 + 24^2} = \sqrt{676} = 26$$

No, radar cannot pick up the liner's sister ship.

84. a. $(x-3)^2 + (y-7)^2 = 12^2$

$$(x-3)^2 + (y-7)^2 = 144$$

b. $d = \sqrt{(13-3)^2 + (1-7)^2}$

$$d = \sqrt{(10)^2 + (-6)^2} = \sqrt{100 + 36}$$

$$= \sqrt{136} \approx 11.66$$

Yes, they would have felt the quake.

85. Red: $(x-2)^2 + (y-2)^2 = 4$;

Center: $(2, 2)$, Radius: 2

Blue: $(x-2)^2 + y^2 = 16$;

Center: $(2, 0)$, Radius: 4

Area of blue: $\pi(16) - \pi(4) = 12\pi \text{ units}^2$

86. $x^2 + y^2 = r^2$

$$(3)^2 + (4)^2 = r^2$$

$$5 = r$$

$$A = \frac{3\sqrt{3}}{4}(5)^2 = \frac{75\sqrt{3}}{4} \text{ units}^2$$

Chapter 2: Relations, Functions and Graphs

87. $x^2 + y^2 + 8x - 6y = 0$

$$x^2 + 8x + y^2 - 6y = 0$$

$$x^2 + 8x + 16 + y^2 - 6y + 9 = 0 + 16 + 9$$

$$(x+4)^2 + (y-3)^2 = 25;$$

$$x^2 + y^2 - 10x + 4y = 0$$

$$x^2 - 10x + y^2 + 4y = 0$$

$$x^2 - 10x + 25 + y^2 + 4y + 4 = 0 + 25 + 4$$

$$(x-5)^2 + (y+2)^2 = 29;$$

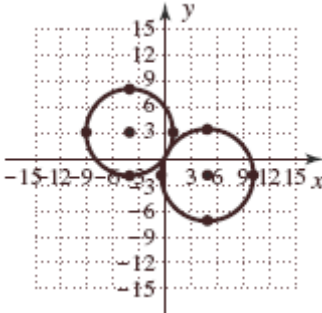
Distance between centers: $(-4, 3), (5, -2)$

$$d = \sqrt{(-4-5)^2 + (3-(-2))^2}$$

$$= \sqrt{81 + 25} = \sqrt{106} \approx 10.30;$$

Sum of the radii: $5 + \sqrt{29} \approx 10.39$

No, Distance between the centers is less than the sum of the radii.



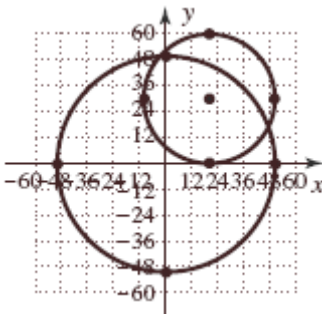
88. $x^2 + y^2 = 2500;$

$$(x-20)^2 + (y-30)^2 = 900;$$

$$20^2 + 30^2 = h^2$$

$$\sqrt{1300} = h;$$

$$10\sqrt{13} + 30 \approx 66 \text{ miles}$$



89. Answers will vary.

90. Statement is true. Answers will vary.

91. a. $x^2 + y^2 - 12x + 4y + 40 = 0$

$$x^2 - 12x + y^2 + 4y = -40$$

$$x^2 - 12x + 36 + y^2 + 4y + 4 = -40 + 36 + 4$$

$$(x-6)^2 + (y+2)^2 = 0$$

Center $(6, -2), r = 0$, degenerate case

b. $x^2 + y^2 - 2x - 8y - 8 = 0$

$$x^2 - 2x + y^2 - 8y = 8$$

$$x^2 - 2x + 1 + y^2 - 8y + 16 = 8 + 1 + 16$$

$$(x-1)^2 + (y-4)^2 = 25$$

Center $(1, 4), r = 5$

c. $x^2 + y^2 - 6x - 10y + 35 = 0$

$$x^2 - 6x + y^2 - 10y = -35$$

$$x^2 - 6x + 9 + y^2 - 10y + 25 = -35 + 9 + 25$$

$$(x-3)^2 + (y-5)^2 = -1$$

Center $(3, 5), r^2 = -1$, degenerate case

92. $\frac{|w-2|}{3} + \frac{1}{4} \geq \frac{5}{6}$

$$12\left(\frac{|w-2|}{3} + \frac{1}{4}\right) \geq 12\left(\frac{5}{6}\right)$$

$$4|w-2| + 3 \geq 10$$

$$4|w-2| \geq 7$$

$$|w-2| \geq \frac{7}{4}$$

$$w-2 \geq \frac{7}{4} \text{ or } w-2 \leq -\frac{7}{4}$$

$$w \geq \frac{15}{4} \text{ or } w \leq \frac{1}{4}$$

$$w \in \left(-\infty, \frac{1}{4}\right] \cup \left[\frac{15}{4}, \infty\right)$$

2.2 Exercises

93. a. 0
 b. not possible
 c. 0.3 ; many answers possible
 d. not possible
 e. not possible
 f. $\sqrt{3}$; many answers possible

94. $x^2 + 13 = 6x$
 $x^2 - 6x + 13 = 0$
 $a = 1, b = -6, c = 13$

$$x = \frac{-(-6) \pm \sqrt{(-6)^2 - 4(1)(13)}}{2(1)}$$

$$x = \frac{6 \pm \sqrt{36 - 52}}{2}$$

$$x = \frac{6 \pm \sqrt{-16}}{2}$$

$$x = \frac{6 \pm 4i}{2} = 3 \pm 2i$$

95. $1 - \sqrt{n+3} = -n$
 $-\sqrt{n+3} = -n-1$
 $\sqrt{n+3} = n+1$
 $(\sqrt{n+3})^2 = (n+1)^2$
 $n+3 = n^2 + 2n + 1$
 $0 = n^2 + n - 2$
 $0 = (n+2)(n-1)$
 $n+2 = 0$ or $n-1 = 0$
 $n = -2$ or $n = 1$
 Check: $n = -2$
 $1 - \sqrt{-2+3} = -(-2)$
 $1 - \sqrt{1} = 2$
 $0 \neq 2$;
 Check: $n = 1$
 $1 - \sqrt{1+3} = -1$
 $1 - \sqrt{4} = -1$
 $-1 = -1$;
 $n = 1$ is a solution, $n = -2$ is extraneous.

2.2 Technology Highlight

Exercise 1: $Y_1 = \frac{2}{3}x + 1$; $(-1.5, 0)$, $(0, 1)$

Exercise 2: $79x - 55y = 869$
 $-55y = -79x + 869$

$$y = \frac{-79}{55}x - \frac{79}{5}$$

x-intercept: $(-11, 0)$

y-intercept: $(0, -15.8)$

2.2 Exercises

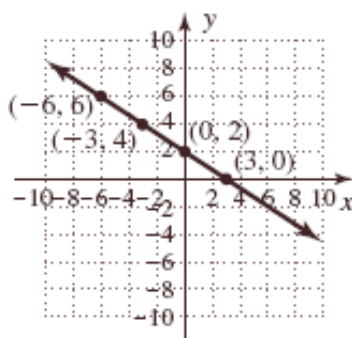
- 0; 0.
- $\frac{y_2 - y_1}{x_2 - x_1} = \frac{\square y}{\square x}$
- negative, downward
- zero, undefined, equal
- yes; slopes are not equal $m_1 \neq m_2$;
 No; $m_1 \cdot m_2 \neq -1$
- Answers will vary.

Chapter 2: Relations, Functions and Graphs

7. $2x + 3y = 6$
 $3y = -2x + 6$

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

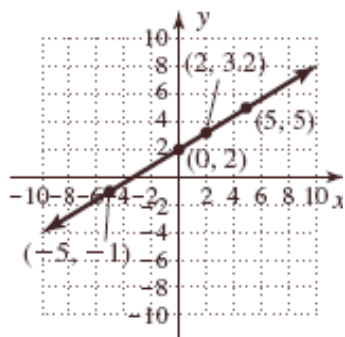
x	y
-6	$-\frac{2}{3}(-6) + 2 = 4 + 2 = 6$
-3	$-\frac{2}{3}(-3) + 2 = 2 + 2 = 4$
0	$-\frac{2}{3}(0) + 2 = 0 + 2 = 2$
3	$-\frac{2}{3}(3) + 2 = -2 + 2 = 0$



8. $-3x + 5y = 10$
 $5y = 3x + 10$

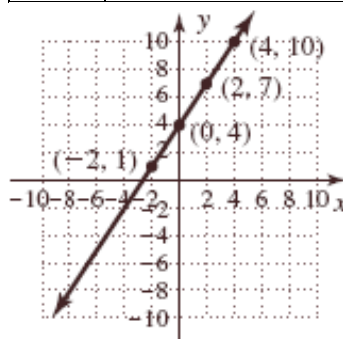
$$y = \frac{3}{5}x + 2$$

x	y
-5	$\frac{3}{5}(-5) + 2 = -3 + 2 = -1$
0	$\frac{3}{5}(0) + 2 = 0 + 2 = 2$
2	$\frac{3}{5}(2) + 2 = 1.2 + 2 = 3.2$
5	$\frac{3}{5}(5) + 2 = 3 + 2 = 5$



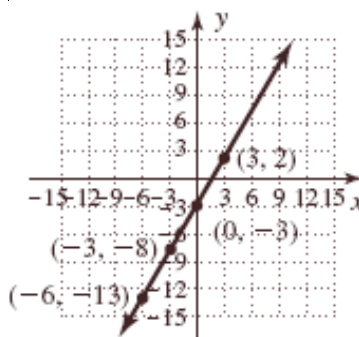
9. $y = \frac{3}{2}x + 4$

x	y
-2	$\frac{3}{2}(-2) + 4 = -3 + 4 = 1$
0	$\frac{3}{2}(0) + 4 = 0 + 4 = 4$
2	$\frac{3}{2}(2) + 4 = 3 + 4 = 7$
4	$\frac{3}{2}(4) + 4 = 6 + 4 = 10$



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

x	y
-6	$\frac{5}{3}(-6) - 3 = -10 - 3 = -13$
-3	$\frac{5}{3}(-3) - 3 = -5 - 3 = -8$
0	$\frac{5}{3}(0) - 3 = 0 - 3 = -3$
3	$\frac{5}{3}(3) - 3 = 5 - 3 = 2$



2.2 Exercises

11. $y = \frac{3}{2}x + 4$

$$-0.5 = \frac{3}{2}(-3) + 4$$

$$-0.5 = -\frac{9}{2} + 4$$

$$-0.5 = -0.5;$$

$$\frac{19}{4} = \frac{3}{2}\left(\frac{1}{2}\right) + 4$$

$$\frac{19}{4} = \frac{3}{4} + 4$$

$$\frac{19}{4} = \frac{19}{4}$$

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

$$-5.5 = \frac{5}{3}(-1.5) - 3$$

$$-5.5 = -2.5 - 3$$

$$-5.5 = -5.5;$$

$$\frac{37}{6} = \frac{5}{3}\left(\frac{11}{2}\right) - 3$$

$$\frac{37}{6} = \frac{55}{6} - 3$$

$$\frac{37}{6} = \frac{37}{6}$$

13. $3x + y = 6$

x-intercept: (2, 0)

$$3x + 0 = 6$$

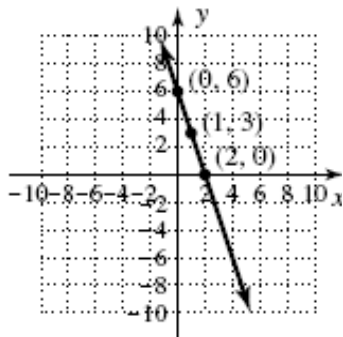
$$3x = 6$$

$$x = 2$$

y-intercept: (0, 6)

$$3(0) + y = 6$$

$$y = 6$$



14. $-2x + y = 12$

x-intercept: (-6, 0)

$$-2x + 0 = 12$$

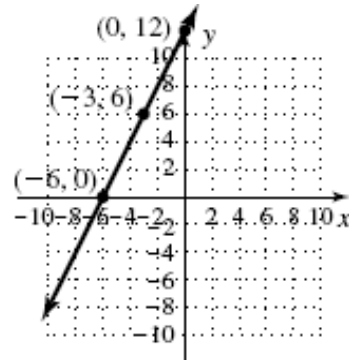
$$-2x = 12$$

$$x = -6$$

y-intercept: (0, 12)

$$-2(0) + y = 12$$

$$y = 12$$



15. $5y - x = 5$

x-intercept: (-5, 0)

$$5(0) - x = 5$$

$$-x = 5$$

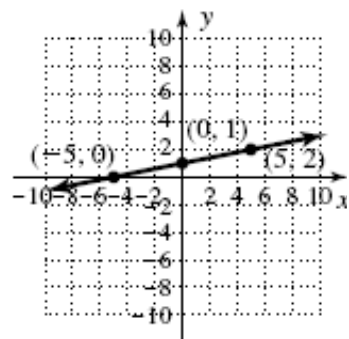
$$x = -5$$

y-intercept: (0, 1)

$$5y - 0 = 5$$

$$5y = 5$$

$$y = 1$$



Chapter 2: Relations, Functions and Graphs

16. $-4y + x = 8$

x-intercept: $(8, 0)$

$$-4(0) + x = 8$$

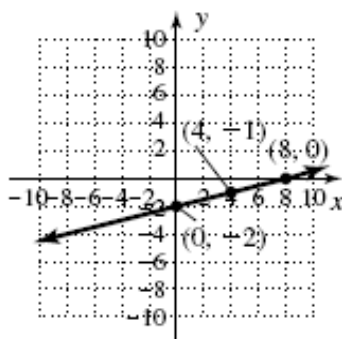
$$x = 8$$

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

$$-4y + 0 = 8$$

$$-4y = 8$$

$$y = -2$$



17. $-5x + 2y = 6$

x-intercept: $(-\frac{6}{5}, 0)$

$$-5x + 2(0) = 6$$

$$-5x = 6$$

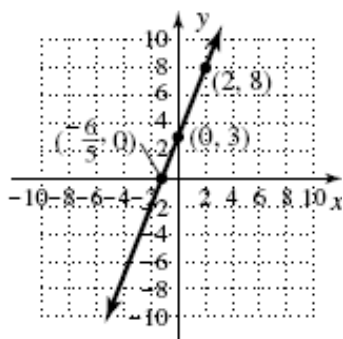
$$x = -\frac{6}{5}$$

y-intercept: $(0, 3)$

$$-5(0) + 2y = 6$$

$$2y = 6$$

$$y = 3$$



18. $3y + 4x = 9$

x-intercept: $(\frac{9}{4}, 0)$

$$3(0) + 4x = 9$$

$$4x = 9$$

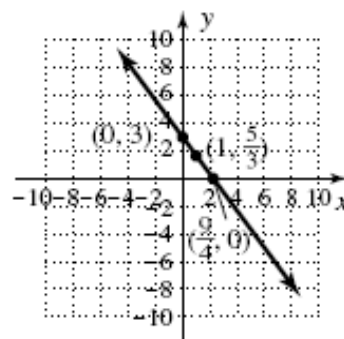
$$x = \frac{9}{4}$$

y-intercept: $(0, 3)$

$$3y + 4(0) = 9$$

$$3y = 9$$

$$y = 3$$



19. $2x - 5y = 4$

x-intercept: $(2, 0)$

$$2x - 5(0) = 4$$

$$2x = 4$$

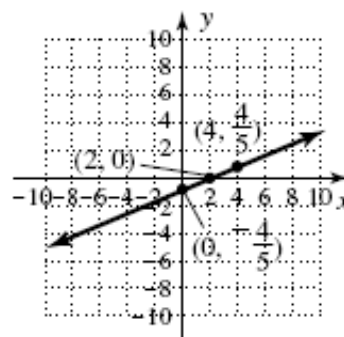
$$x = 2$$

y-intercept: $(0, -\frac{4}{5})$

$$2(0) - 5y = 4$$

$$-5y = 4$$

$$y = -\frac{4}{5}$$



2.2 Exercises

20. $-6x + 4y = 8$

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

$$-6x + 4(0) = 8$$

$$-6x = 8$$

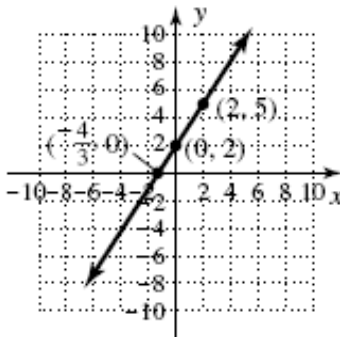
$$x = -\frac{4}{3}$$

y-intercept: $(0, 2)$

$$-6(0) + 4y = 8$$

$$4y = 8$$

$$y = 2$$



21. $2x + 3y = -12$

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

$$2x + 3(0) = -12$$

$$2x = -12$$

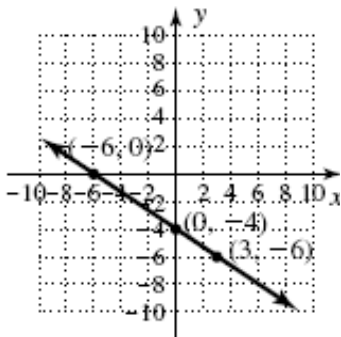
$$x = -6$$

y-intercept: $(0, -4)$

$$2(0) + 3y = -12$$

$$3y = -12$$

$$y = -4$$



22. $-3x - 2y = 6$

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

$$-3x - 2(0) = 6$$

$$-3x = 6$$

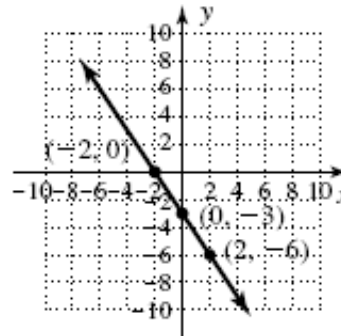
$$x = -2$$

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

$$-3(0) - 2y = 6$$

$$-2y = 6$$

$$y = -3$$



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

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

$$y = -1$$

$$(2, -1);$$

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

$$y = -\frac{1}{2}(4)$$

$$y = -2$$

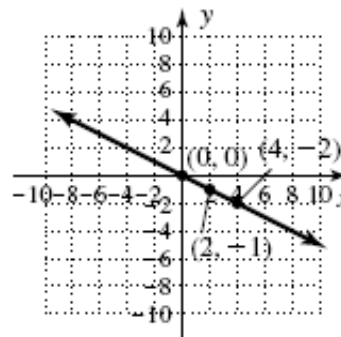
$$(4, -2);$$

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

$$y = -\frac{1}{2}(0)$$

$$y = 0$$

$$(0, 0)$$



Chapter 2: Relations, Functions and Graphs

24. $y = \frac{2}{3}x$

$$y = \frac{2}{3}(3)$$

$$y = 2$$

$$(3, 2);$$

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

$$y = \frac{2}{3}(6)$$

$$y = 4$$

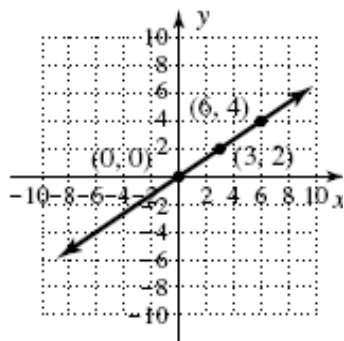
$$(6, 4);$$

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

$$y = \frac{2}{3}(0)$$

$$y = 0$$

$$(0, 0)$$



25. $y - 25 = 50x$

$$y - 25 = 50(-1)$$

$$y - 25 = -50$$

$$y = -25$$

$$(-1, -25);$$

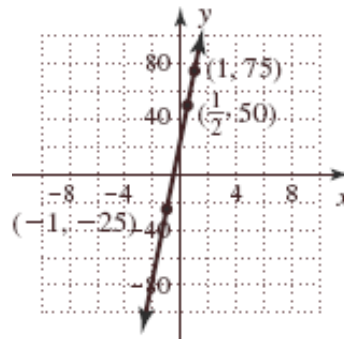
$$y - 25 = 50x$$

$$y - 25 = 50(1)$$

$$y - 25 = 50$$

$$y = 75$$

$$(1, 75)$$



26. $y + 30 = 60x$

$$y + 30 = 60(-1)$$

$$y + 30 = -60$$

$$y = -90$$

$$(-1, -90);$$

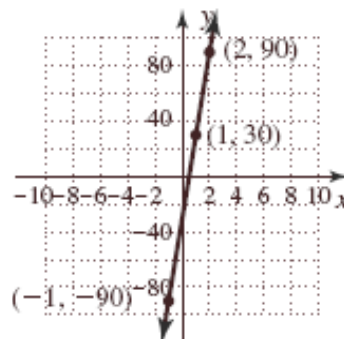
$$y + 30 = 60x$$

$$y + 30 = 60(1)$$

$$y + 30 = 60$$

$$y = 30$$

$$(1, 30)$$



2.2 Exercises

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

x-intercept: $(-5, 0)$

$$0 = -\frac{2}{5}x - 2$$

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

$$\left(-\frac{5}{2}\right)(2) = \left(-\frac{5}{2}\right)\left(-\frac{2}{5}x\right)$$

$$-5 = x$$

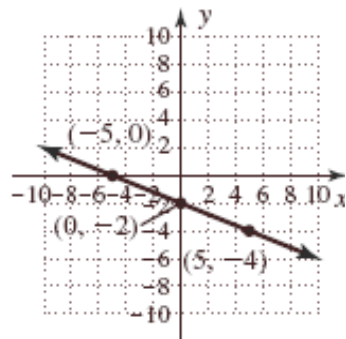
$(-5, 0);$

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

$$y = -\frac{2}{5}(0) - 2$$

$$y = -2$$

$(0, -2)$



28. $y = \frac{3}{4}x + 2$

$$y = \frac{3}{4}(-4) + 2$$

$$y = -3 + 2$$

$$y = -1$$

$(-4, -1);$

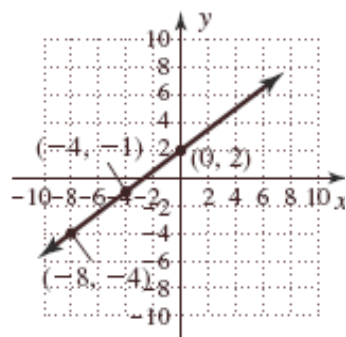
$$y = \frac{3}{4}x + 2$$

$$y = \frac{3}{4}(-8) + 2$$

$$y = -6 + 2$$

$$y = -4$$

$(-8, -4)$



29. $2y - 3x = 0$

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

$$2y - 6 = 0$$

$$2y = 6$$

$$y = 3$$

$(2, 3);$

$$2y - 3x = 0$$

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

$$2y - 12 = 0$$

$$2y = 12$$

$$y = 6$$

$(4, 6);$

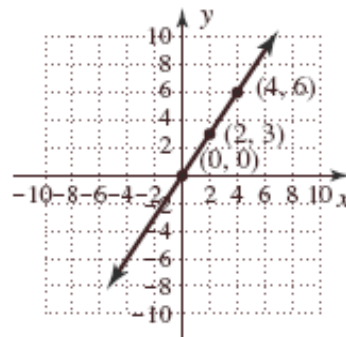
$$2y - 3x = 0$$

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

$$2y = 0$$

$$y = 0$$

$(0, 0)$



Chapter 2: Relations, Functions and Graphs

30. $y + 3x = 0$

$$y + 3(-1) = 0$$

$$y - 3 = 0$$

$$y = 3$$

$$(-1, 3);$$

$$y + 3x = 0$$

$$y + 3(1) = 0$$

$$y + 3 = 0$$

$$y = -3$$

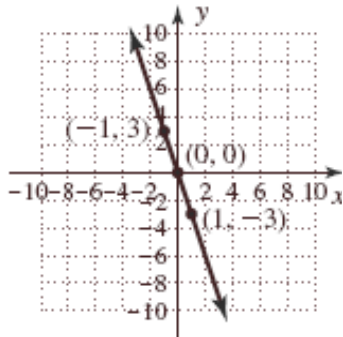
$$(1, -3);$$

$$y + 3x = 0$$

$$y + 3(0) = 0$$

$$y = 0$$

$$(0, 0)$$



31. $3y + 4x = 12$

$$x\text{-intercept: } (3, 0)$$

$$3(0) + 4x = 12$$

$$4x = 12$$

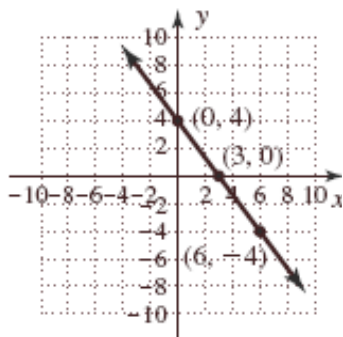
$$x = 3$$

$$y\text{-intercept: } (0, 4)$$

$$3y + 4(0) = 12$$

$$3y = 12$$

$$y = 4$$



32. $-2x + 5y = 8$

$$x\text{-intercept: } (-4, 0)$$

$$-2x + 5(0) = 8$$

$$-2x = 8$$

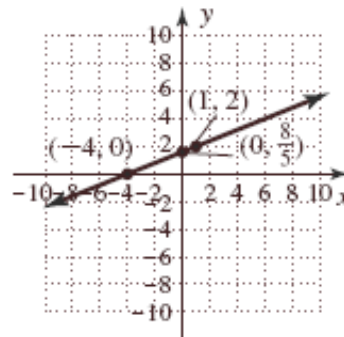
$$x = -4$$

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

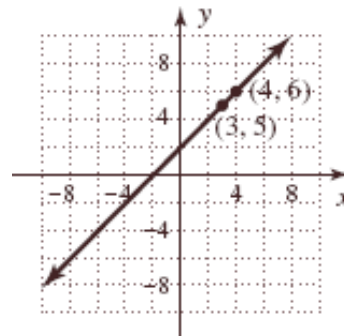
$$-2(0) + 5y = 8$$

$$5y = 8$$

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



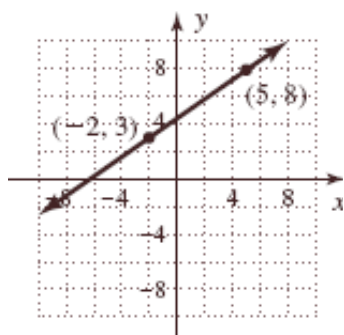
33. $m = \frac{6-5}{4-3} = \frac{1}{1} = 1$



$$(2, 4), (1, 3)$$

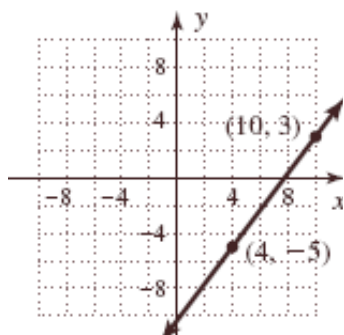
2.2 Exercises

$$34. m = \frac{8-3}{5-(-2)} = \frac{5}{7}$$



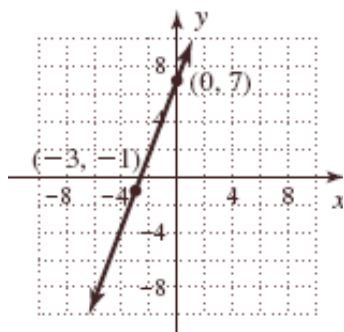
$$(-9, -2), (13, 12)$$

$$35. m = \frac{3-(-5)}{10-4} = \frac{8}{6} = \frac{4}{3}$$



$$(7, -1), (1, -9)$$

$$36. m = \frac{-1-7}{-3-0} = \frac{-8}{-3} = \frac{8}{3}$$



$$(-6, -9), (3, 15)$$

$$37. m = \frac{-8-7}{1-(-3)} = \frac{-15}{4} = -\frac{15}{4}$$

$$(1, -8), \left(-1, -\frac{1}{2}\right)$$

$$38. m = \frac{-5-5}{0-(-5)} = \frac{-10}{5} = -2$$

$$(-3, 1), (-7, 9)$$

$$39. m = \frac{2-6}{4-(-3)} = \frac{-4}{7} = -\frac{4}{7}$$

$$(-10, 10), (11, -2)$$

$$40. m = \frac{-1-(-4)}{-3-(-2)} = \frac{-1+4}{-3+2} = \frac{3}{-1} = -3$$

$$(-4, 2), (-1, -7)$$

41. a.

$$m = \frac{500-250}{4-2} = \frac{250}{2} = 125$$

Cost increased \$125,000 per 1000 square feet.

b. \$375,000

$$42. a. m = \frac{960-360}{80-30} = \frac{600}{50} = 12$$

12 m³ dumped per garbage truck.

b. 83 trucks

$$43. a. m = \frac{270-90}{12-4} = \frac{180}{8} = 22.5$$

Distance increases 22.5 miles per hour.

b. 186 miles

$$44. a. m = \frac{300-150}{8-4} = \frac{150}{4} = 37.5$$

37.5 circuit boards are assembled per hour.

b. 6 hours

$$45. a. m = \frac{165-142}{70-64} = \frac{23}{6}$$

A person weighs 23 pounds more for each additional 6 inches in height.

$$b. \frac{23}{6} \approx 3.8 \text{ pounds}$$

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46. a. $m = \frac{32000 - 10000}{15 - 5} = \frac{22000}{10} = 2200$

A plane climbs 2200 feet in 1 minute.

b. $\frac{25400 - 12200}{2200} = 6 \text{ minutes}$

47. Convert 48 feet to inches: $48(12) = 576$;
 $(0, -6)$ represents position of the sewer line at edge of house;
 $(576, -18)$ represents position of sewer line at the main line.

$$m = \frac{-18 - (-6)}{576 - 0} = \frac{-12}{576} = -\frac{1}{48}$$

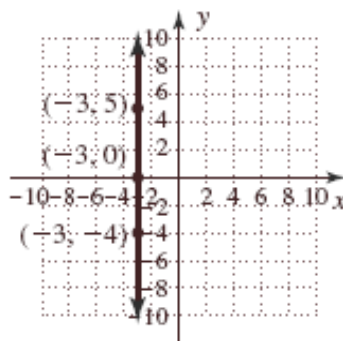
The sewer line is one inch deeper for each 48 inches in length.

48. $(0, 4)$ represents height of 4 ft from ridge;
 $(12, 0)$ represents 12 ft from ridge at height of 0 ft.

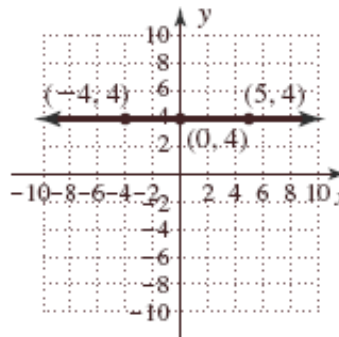
$$m = \frac{0 - 4}{12 - 0} = \frac{-4}{12} = -\frac{1}{3}$$

The roof decreases 1 foot in height for every 3 feet in horizontal distance from the ridge.

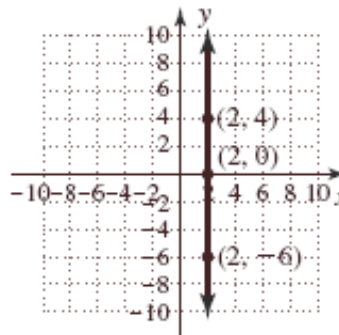
49. $x = -3$
 $x + 0y = -3$
 $x + 0(4) = -3$
 $x = -3$
 $(-3, 4)$;
 $x + 0y = -3$
 $x + 0(-4) = -3$
 $x = -3$
 $(-3, -4)$



50. $y = 4$
 $0x + y = 4$
 $0(3) + y = 4$
 $y = 4$
 $(3, 4)$;
 $0x + y = 4$
 $0(-3) + y = 4$
 $y = 4$
 $(-3, 4)$



51. $x = 2$
 $x + 0y = 2$
 $x + 0(2) = 2$
 $x = 2$
 $(2, 0)$
 $x + 0y = 2$
 $x + 0(-2) = 2$
 $x = 2$
 $(2, 0)$



2.2 Exercises

52. $y = -2$

$$0x + y = -2$$

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

$$y = -2$$

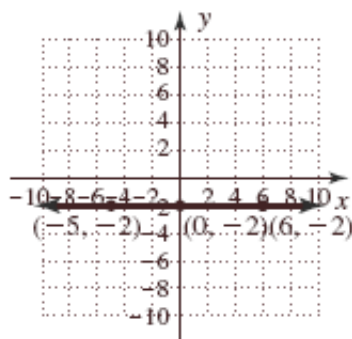
$$(0, -2)$$

$$0x + y = -2$$

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

$$y = -2$$

$$(0, -2)$$



53. $L_1 : x = 2$

$$L_2 : y = 4$$

Point of intersection: $(2, 4)$

54. $L_1 : x = -3$

$$L_2 : y = 1$$

Point of intersection: $(-3, 1)$

55. a. Choose any two points (t, j) .

$$(0, 9), (10, 9)$$

$$m = \frac{9-9}{10-0} = \frac{0}{10} = 0$$

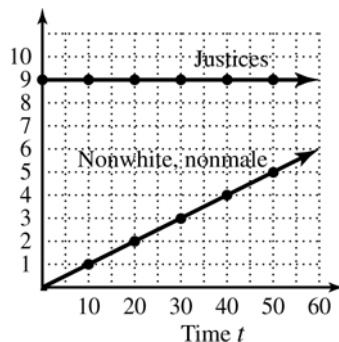
Which indicates there is no increase or decrease in the number of Supreme Court justices.

b. Choose any two points (t, n) .

$$(0, 0), (10, 1)$$

$$m = \frac{1-0}{10-0} = \frac{1}{10}$$

Which indicates that over the last 5 decades, one non-white or non-female justice has been added to the court every ten years.

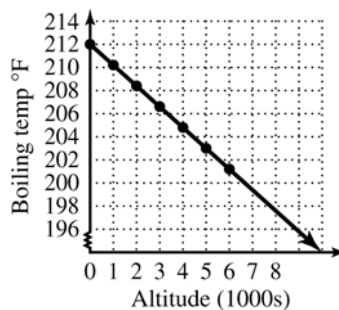


56. Choose any two points (h, t) .

$$(0, 212), (5000, 203)$$

$$m = \frac{203-212}{5000-0} = \frac{-9}{5000}$$

which indicates that the boiling point of water decreases by 9° F for each increase in 5000 feet in altitude.



57. $L_1 : m = \frac{6-0}{0-(-2)} = \frac{6}{2} = 3$

$$L_2 : m = \frac{5-8}{0-1} = \frac{-3}{-1} = 3$$

Parallel

58. $L_1 : m = \frac{7-10}{-1-1} = \frac{-3}{-2} = \frac{3}{2}$

$$L_2 : m = \frac{5-3}{1-0} = \frac{2}{1} = 2$$

Neither

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$$59. L_1: m = \frac{-4-1}{-3-0} = \frac{-5}{-3} = \frac{5}{3}$$

$$L_2: m = \frac{4-0}{-4-0} = \frac{4}{-4} = -1$$

Neither

$$60. L_1: m = \frac{-2-2}{8-6} = \frac{-4}{2} = -2$$

$$L_2: m = \frac{1-0}{5-3} = \frac{1}{2}$$

Perpendicular

$$61. L_1: m = \frac{7-3}{8-6} = \frac{4}{2} = 2$$

$$L_2: m = \frac{2-0}{7-6} = \frac{2}{1} = 2$$

Parallel

$$62. L_1: m = \frac{-1-4}{-5-4} = \frac{-5}{-9} = \frac{5}{9}$$

$$L_2: m = \frac{-7-10}{4-8} = \frac{-17}{-4} = \frac{17}{4}$$

Neither

$$63. (5, 2) (0, -3)$$

$$m = \frac{-3-2}{0-5} = \frac{-5}{-5} = 1;$$

$$(0, -3) (4, -4)$$

$$m = \frac{-4-(-3)}{4-0} = \frac{-4+3}{4} = \frac{-1}{4};$$

$$(5, 2) (4, -4)$$

$$m = \frac{-4-2}{4-5} = \frac{-6}{-1} = 6$$

Not a right triangle. Lines are not

perpendicular. Slopes: $1; \frac{-1}{4}; 6$

$$64. (7, 0) (-1, 0)$$

$$m = \frac{0-0}{-1-7} = 0;$$

$$(7, 0) (7, 4)$$

$$m = \frac{4-0}{7-7} \text{ Undefined}$$

Right triangle because these two lines are perpendicular. Slopes: $0; \text{undefined}$.

$$65. (-4, 3) (-7, -1)$$

$$m = \frac{-1-3}{-7-(-4)} = \frac{-4}{-7+4} = \frac{-4}{-3} = \frac{4}{3};$$

$$(-7, -1) (3, -2)$$

$$m = \frac{-2-(-1)}{3-(-7)} = \frac{-2+1}{3+7} = \frac{-1}{10};$$

$$(-4, 3) (3, -2)$$

$$m = \frac{-2-3}{3-(-4)} = \frac{-5}{7}$$

Not a right triangle. Lines are not

perpendicular. Slopes: $\frac{4}{3}; \frac{-1}{10}; \frac{-5}{7}$

$$66. (-3, 7) (2, 2)$$

$$m = \frac{2-7}{2-(-3)} = \frac{-5}{2+3} = \frac{-5}{5} = -1;$$

$$(2, 2) (5, 5)$$

$$m = \frac{5-2}{5-2} = \frac{3}{3} = 1$$

Right triangle because these two lines are perpendicular. Slopes: $-1; 1$

$$67. (-3, 2) (-1, 5)$$

$$m = \frac{5-2}{-1-(-3)} = \frac{3}{-1+3} = \frac{3}{2};$$

$$(-3, 2) (-6, 4)$$

$$m = \frac{4-2}{-6-(-3)} = \frac{2}{-6+3} = \frac{2}{-3}$$

Right triangle because these two lines are

perpendicular. Slopes: $\frac{3}{2}; \frac{-2}{3}$

$$68. (0, 0) (-5, 2)$$

$$m = \frac{2-0}{-5-0} = \frac{2}{-5} = -\frac{2}{5};$$

$$(-5, 2) (2, -5)$$

$$m = \frac{-5-2}{2-(-5)} = \frac{-7}{2+5} = \frac{-7}{7} = -1;$$

$$(0, 0) (2, -5)$$

$$m = \frac{-5-0}{2-0} = \frac{-5}{2}$$

Not a right triangle. Lines are not

perpendicular. Slopes: $-\frac{2}{5}, -1, -\frac{5}{2}$

2.2 Exercises

69. $L = 0.11T + 74.2$
 a. $L(20) = 0.11(20) + 74.2 = 76.4$ years
 b. $77.5 = 0.11T + 74.2$
 $3.3 = 0.11T$
 $30 = T$
 $1980 + 30 = 2010$
70. $I = \left(\frac{7}{100}\right)(5000)T$
 a. $I(5) = \left(\frac{7}{100}\right)(5000)(5) = \1750
 b. $I(10) = \left(\frac{7}{100}\right)(5000)(10) = \3500
 c. $m = \frac{3500 - 1750}{10 - 5} = \frac{1750}{5} = 350$
 Interest increases \$350 per year.
71. $V = 8500 - 1250y$
 a. $V = 8500 - 1250(4) = \$3500$
 b. $2250 = 8500 - 1250y$
 $-6250 = -1250y$
 $5 = y$
 5 years
72. $V = 85 + 1.5y$
 a. $V = 85 + 1.5(7) = \$95.50$
 b. $100 = 85 + 1.5y$
 $15 = 1.5y$
 $10 = y$
 10 years
73. Let h represent the water level, in inches.
 Let t represent the time, in months.
 $h = -3t + 300$
 a. $h = -3(9) + 300 = 273$ in .
 b. Convert feet to inches: $20(12) = 240$;
 $240 = -3t + 300$
 $-60 = -3t$
 $20 = t$
 20 months
74. Let w represent the weight of cargo, in tons.
 Let m represent the gas mileage per gallon.
 Find two points (w, m) from the given data:
 $(0, 15), (3, 14.25)$
 $m = \frac{14.25 - 15}{3 - 0} = -0.25$;
 $m = -0.25w + 15$
 a. $m = -0.25(10) + 15 = 12.5$ mpg
 b. $10 = -0.25w + 15$
 $-5 = -0.25w$
 $20 = w$
 20 tons
75. Slope of FM 1960: $\frac{38}{12}$;
 Slope of FM 380: $\frac{30}{9.5}$;
 Since $\frac{38}{12} \neq \frac{30}{9.5}$, the roads are not parallel
 and yes, the roads will meet.
76. Harbor is at $(0, 0)$. The first trawler is at $(3, 12)$ and the second trawler is at $(8, -2)$.
 Slope of first route: $m = \frac{12}{3} = 4$;
 Slope of second route: $m = \frac{-2}{8} = -\frac{1}{4}$;
 Yes, the routes are perpendicular.
 Distance between two boats:
 $d = \sqrt{(8-3)^2 + (-2-12)^2}$
 $= \sqrt{221} \approx 14.9$ miles
77. $y = 144x + 621$
 a. $y = 144(22) + 621$
 $y = 3789$
 \$3,789
 b. $5250 = 144x + 621$
 $4629 = 144x$
 $32.15 \approx x$
 $1980 + 32 = 2012$
 Year 2012

Chapter 2: Relations, Functions and Graphs

78. $y = 0.72x + 11$

a. $y = 0.72(12) + 11$

$$y = 8.64 + 11$$

$$y = 19.64$$

20%

b. $30 = 0.72x + 11$

$$19 = 0.72x$$

$$26.38 = x$$

$$1980 + 26.38 = 2006.38$$

During the year 2006

79. $y = -\frac{7}{15}x + 32$

a. $y = -\frac{7}{15}(20) + 32$

$$y = \frac{-28}{3} + 32$$

$$y = 22\frac{2}{3}$$

23%

b. $20 = -\frac{7}{15}x + 32$

$$-12 = -\frac{7}{15}x$$

$$-180 = -7x$$

$$25.7 = x$$

$$1980 + 25.7 = 2005.7$$

During the year 2005

80. $T = \frac{N}{4} + 40$

a. $T(48) = \frac{48}{4} + 40 = 12 + 40 = 52$

52° F

b. $70 = \frac{N}{4} + 40$

$$30 = \frac{N}{4}$$

$$120 = N$$

120 chirps per minute

81. $4y + 2x = -5$

$$4y = -2x - 5$$

$$y = -\frac{1}{2}x - \frac{5}{4};$$

$$3y + ax = -2$$

$$3y = -ax - 2$$

$$y = -\frac{a}{3}x - \frac{2}{3};$$

$$-\frac{a}{3} - \frac{1}{2} = -1$$

$$\frac{a}{6} = -1$$

$$a = -6$$

82. e.

83. $t_n = t_1 + (n-1)d$

a. $n = 21, t_1 = 2, d = 9 - 2 = 7$

$$t_{21} = 2 + (21-1)7 = 142$$

b. $n = 31, t_1 = 7, d = 4 - 7 = -3$

$$t_{31} = 7 + (31-1)(-3) = -83$$

c. $n = 27, t_1 = 5.10, d = 5.25 - 5.10 = 0.15$

$$t_{27} = 5.10 + (27-1)(0.15) = 9$$

d. $n = 17, t_1 = \frac{3}{2}, d = \frac{9}{4} - \frac{3}{2} = \frac{3}{4}$

$$t_{17} = \frac{3}{2} + (17-1)\left(\frac{3}{4}\right) = \frac{27}{2}$$

84. $3x^2 - 3 + 4x + 6 = 4x^2 - 3(x+5)$

$$3x^2 + 4x + 3 = 4x^2 - 3x - 15$$

$$-x^2 + 7x + 18 = 0$$

$$-(x^2 - 7x - 18) = 0$$

$$-(x-9)(x+2) = 0$$

$$x = -2 \text{ or } x = 9$$

Check:

$$3(-2)^2 - 3 + 4(-2) + 6 = 4(-2)^2 - 3(-2+5)$$

$$3(4) - 3 - 8 + 6 = 4(4) - 3(3)$$

$$12 - 3 - 8 + 6 = 16 - 9$$

$$7 = 7;$$

$$3(9)^2 - 3 + 4(9) + 6 = 4(9)^2 - 3(9+5)$$

$$3(81) - 3 + 36 + 6 = 4(81) - 3(14)$$

$$243 - 3 + 36 + 6 = 324 - 42$$

$$282 = 282$$

2.3 Exercises

85. $P = 2L + 2W$

Perimeter of a rectangle;

$$V = LWH$$

Volume of a rectangular prism;

$$V = \pi r^2 h$$

Volume of a cylinder;

$$C = 2\pi r$$

Circumference of a circle

86. Let x represent the number of gallons of 35% brine solution.

Let y represent the total number of gallons of 45% brine solution.

$$\begin{cases} x + 12 = y \\ 0.35x + 0.55(12) = 0.45(12 + x) \end{cases}$$

$$0.35x + 0.55(12) = 0.45(12 + x)$$

$$0.35x + 6.6 = 5.4 + 0.45x$$

$$-0.1x = -1.2$$

$$x = 12$$

12 gallons

87.

	Distance	Rate	Time
Westbound Boat	D	15	t
Eastbound Boat	$70 - D$	20	t

$$\begin{cases} D = 15t \\ 70 - D = 20t \end{cases}$$

$$70 - 15t = 20t$$

$$70 = 35t$$

$$2 = t$$

2 hours

2.3 Exercises

1. $-\frac{7}{4}; (0, 3)$

2. Cost; time

3. 2.5

4. Point-slope

5. Answers will vary.

6. Answers will vary.

7. $4x + 5y = 10$

$$5y = -4x + 10$$

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

x	$y = -\frac{4}{5}x + 2$
-5	$y = -\frac{4}{5}(-5) + 2 = 4 + 2 = 6$
-2	$y = -\frac{4}{5}(-2) + 2 = \frac{8}{5} + 2 = \frac{18}{5}$
0	$y = -\frac{4}{5}(0) + 2 = 0 + 2 = 2$
1	$y = -\frac{4}{5}(1) + 2 = -\frac{4}{5} + 2 = \frac{6}{5}$
3	$y = -\frac{4}{5}(3) + 2 = -\frac{12}{5} + 2 = -\frac{2}{5}$

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8. $3y - 2x = 9$

$$3y = 2x + 9$$

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

x	$y = \frac{2}{3}x + 3$
-5	$y = \frac{2}{3}(-5) + 3 = -\frac{10}{3} + 3 = -\frac{1}{3}$
-2	$y = \frac{2}{3}(-2) + 3 = -\frac{4}{3} + 3 = \frac{5}{3}$
0	$y = \frac{2}{3}(0) + 3 = 0 + 3 = 3$
1	$y = \frac{2}{3}(1) + 3 = \frac{2}{3} + 3 = \frac{11}{3}$
3	$y = \frac{2}{3}(3) + 3 = 2 + 3 = 5$

9. $-0.4x + 0.2y = 1.4$

$$0.2y = 0.4x + 1.4$$

$$y = 2x + 7$$

x	$y = 2x + 7$
-5	$y = 2(-5) + 7 = -10 + 7 = -3$
-2	$y = 2(-2) + 7 = -4 + 7 = 3$
0	$y = 2(0) + 7 = 0 + 7 = 7$
1	$y = 2(1) + 7 = 2 + 7 = 9$
3	$y = 2(3) + 7 = 6 + 7 = 13$

10. $-0.2x + 0.7y = -2.1$

$$0.7y = 0.2x - 2.1$$

$$y = \frac{2}{7}x - 3$$

x	$y = \frac{2}{7}x - 3$
-5	$y = \frac{2}{7}(-5) - 3 = -\frac{10}{7} - 3 = -\frac{31}{7}$
-2	$y = \frac{2}{7}(-2) - 3 = -\frac{4}{7} - 3 = -\frac{25}{7}$
0	$y = \frac{2}{7}(0) - 3 = 0 - 3 = -3$
1	$y = \frac{2}{7}(1) - 3 = \frac{2}{7} - 3 = -\frac{19}{7}$
3	$y = \frac{2}{7}(3) - 3 = \frac{6}{7} - 3 = -\frac{15}{7}$

11. $\frac{1}{3}x + \frac{1}{5}y = -1$

$$\frac{1}{5}y = -\frac{1}{3}x - 1$$

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

x	$y = -\frac{5}{3}x - 5$
-5	$y = -\frac{5}{3}(-5) - 5 = \frac{25}{3} - 5 = \frac{10}{3}$
-2	$y = -\frac{5}{3}(-2) - 5 = \frac{10}{3} - 5 = -\frac{5}{3}$
0	$y = -\frac{5}{3}(0) - 5 = 0 - 5 = -5$
1	$y = -\frac{5}{3}(1) - 5 = -\frac{5}{3} - 5 = -\frac{20}{3}$
3	$y = -\frac{5}{3}(3) - 5 = -5 - 5 = -10$

12. $\frac{1}{7}y - \frac{1}{3}x = 2$

$$\frac{1}{7}y = \frac{1}{3}x + 2$$

$$y = \frac{7}{3}x + 14$$

x	$y = \frac{7}{3}x + 14$
-5	$y = \frac{7}{3}(-5) + 14 = \frac{-35}{3} + 14 = \frac{7}{3}$
-2	$y = \frac{7}{3}(-2) + 14 = -\frac{14}{3} + 14 = \frac{28}{3}$
0	$y = \frac{7}{3}(0) + 14 = 0 + 14 = 14$
1	$y = \frac{7}{3}(1) + 14 = \frac{7}{3} + 14 = \frac{49}{3}$
3	$y = \frac{7}{3}(3) + 14 = 7 + 14 = 21$

2.3 Exercises

$$13. \begin{aligned} 6x - 3y &= 9 \\ -3y &= -6x + 9 \\ y &= 2x - 3 \end{aligned}$$

New Coefficient: 2
New Constant: -3

$$14. \begin{aligned} 9y - 4x &= 18 \\ 9y &= 4x + 18 \\ y &= \frac{4}{9}x + 2 \end{aligned}$$

New Coefficient: $\frac{4}{9}$
New Constant: 2

$$15. \begin{aligned} -0.5x - 0.3y &= 2.1 \\ -0.3y &= 0.5x + 2.1 \\ y &= \frac{-5}{3}x - 7 \end{aligned}$$

New Coefficient: $\frac{-5}{3}$
New Constant: -7

$$16. \begin{aligned} -0.7x + 0.6y &= -2.4 \\ 0.6y &= 0.7x - 2.4 \\ y &= \frac{7}{6}x - 4 \end{aligned}$$

New Coefficient: $\frac{7}{6}$
New Constant: -4

$$17. \begin{aligned} \frac{5}{6}x + \frac{1}{7}y &= -\frac{4}{7} \\ \frac{1}{7}y &= -\frac{5}{6}x - \frac{4}{7} \\ y &= -\frac{35}{6}x - 4 \end{aligned}$$

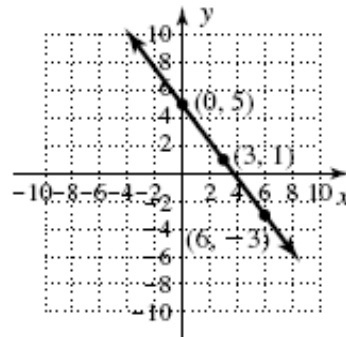
New Coefficient: $-\frac{35}{6}$
New Constant: -4

$$18. \begin{aligned} \frac{7}{12}y - \frac{4}{15}x &= \frac{7}{6} \\ \frac{7}{12}y &= \frac{4}{15}x + \frac{7}{6} \\ y &= \frac{16}{35}x + 2 \end{aligned}$$

New Coefficient: $\frac{16}{35}$
New Constant: 2

$$19. y = -\frac{4}{3}x + 5$$

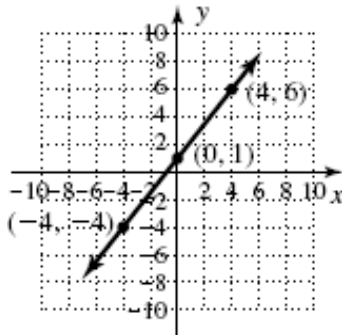
x	$y = -\frac{4}{3}x + 5$
0	$y = -\frac{4}{3}(0) + 5 = 0 + 5 = 5$
3	$y = -\frac{4}{3}(3) + 5 = -4 + 5 = 1$
6	$y = -\frac{4}{3}(6) + 5 = -8 + 5 = -3$



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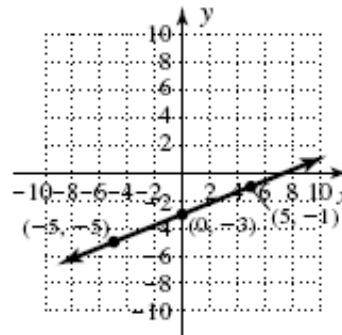
20. $y = \frac{5}{4}x + 1$

x	$y = \frac{5}{4}x + 1$
-4	$y = \frac{5}{4}(-4) + 1 = -5 + 1 = -4$
0	$y = \frac{5}{4}(0) + 1 = 0 + 1 = 1$
4	$y = \frac{5}{4}(4) + 1 = 5 + 1 = 6$



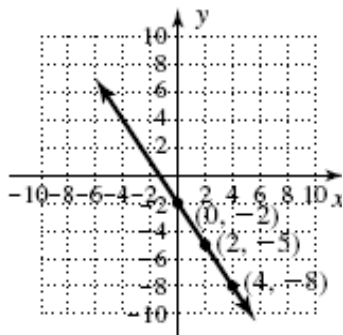
22. $y = \frac{2}{5}x - 3$

x	$y = \frac{2}{5}x - 3$
-5	$y = \frac{2}{5}(-5) - 3 = -2 - 3 = -5$
0	$y = \frac{2}{5}(0) - 3 = 0 - 3 = -3$
5	$y = \frac{2}{5}(5) - 3 = 2 - 3 = -1$



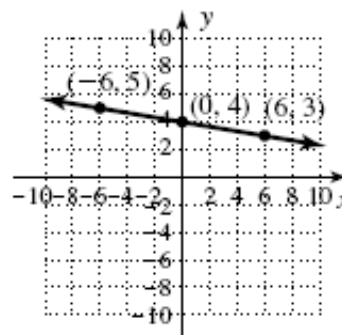
21. $y = -\frac{3}{2}x - 2$

x	$y = -\frac{3}{2}x - 2$
0	$y = -\frac{3}{2}(0) - 2 = 0 - 2 = -2$
2	$y = -\frac{3}{2}(2) - 2 = -3 - 2 = -5$
4	$y = -\frac{3}{2}(4) - 2 = -6 - 2 = -8$



23. $y = -\frac{1}{6}x + 4$

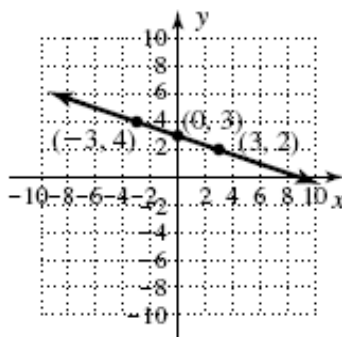
x	$y = -\frac{1}{6}x + 4$
-6	$y = -\frac{1}{6}(-6) + 4 = 1 + 3 = 4$
0	$y = -\frac{1}{6}(0) + 4 = 0 + 4 = 4$
6	$y = -\frac{1}{6}(6) + 4 = -1 + 4 = 3$



2.3 Exercises

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

x	$y = -\frac{1}{3}x + 3$
-3	$y = -\frac{1}{3}(-3) + 3 = 1 + 3 = 4$
0	$y = -\frac{1}{3}(0) + 3 = 0 + 3 = 3$
3	$y = -\frac{1}{3}(3) + 3 = -1 + 3 = 2$



25. $3x + 4y = 12$

x-intercept: (4, 0) y-intercept: (0, 3)
 $3x + 4(0) = 12$ $3(0) + 4y = 12$
 $3x = 12$ $4y = 12$
 $x = 4$ $y = 3$

a. $m = \frac{0-3}{4-0} = -\frac{3}{4}$

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

c. The coefficient of x is the slope and the constant is the y -intercept.

26. $3y - 2x = -6$

x-intercept: (3, 0) y-intercept: (0, -2)
 $3(0) - 2x = -6$ $3y - 2(0) = -6$
 $-2x = -6$ $3y = -6$
 $x = 3$ $y = -2$

a. $m = \frac{0-(-2)}{3-0} = \frac{2}{3}$

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

c. The coefficient of x is the slope and the constant is the y -intercept.

27. $2x - 5y = 10$

x-intercept: (5, 0) y-intercept: (0, -2)
 $2x - 5(0) = 10$ $2(0) - 5y = 10$
 $2x = 10$ $-5y = 10$
 $x = 5$ $y = -2$

a. $m = \frac{0-(-2)}{5-0} = \frac{2}{5}$

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

c. The coefficient of x is the slope and the constant is the y -intercept.

28. $2x + 3y = 9$

x-intercept: $(\frac{9}{2}, 0)$ y-intercept: (0, 3)

$2x + 3(0) = 9$ $2(0) + 3y = 9$
 $2x = 9$ $3y = 9$
 $x = \frac{9}{2}$ $y = 3$

a. $m = \frac{0-3}{\frac{9}{2}-0} = \frac{-3}{\frac{9}{2}} = -\frac{6}{9} = -\frac{2}{3}$

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

c. The coefficient of x is the slope and the constant is the y -intercept.

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29. $4x - 5y = -15$

x -intercept: $\left(-\frac{15}{4}, 0\right)$ y -intercept: $(0, 3)$

$$4x - 5(0) = -15$$

$$4x = -15$$

$$x = -\frac{15}{4}$$

$$4(0) - 5y = -15$$

$$-5y = -15$$

$$y = 3$$

a. $m = \frac{0-3}{-\frac{15}{4}-0} = \frac{-3}{-\frac{15}{4}} = \frac{12}{15} = \frac{4}{5}$

b. $y = \frac{4}{5}x + 3$

c. The coefficient of x is the slope and the constant is the y -intercept.

30. $5y + 6x = -25$

x -intercept: $\left(-\frac{25}{6}, 0\right)$ y -intercept: $(0, -5)$

$$5(0) + 6x = -25$$

$$6x = -25$$

$$x = -\frac{25}{6}$$

$$5y + 6(0) = -25$$

$$5y = -25$$

$$y = -5$$

a. $m = \frac{0-(-5)}{-\frac{25}{6}-0} = \frac{5}{-\frac{25}{6}} = -\frac{30}{25} = -\frac{6}{5}$

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

c. The coefficient of x is the slope and the constant is the y -intercept.

31. $2x + 3y = 6$

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

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

$$m = -\frac{2}{3}; y\text{-intercept } (0, 2)$$

32. $4y - 3x = 12$

$$4y = 3x + 12$$

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

$$m = \frac{3}{4}; y\text{-intercept } (0, 3)$$

33. $5x + 4y = 20$

$$4y = -5x + 20$$

$$y = -\frac{5}{4}x + 5$$

$$m = -\frac{5}{4}; y\text{-intercept } (0, 5)$$

34. $y + 2x = 4$

$$y = -2x + 4$$

$$m = -2; y\text{-intercept } (0, 4)$$

35. $x = 3y$

$$y = \frac{1}{3}x$$

$$m = \frac{1}{3}; y\text{-intercept } (0, 0)$$

36. $2x = -5y$

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

$$m = -\frac{2}{5}; y\text{-intercept } (0, 0)$$

37. $3x + 4y - 12 = 0$

$$4y = -3x + 12$$

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

$$m = -\frac{3}{4}; y\text{-intercept } (0, 3)$$

38. $5y - 3x + 20 = 0$

$$5y = 3x - 20$$

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

$$m = \frac{3}{5}; y\text{-intercept } (0, -4)$$

2.3 Exercises

39. $m = \frac{2}{3}$; y-intercept (0, 1)

$$y = mx + b$$

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

40. $m = -\frac{2}{5}$; y-intercept (0, 3)

$$y = mx + b$$

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

41. $m = 3$; y-intercept (0, 3)

$$y = mx + b$$

$$y = 3x + 3$$

42. $m = -2$; y-intercept (0, -3)

$$y = mx + b$$

$$y = -2x - 3$$

43. $m = 3$; y-intercept (0, 2)

$$y = mx + b$$

$$y = 3x + 2$$

44. $m = -\frac{3}{2}$; y-intercept (0, -4)

$$y = mx + b$$

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

45. $m = 250$; (14, 4000)

$$y - y_1 = m(x - x_1)$$

$$y - 4000 = 250(x - 14)$$

$$y - 4000 = 250x - 3500$$

$$y = 250x + 500$$

$$f(x) = 250x + 500$$

46. $m = -100$; (7, 1200)

$$y - y_1 = m(x - x_1)$$

$$y - 1200 = -100(x - 7)$$

$$y - 1200 = -100x + 700$$

$$y = -100x + 1900$$

$$f(x) = -100x + 1900$$

47. $m = \frac{75}{2}$; (24, 1050)

$$y - y_1 = m(x - x_1)$$

$$y - 1050 = \frac{75}{2}(x - 24)$$

$$y - 1050 = \frac{75}{2}x - 900$$

$$y = \frac{75}{2}x + 150$$

$$f(x) = \frac{75}{2}x + 150$$

48. $m = -4$; (-3, 2)

$$y - y_1 = m(x - x_1)$$

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

$$y - 2 = -4x - 12$$

$$y = -4x - 10$$

49. $m = 2$; (5, -3)

$$y - y_1 = m(x - x_1)$$

$$y + 3 = 2(x - 5)$$

$$y + 3 = 2x - 10$$

$$y = 2x - 13$$

50. $m = -\frac{3}{2}$; (-4, 7)

$$y - y_1 = m(x - x_1)$$

$$y - 7 = -\frac{3}{2}(x + 4)$$

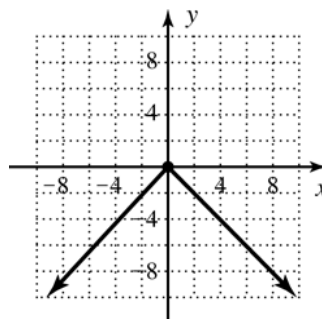
$$y - 7 = -\frac{3}{2}x - 6$$

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

51. $3x + 5y = 20$

$$5y = -3x + 20$$

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

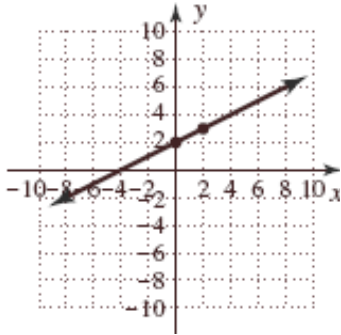


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52. $2y - x = 4$

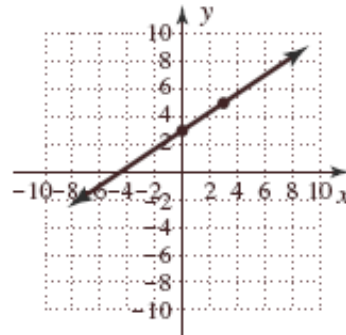
$2y = x + 4$

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



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

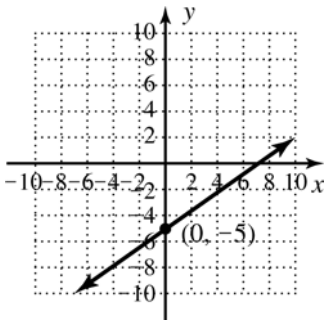
$m = \frac{2}{3}$; y-intercept (0, 3)



53. $2x - 3y = 15$

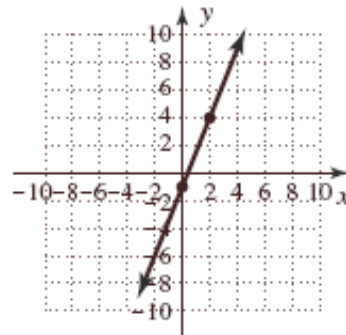
$-3y = -2x + 15$

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



56. $y = \frac{5}{2}x - 1$

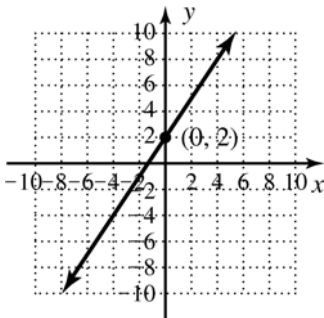
$m = \frac{5}{2}$; y-intercept (0, -1)



54. $-3x + 2y = 4$

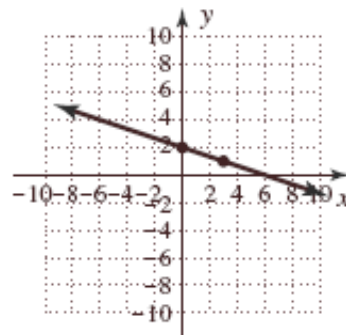
$2y = 3x + 4$

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



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

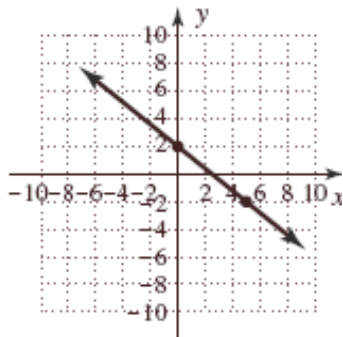
$m = -\frac{1}{3}$; y-intercept (0, 2)



2.3 Exercises

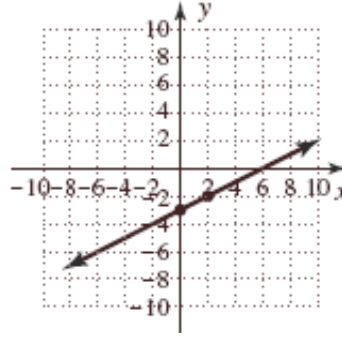
58. $y = -\frac{4}{5}x + 2$

$m = -\frac{4}{5}$; y-intercept (0, 2)



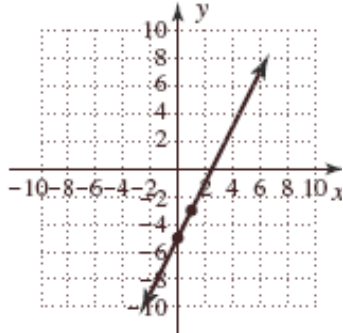
61. $f(x) = \frac{1}{2}x - 3$

$m = \frac{1}{2}$; y-intercept (0, -3)



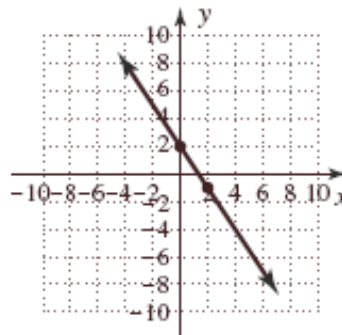
59. $y = 2x - 5$

$m = 2$; y-intercept (0, -5)



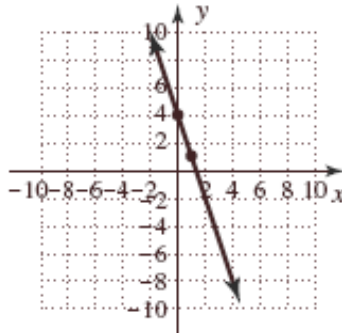
62. $f(x) = -\frac{3}{2}x + 2$

$m = -\frac{3}{2}$; y-intercept (0, 2)



60. $y = -3x + 4$

$m = -3$; y-intercept (0, 4)



63. $2x - 5y = 10$

$-5y = -2x + 10$

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

$m = \frac{2}{5}$; (-5, 2)

$y - y_1 = m(x - x_1)$

$y - 2 = \frac{2}{5}(x - (-5))$

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

$y = \frac{2}{5}x + 4$

Chapter 2: Relations, Functions and Graphs

64. $6x + 9y = 27$

$$9y = -6x + 27$$

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

$$m = -\frac{2}{3}; (-3, -5);$$

$$y - y_1 = m(x - x_1)$$

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

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

$$y = -\frac{2}{3}x - 7$$

65. $5y - 3x = 9$

$$5y = 3x + 9$$

$$y = \frac{3}{5}x + \frac{9}{5}$$

$$m = \frac{3}{5}; (6, -3);$$

$$y - y_1 = m(x - x_1)$$

$$y - (-3) = \frac{3}{5}(x - 6)$$

$$y + 3 = \frac{3}{5}x - \frac{18}{5}$$

$$y = \frac{3}{5}x - \frac{21}{5}$$

66. $x - 4y = 7$

$$-4y = -x + 7$$

$$y = \frac{1}{4}x - \frac{7}{4}$$

$$m = -\frac{1}{4}; (-5, 3)$$

$$y - y_1 = m(x - x_1)$$

$$y - 3 = -\frac{1}{4}(x + 5)$$

$$y - 3 = -\frac{1}{4}x - \frac{5}{4}$$

$$y = -\frac{1}{4}x - \frac{7}{4}$$

67. $12x + 5y = 65$

$$5y = -12x + 65$$

$$y = -\frac{12}{5}x + 13$$

$$m = -\frac{12}{5}; (-2, -1)$$

$$y - y_1 = m(x - x_1)$$

$$y + 1 = -\frac{12}{5}(x + 2)$$

$$y + 1 = -\frac{12}{5}x - \frac{24}{5}$$

$$y = -\frac{12}{5}x - \frac{29}{5}$$

68. $15y - 8x = 50$

$$15y = 8x + 50$$

$$y = \frac{8}{15}x + \frac{10}{3}$$

$$m = \frac{8}{15}; (3, -4)$$

$$y - y_1 = m(x - x_1)$$

$$y + 4 = \frac{8}{15}(x - 3)$$

$$y + 4 = \frac{8}{15}x - \frac{24}{15}$$

$$y = \frac{8}{15}x - \frac{28}{5}$$

69. $y = -3$ has slope of zero.

Slope of any line parallel to this line has the same slope, 0.

$$y = mx + b$$

$$5 = 0(2) + b$$

$$5 = b;$$

$$y = 0x + 5$$

$$y = 5$$

70. $y = -3$ has slope of zero.

Slope of any line perpendicular to this line has an undefined slope. Thus, it is a vertical line. Equation of the vertical line passing through (2, 5): $x = 2$

2.3 Exercises

71. $4y - 5x = 8$

$$4y = 5x + 8$$

$$y = \frac{5}{4}x + 2;$$

$$5y + 4x = -15$$

$$5y = -4x - 15$$

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

perpendicular

72. $3y - 2x = 6$

$$3y = 2x + 6$$

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

$$-2x + 3y = -3$$

$$3y = 2x - 3$$

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

parallel

73. $2x - 5y = 20$

$$-5y = -2x + 20$$

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

$$4x - 3y = 18$$

$$-3y = -4x + 18$$

$$y = \frac{4}{3}x - 6$$

Neither

74. $5y = 11x + 135$

$$y = \frac{11}{5}x + 27;$$

$$11y + 5x = -77$$

$$11y = -5x - 77$$

$$y = -\frac{5}{11}x - 7$$

Perpendicular; slopes are opposite reciprocals.

75. $-4x + 6y = 12$

$$6y = 4x + 12$$

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

$$2x + 3y = 6$$

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

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

Neither

76. $3x + 4y = 12$

$$4y = -3x + 12$$

$$y = -\frac{3}{4}x + 3;$$

$$6x + 8y = 2$$

$$8y = -6x + 2$$

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

Parallel; slopes are the same.

77. $(0,1), (4,-2)$

$$m = \frac{-2-1}{4-0} = -\frac{3}{4}$$

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

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

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

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

$$y + 4 = \frac{4}{3}x - \frac{8}{3}$$

$$y = \frac{4}{3}x - \frac{20}{3}$$

Chapter 2: Relations, Functions and Graphs

78. $(-2, 2), (3, 0)$

$$m = \frac{0-2}{3-(-2)} = \frac{-2}{5}$$

a. $y - 3 = \frac{-2}{5}(x - 1)$

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

$$y = \frac{-2}{5}x + \frac{17}{5}$$

b. $y - 3 = \frac{5}{2}(x - 1)$

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

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

79. $(-4, 0), (5, 4)$

$$m = \frac{4-0}{5-(-4)} = \frac{4}{9}$$

a. $y - 3 = \frac{4}{9}(x - (-1))$

$$y - 3 = \frac{4}{9}(x + 1)$$

$$y - 3 = \frac{4}{9}x + \frac{4}{9}$$

$$y = \frac{4}{9}x + \frac{31}{9}$$

b. $y - 3 = \frac{-9}{4}(x - (-1))$

$$y - 3 = \frac{-9}{4}(x + 1)$$

$$y - 3 = \frac{-9}{4}x - \frac{9}{4}$$

$$y = \frac{-9}{4}x + \frac{3}{4}$$

80. $(-2, 4), (4, 0)$

$$m = \frac{0-4}{4-(-2)} = \frac{-4}{6} = \frac{-2}{3}$$

a. $y - (-2.5) = \frac{-2}{3}(x - 1)$

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

$$y = \frac{-2}{3}x - \frac{11}{6}$$

b. $y - (-2.5) = \frac{3}{2}(x - 1)$

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

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

81. $(-2, 3), (4, 0)$

$$m = \frac{0-3}{4-(-2)} = \frac{-3}{6} = \frac{-1}{2}$$

a. $y - (-2) = \frac{-1}{2}(x - 0)$

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

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

b. $y - (-2) = 2(x - 0)$

$$y + 2 = 2x$$

$$y = 2x - 2$$

82. $(-3, 5), (2, 0)$

$$m = \frac{0-5}{2-(-3)} = \frac{-5}{5} = -1$$

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

$$y - 3 = -1x + 1$$

$$y = -x + 4$$

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

$$y - 3 = x - 1$$

$$y = x + 2$$

2.3 Exercises

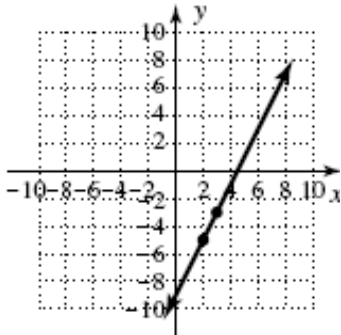
83. $m = 2$; $P_1 = (2, -5)$

$$y - y_1 = m(x - x_1)$$

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

$$y + 5 = 2x - 4$$

$$y = 2x - 9$$



84. $m = -1$; $P_1 = (2, -3)$

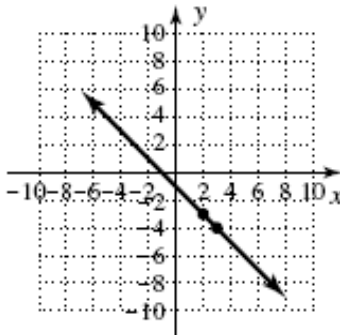
$$y - y_1 = m(x - x_1)$$

$$y + 3 = -1(x - 2)$$

$$y + 3 = -x + 2$$

$$y = -x - 1$$

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



85. $P_1(3, -4), P_2(11, -1)$

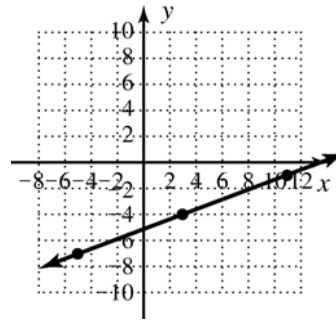
$$m = \frac{-1 - (-4)}{11 - 3} = \frac{3}{8};$$

$$y - y_1 = m(x - x_1)$$

$$y - (-4) = \frac{3}{8}(x - 3)$$

$$y + 4 = \frac{3}{8}x - \frac{9}{8}$$

$$y = \frac{3}{8}x - \frac{41}{8}$$



86. $P_1(-1, 6), P_2(5, 1)$

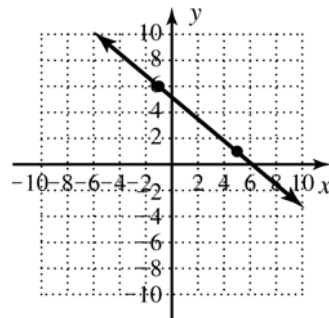
$$m = \frac{1 - 6}{5 - (-1)} = -\frac{5}{6};$$

$$y - y_1 = m(x - x_1)$$

$$y - 1 = -\frac{5}{6}(x - 5)$$

$$y - 1 = -\frac{5}{6}x + \frac{25}{6}$$

$$y = -\frac{5}{6}x + \frac{31}{6}$$



Chapter 2: Relations, Functions and Graphs

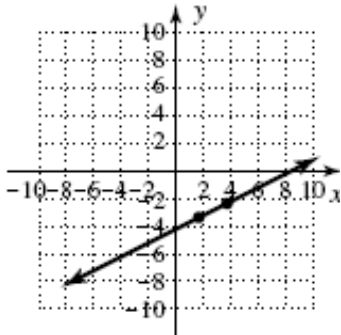
87. $m = 0.5$; $P_1 = (1.8, -3.1)$

$$y - y_1 = m(x - x_1)$$

$$y + 3.1 = 0.5(x - 1.8)$$

$$y + 3.1 = 0.5x - 0.9$$

$$y = 0.5x - 4$$



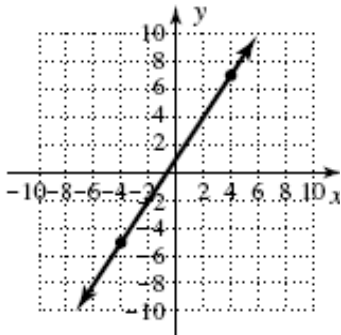
88. $m = 1.5$; $P_1 = (-0.75, -0.125)$

$$y - y_1 = m(x - x_1)$$

$$y + 0.125 = 1.5(x + 0.75)$$

$$y + 0.125 = 1.5x + 1.125$$

$$y = 1.5x + 1$$



89. $m = \frac{6}{5}$; $(4, 2)$

$$y - y_1 = m(x - x_1)$$

$$y - 2 = \frac{6}{5}(x - 4)$$

For each 5000 additional sales, income rises \$6000.

90. $m = -\frac{3}{2}$; $(3, 9)$

$$y - y_1 = m(x - x_1)$$

$$y - 9 = -\frac{3}{2}(x - 3)$$

Every two years, 30,000 typewriters are no longer in service.

91. $m = -20$; $(0.5, 100)$

$$y - y_1 = m(x - x_1)$$

$$y - 100 = -20(x - 0.5)$$

For every hour of television, a student's final grade falls 20%.

92. $m = \frac{3}{7}$; $(2, 3)$

$$y - y_1 = m(x - x_1)$$

$$y - 3 = \frac{3}{7}(x - 2)$$

Every 7000 investors increases the number of online brokerage houses by 3.

93. $m = \frac{35}{2}$; $(0.5, 10)$

$$y - y_1 = m(x - x_1)$$

$$y - 10 = \frac{35}{2}(x - 0.5)$$

Every 2 inches of rainfall increases the number of cattle raised per acre by 35.

94. $m = \frac{2}{5}$; $(60, 2)$

$$y - y_1 = m(x - x_1)$$

$$y - 2 = \frac{2}{5}(x - 60)$$

For every 5° rise in temperature, there are 2 additional eggs per hen per week.

95. C

96. H

97. A

98. F

99. B

100. G

101. D

102. E

2.3 Exercises

103. $ax + by = c$

$$by = -ax + c$$

$$y = -\frac{a}{b}x + \frac{c}{b};$$

Slope $-\frac{a}{b}$, y -intercept $\left(0, \frac{c}{b}\right)$

a. $3x + 4y = 8$

$$m = -\frac{a}{b} = -\frac{3}{4};$$

$$y\text{-int} = \frac{c}{b} = \frac{8}{4} = 2, (0, 2)$$

b. $2x + 5y = -15$

$$m = -\frac{a}{b} = -\frac{2}{5};$$

$$y\text{-int} = \frac{c}{b} = -\frac{15}{5} = -3, (0, -3)$$

c. $5x - 6y = -12$

$$m = -\frac{5}{-6} = \frac{5}{6};$$

$$y\text{-int} = \frac{c}{b} = \frac{-12}{-6} = 2, (0, 2)$$

d. $3y - 5x = 9$

$$m = -\frac{a}{b} = -\frac{-5}{3} = \frac{5}{3};$$

$$y\text{-int} = \frac{c}{b} = \frac{9}{3} = 3, (0, 3)$$

104.a. $2x + 5y = 10$

$$\frac{2}{10}x + \frac{5}{10}y = \frac{10}{10}$$

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

x -intercept: $(5, 0)$

y -intercept: $(0, 2)$

b. $3x - 4y = -12$

$$\frac{3}{-12}x - \frac{4}{-12}y = \frac{-12}{-12}$$

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

x -intercept: $(-4, 0)$

y -intercept: $(0, 3)$

c. $5x + 4y = 8$

$$\frac{5}{8}x + \frac{4}{8}y = \frac{8}{8}$$

$$\frac{x}{8} + \frac{y}{2} = 1$$

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

y -intercept: $(0, 2)$

Slope m is always equal to $-\frac{k}{h}$.

105.a. As the temperature increases 5°C , the velocity of sound waves increases 3 m/s. At a temperature of 0°C , the velocity is 331 m/s.

b. $V(20) = \frac{3}{5}(20) + 331 = 343 \text{ m/s}$

c. $361 = \frac{3}{5}C + 331$

$$30 = \frac{3}{5}C$$

$$50 = C$$

$$50^\circ\text{C}$$

106.a. Every 5 seconds the velocity is increasing 26 ft/sec. The initial velocity is 60 ft/sec.

b. $V(9.4) = \frac{26}{5}(9.4) + 60 = 108.88 \text{ ft/sec}$

c. $100 = \frac{26}{5}t + 60$

$$40 = \frac{26}{5}t$$

$$7.7 \approx t$$

Approximately 7.7 seconds

Chapter 2: Relations, Functions and Graphs

$$107.a. m = \frac{190-150}{6-0} = \frac{40}{6} = \frac{20}{3}$$

$$V(t) = \frac{20}{3}t + 150$$

- b. Every three years, the coin increased in value by \$20. The initial value was \$150.

$$108.a. m = \frac{11500-18500}{2-0} = \frac{-7000}{2} = -3500$$

$$V(t) = -3500t + 18500$$

- b. Every year the equipment decreases in value by \$3500. Its initial value was \$18500.

$$c. V(4) = -3500(4) + 18500 = \$4500$$

$$d. 6000 = -3500t + 18500$$

$$-12500 = -3500t$$

$$3.6 \approx t$$

About 3.6 yr

$$e. 1000 = -3500t + 18500$$

$$-17000 = -3500t$$

$$5 \approx t$$

About 5 yr

$$109.a. m = \frac{51-9}{2001-1995} = \frac{42}{6} = 7$$

$$N(t) = 7t + 9$$

- b. Every 1 year, the number of homes hooked to the internet increases by 7 million.

$$c. 0 = 7t + 9$$

$$-9 = 7t$$

$$-\frac{9}{7} = t$$

$$-1.29 = t$$

1.29 years prior to 1995 is 1993.

$$110.a. m = \frac{146-72}{2000-1995} = \frac{74}{5} = 14.8$$

$$N(t) = 14.8t + 72$$

- b. Every 1 year, sales increase by \$14.8 billion dollars.

$$c. 250 = 14.8t + 72$$

$$178 = 14.8t$$

$$12.03 = t$$

12.03 years after 1995 is 2007.

$$111. m = \frac{1320000-740000}{2000-1990}$$

$$= \frac{580000}{10} = 58000$$

$$P(t) = 58000t + 740000$$

Grows 58,000 every year.

$$P(17) = 58000(17) + 740000 = 1726000$$

$$112.a. m = \frac{170-143}{2000-1990} = \frac{27}{10} = 2.7$$

$$M(t) = 2.7t + 143$$

- b. Every year, the number of restaurant meals increases by about 3 meals.

$$c. M(16) = 2.7(16) + 143 = 186.2$$

About 186 meals per year.

113. Answers will vary.

114. Graph 1: D

Graph 2: A

Graph 3: C

Graph 4: B

Graph 5: F

Graph 6: H

2.3 Exercises

115.a. $ax + by = c$

Find x -intercept by letting $y = 0$.

$$ax + b(0) = c$$

$$x = \frac{c}{a}$$

$$\left(\frac{c}{a}, 0\right);$$

Find y -intercept by letting $x = 0$.

$$a(0) + by = c$$

$$y = \frac{c}{b}$$

$$\left(0, \frac{c}{b}\right)$$

The intercept method works most efficiently when a and b are factors of c .

b. Solve $ax + by = c$ for y .

$$ax + by = c$$

$$by = -ax + c$$

$$y = -\frac{a}{b}x + \frac{c}{b};$$

$$m = -\frac{a}{b}; y\text{-intercept} \left(0, \frac{c}{b}\right)$$

The slope-intercept method works most efficiently when b is a factor of c .

116.a. $y = \sqrt{2x-5}$

$$2x - 5 \geq 0$$

$$2x \geq 5$$

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

$$x \in \left[\frac{5}{2}, \infty\right)$$

b. $y = \frac{5}{2x^2 + 3x - 2}$

$$2x^2 + 3x - 2 = 0$$

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

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

$$x \in (-\infty, -2) \cup \left(-2, \frac{1}{2}\right) \cup \left(\frac{1}{2}, \infty\right)$$

117. $3x^2 - 10x = 9$

$$3x^2 - 10x - 9 = 0$$

$$x = \frac{10 \pm \sqrt{(-10)^2 - 4(3)(-9)}}{2(3)}$$

$$x = \frac{10 \pm \sqrt{100 + 108}}{6}$$

$$x = \frac{10 \pm \sqrt{208}}{6}$$

$$x = \frac{10 \pm 4\sqrt{13}}{6}$$

$$x = \frac{5 \pm 2\sqrt{13}}{3}$$

$$x \approx 4.07 \text{ or } x \approx -0.74$$

118. $2(x-5) + 13 - 1 = 9 - 7 + 2x$

$$2x - 10 + 13 - 1 = 2 + 2x$$

$$2x + 2 = 2 + 2x$$

Identity;

$$2(x-4) + 13 - 1 = 9 + 7 - 2x$$

$$2x - 8 + 13 - 1 = 16 - 2x$$

$$2x + 4 = 16 - 2x$$

$$4x = 12$$

$$x = 3$$

Has a solution; $x = 3$;

$$2(x-5) + 13 - 1 = 9 + 7 + 2x$$

$$2x - 10 + 13 - 1 = 16 + 2x$$

$$2x + 2 = 16 + 2x$$

Contradiction

119. $A = \pi r^2$

Larger circle:

$$A = \pi(10)^2$$

$$A = 100\pi$$

$$100\pi - 64\pi = 36\pi \approx 113.10 \text{ yds}^2$$

Smaller Circle

$$A = \pi(8)^2$$

$$A = 64\pi$$

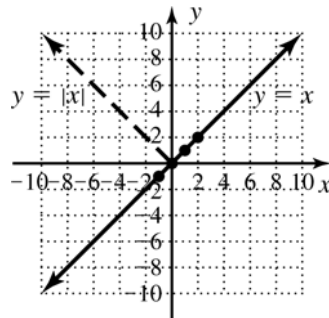
Chapter 2: Relations, Functions and Graphs

2.4 Exercises

1. First
2. Domain; exactly one
3. Range
4. $f(3) = -5$
5. Answers will vary.
6. Answers will vary.
7. Function
8. Function
9. Not a function. The Shaq is paired with two heights.
10. Not a function. Canada is paired with 2 languages and Brazil is paired with 2.
11. Not a function, 4 is paired with 2 and -5 .
12. Not a function, -5 is paired with 3 and 7.
13. Function
14. Function
15. Function
16. Function
17. Not a function, -2 is paired with 3 and -4 .
18. Not a function, 3 is paired with 3 and -2 .
19. Function
20. Function
21. Function
22. Function

23. Not a function, 0 is paired with 4 and -4 .
24. Not a function, 2 is paired with -2 and 2.
25. Function
26. Function
27. Not a function, 5 is paired with -1 and 1.
28. Not a function, 0 is paired with 4 and -4 .
29. Function
30. Function
- 31.

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

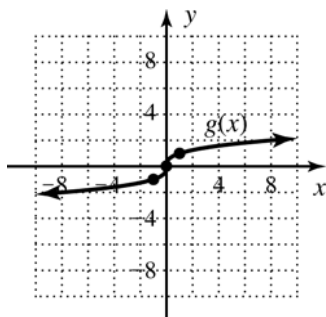


Function

2.4 Exercises

32.

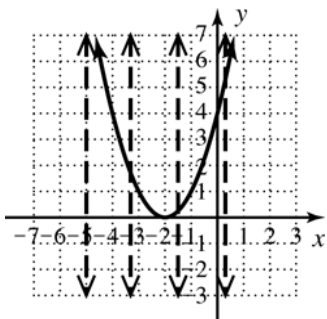
x	$y = \sqrt[3]{x}$
-8	$y = \sqrt[3]{-8} = -2$
-1	$y = \sqrt[3]{-1} = -1$
0	$y = \sqrt[3]{0} = 0$
1	$y = \sqrt[3]{1} = 1$
8	$y = \sqrt[3]{8} = 2$



Function

33.

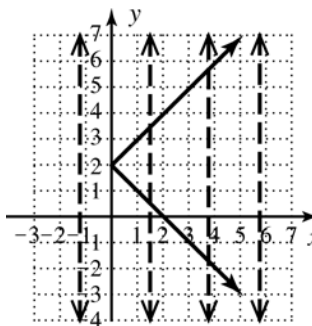
x	$y = (x + 2)^2$
-4	$y = (-4 + 2)^2 = 4$
-3	$y = (-3 + 2)^2 = 1$
-2	$y = (-2 + 2)^2 = 0$
-1	$y = (-1 + 2)^2 = 1$
0	$y = (0 + 2)^2 = 4$
1	$y = (1 + 2)^2 = 9$



Function

34.

x	$x = y - 2 $
2	$2 = y - 2 $ $y - 2 = 2$ or $y - 2 = -2$ $y = 4$ or $y = 0$
1	$1 = y - 2 $ $y - 2 = 1$ or $y - 2 = -1$ $y = 3$ or $y = 1$
0	$0 = y - 2 $ $y - 2 = 0$ $y = 2$



Not a Function

35. Function; $x \in [-4, -5]$ $y \in [-2, 3]$

36. Function; $x \in [-4, \infty)$ $y \in (-\infty, 5]$

37. Function; $x \in [-4, \infty)$ $y \in [-4, \infty)$

38. Not a Function; $x \in [0, 3]$ $y \in [-4, 4]$

39. Function; $x \in [-4, 4]$ $y \in [-5, -1]$

40. Function; $x \in (-\infty, \infty)$ $y \in (-\infty, \infty)$

41. Function; $x \in (-\infty, \infty)$ $y \in (-\infty, \infty)$

42. Not a function; $x \in [-3, 4]$ $y \in [-3, 4]$

43. Not a function; $x \in [-3, 5]$ $y \in [-3, 3]$

Chapter 2: Relations, Functions and Graphs

44. Function; $x \in (-\infty, \infty)$ $y \in [-3, \infty)$

45. Not a function; $x \in (-\infty, 3]$ $y \in (-\infty, \infty)$

46. Function; $x \in [-4, \infty)$ $y \in [0, \infty)$

47. $f(x) = \frac{3}{x-5}$
 $x-5=0$
 $x=5$
 $x \in (-\infty, 5) \cup (5, \infty)$

48. $g(x) = \frac{-2}{3+x}$
 $3+x=0$
 $x=-3$
 $x \in (-\infty, -3) \cup (-3, \infty)$

49. $h(a) = \sqrt{3a+5}$
 $3a+5 \geq 0$
 $3a \geq -5$
 $a \geq -\frac{5}{3}$
 $a \in \left[-\frac{5}{3}, \infty\right)$

50. $p(a) = \sqrt{5a-2}$
 $5a-2 \geq 0$
 $5a \geq 2$
 $a \geq \frac{2}{5}$
 $a \in \left[\frac{2}{5}, \infty\right)$

51. $v(x) = \frac{x+2}{x^2-25}$
 $x^2-25=0$
 $x^2=25$
 $x=\pm 5$
 $x \in (-\infty, -5) \cup (-5, 5) \cup (5, \infty)$

52. $w(x) = \frac{x-4}{x^2-49}$

$$x^2 - 49 = 0$$

$$x^2 = 49$$

$$x = \pm 7$$

$$x \in (-\infty, -7) \cup (-7, 7) \cup (7, \infty)$$

53. $u = \frac{v-5}{v^2-18}$

$$v^2 - 18 = 0$$

$$v^2 = 18$$

$$v = \pm 3\sqrt{2}$$

$$v \in (-\infty, -3\sqrt{2}) \cup (-3\sqrt{2}, 3\sqrt{2}) \cup (3\sqrt{2}, \infty)$$

54. $p = \frac{q+7}{q^2-12}$

$$q^2 - 12 = 0$$

$$q^2 = 12$$

$$q = \pm 2\sqrt{3}$$

$$q \in (-\infty, -2\sqrt{3}) \cup (-2\sqrt{3}, 2\sqrt{3}) \cup (2\sqrt{3}, \infty)$$

55. $y = \frac{17}{25}x + 123$
 $x \in (-\infty, \infty)$

56. $y = \frac{11}{19}x - 89$
 $x \in (-\infty, \infty)$

57. $m = n^2 - 3n - 10$
 $n \in (-\infty, \infty)$

58. $s = t^2 - 3t - 10$
 $t \in (-\infty, \infty)$

59. $y = 2|x| + 1$
 $x \in (-\infty, \infty)$

60. $y = |x-2| + 3$
 $x \in (-\infty, \infty)$

2.4 Exercises

$$61. \ y_1 = \frac{x}{x^2 - 3x - 10}$$

$$x^2 - 3x - 10 = 0$$

$$(x-5)(x+2) = 0$$

$$x = 5 \text{ or } x = -2$$

$$x \in (-\infty, -2) \cup (-2, 5) \cup (5, \infty)$$

$$62. \ y_2 = \frac{x-4}{x^2 + 2x - 15}$$

$$x^2 + 2x - 15 = 0$$

$$(x+5)(x-3) = 0$$

$$x = -5 \text{ or } x = 3$$

$$x \in (-\infty, -5) \cup (-5, 3) \cup (3, \infty)$$

$$63. \ y = \frac{\sqrt{x-2}}{2x-5}, \ x \geq 2$$

$$2x-5 = 0$$

$$2x = 5$$

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

$$x \in \left[2, \frac{5}{2}\right) \cup \left(\frac{5}{2}, \infty\right)$$

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

$$3x+2 = 0$$

$$3x = -2$$

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

$$x \in \left[-1, -\frac{2}{3}\right) \cup \left(-\frac{2}{3}, \infty\right)$$

$$65. \ f(x) = \sqrt{\frac{5}{x-2}}$$

Since the radicand must be non-negative,

solve the inequality: $\frac{5}{x-2} \geq 0, x \neq 2$

Use test points to each side of 2.

If $x = 0, \frac{5}{0-2} \geq 0$ false

If $x = 3, \frac{5}{3-2} \geq 0$ true

Domain: $x \in (2, \infty)$

$$66. \ g(x) = \sqrt{\frac{-4}{3-x}}$$

Since the radicand must be non-negative,

solve the inequality: $\frac{-4}{3-x} \geq 0, x \neq 3$

Use test points to each side of 3.

If $x = 0, \frac{-4}{3-0} \geq 0$ false

If $x = 4, \frac{-4}{3-4} \geq 0$ true

Domain: $x \in (3, \infty)$

$$67. \ h(x) = \frac{-2}{\sqrt{4+x}}$$

Since the radicand must be non-negative and the denominator cannot equal zero, solve the inequality: $4+x > 0, x > -4$.

Domain: $x \in (-4, \infty)$

$$68. \ p(x) = \frac{-7}{\sqrt{5-x}}$$

Since the radicand must be non-negative and the denominator cannot equal zero, solve the inequality: $5-x > 0$

inequality: $-x > -5$

$x < 5$

Domain: $x \in (-\infty, 5)$

$$69. \ f(x) = \frac{1}{2}x + 3$$

$$f(-6) = \frac{1}{2}(-6) + 3 = -3 + 3 = 0;$$

$$f\left(\frac{3}{2}\right) = \frac{1}{2}\left(\frac{3}{2}\right) + 3 = \frac{3}{4} + 3 = \frac{15}{4};$$

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

$$70. \ f(x) = \frac{2}{3}x - 5$$

$$f(-6) = \frac{2}{3}(-6) - 5 = -4 - 5 = -9;$$

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

$$f(2c) = \frac{2}{3}(2c) - 5 = \frac{4}{3}c - 5$$

Chapter 2: Relations, Functions and Graphs

$$\begin{aligned}
 71. \quad f(x) &= 3x^2 - 4x \\
 f(-6) &= 3(-6)^2 - 4(-6) = 108 + 24 = 132; \\
 f\left(\frac{3}{2}\right) &= 3\left(\frac{3}{2}\right)^2 - 4\left(\frac{3}{2}\right) = 3\left(\frac{9}{4}\right) - 6 \\
 &= \frac{27}{4} - 6 = \frac{3}{4}; \\
 f(2c) &= 3(2c)^2 - 4(2c) = 3(4c^2) - 8c \\
 &= 12c^2 - 8c
 \end{aligned}$$

$$\begin{aligned}
 72. \quad f(x) &= 2x^2 + 3x \\
 f(-6) &= 2(-6)^2 + 3(-6) = 2(36) - 18 \\
 &= 72 - 18 = 54; \\
 f\left(\frac{3}{2}\right) &= 2\left(\frac{3}{2}\right)^2 + 3\left(\frac{3}{2}\right) = 2\left(\frac{9}{4}\right) + \frac{9}{2} \\
 &= \frac{9}{2} + \frac{9}{2} = \frac{18}{2} = 9; \\
 f(2c) &= 2(2c)^2 + 3(2c) = 2(4c^2) + 6c \\
 &= 8c^2 + 6c
 \end{aligned}$$

$$\begin{aligned}
 73. \quad h(x) &= \frac{3}{x} \\
 h(3) &= \frac{3}{(3)} = 1; \\
 h\left(-\frac{2}{3}\right) &= \frac{3}{\left(-\frac{2}{3}\right)} = -\frac{9}{2}; \\
 h(3a) &= \frac{3}{3a} = \frac{1}{a}
 \end{aligned}$$

$$\begin{aligned}
 74. \quad h(x) &= \frac{2}{x^2} \\
 h(3) &= \frac{2}{(3)^2} = \frac{2}{9}; \\
 h\left(-\frac{2}{3}\right) &= \frac{2}{\left(-\frac{2}{3}\right)^2} = \frac{2}{\frac{4}{9}} = \frac{18}{4} = \frac{9}{2}; \\
 h(3a) &= \frac{2}{(3a)^2} = \frac{2}{9a^2}
 \end{aligned}$$

$$\begin{aligned}
 75. \quad h(x) &= \frac{5|x|}{x} \\
 h(3) &= \frac{5|3|}{3} = \frac{5(3)}{3} = 5; \\
 h\left(-\frac{2}{3}\right) &= \frac{5\left|-\frac{2}{3}\right|}{-\frac{2}{3}} = \frac{5\left(\frac{2}{3}\right)}{-\frac{2}{3}} = -5; \\
 h(3a) &= \frac{5|3a|}{3a} = \frac{15|a|}{3a} = \frac{5|a|}{a}; \\
 &= -5 \text{ if } a < 0; 5 \text{ if } a > 0
 \end{aligned}$$

$$\begin{aligned}
 76. \quad h(x) &= \frac{4|x|}{x} \\
 h(3) &= \frac{4|3|}{3} = \frac{4(3)}{3} = 4; \\
 h\left(-\frac{2}{3}\right) &= \frac{4\left|-\frac{2}{3}\right|}{-\frac{2}{3}} = \frac{4\left(\frac{2}{3}\right)}{-\frac{2}{3}} = -4; \\
 h(3a) &= \frac{4|3a|}{3a} = \frac{4(3)|a|}{3a} = \frac{4|a|}{a}; \\
 &= -4 \text{ if } a < 0; 4 \text{ if } a > 0
 \end{aligned}$$

$$\begin{aligned}
 77. \quad g(r) &= 2\pi r \\
 g(0.4) &= 2\pi(0.4) = 0.8\pi; \\
 g\left(\frac{9}{4}\right) &= 2\pi\left(\frac{9}{4}\right) = \frac{9}{2}\pi; \\
 g(h) &= 2\pi(h) = 2\pi h;
 \end{aligned}$$

$$\begin{aligned}
 78. \quad g(r) &= 2\pi rh \\
 g(0.4) &= 2\pi(0.4)h = 0.8\pi h; \\
 g\left(\frac{9}{4}\right) &= 2\pi\left(\frac{9}{4}\right)h = \frac{9}{2}\pi h; \\
 g(h) &= 2\pi(h)h = 2\pi h^2
 \end{aligned}$$

$$\begin{aligned}
 79. \quad g(r) &= \pi r^2 \\
 g(0.4) &= \pi(0.4)^2 = 0.16\pi; \\
 g\left(\frac{9}{4}\right) &= \pi\left(\frac{9}{4}\right)^2 = \frac{81}{16}\pi; \\
 g(h) &= \pi(h)^2 = \pi h^2
 \end{aligned}$$

2.4 Exercises

80. $g(r) = \pi^2 h$
 $g(0.4) = \pi(0.4)^2 h = 0.16\pi h$;
 $g\left(\frac{9}{4}\right) = \pi\left(\frac{9}{4}\right)^2 h = \frac{81}{16}\pi h$;
 $g(h) = \pi(h)^2 h = \pi h^3$
81. $p(x) = \sqrt{2x+3}$
 $p(0.5) = \sqrt{2(0.5)+3} = \sqrt{1+3} = \sqrt{4} = 2$;
 $p\left(\frac{9}{4}\right) = \sqrt{2\left(\frac{9}{4}\right)+3} = \sqrt{\frac{9}{2}+3} = \sqrt{\frac{15}{2}} = \frac{\sqrt{30}}{2}$;
 $p(a) = \sqrt{2(a)+3} = \sqrt{2a+3}$
82. $p(x) = \sqrt{4x-1}$
 $p(0.5) = \sqrt{4(0.5)-1} = \sqrt{2-1} = \sqrt{1} = 1$;
 $p\left(\frac{9}{4}\right) = \sqrt{4\left(\frac{9}{4}\right)-1} = \sqrt{9-1} = \sqrt{8} = 2\sqrt{2}$;
 $p(a) = \sqrt{4(a)-1} = \sqrt{4a-1}$
83. $p(x) = \frac{3x^2-5}{x^2}$
 $p(0.5) = \frac{3(0.5)^2-5}{(0.5)^2} = \frac{3(0.25)-5}{0.25}$
 $= \frac{0.75-5}{0.25} = \frac{-4.25}{0.25} = -17$
 $p\left(\frac{9}{4}\right) = \frac{3\left(\frac{9}{4}\right)^2-5}{\left(\frac{9}{4}\right)^2} = \frac{3\left(\frac{81}{16}\right)-5}{\frac{81}{16}}$
 $= \frac{\frac{243}{16}-5}{\frac{81}{16}} = \frac{\frac{163}{16}}{\frac{81}{16}} = \frac{163}{81}$;
 $p(a) = \frac{3(a)^2-5}{(a)^2} = \frac{3a^2-5}{a^2}$
84. $p(x) = \frac{2x^2+3}{x^2}$
 $p(0.5) = \frac{2(0.5)^2+3}{(0.5)^2} = \frac{2(0.25)+3}{0.25}$
 $= \frac{0.5+3}{0.25} = \frac{3.5}{0.25} = 14$;
 $p\left(\frac{9}{4}\right) = \frac{2\left(\frac{9}{4}\right)^2+3}{\left(\frac{9}{4}\right)^2} = \frac{2\left(\frac{81}{16}\right)+3}{\frac{81}{16}}$
 $= \frac{\frac{81}{8}+3}{\frac{81}{16}} = \frac{\frac{105}{8}}{\frac{81}{16}} = \frac{210}{81} = \frac{70}{27}$
 $p(a) = \frac{2(a)^2+3}{(a)^2} = \frac{2a^2+3}{a^2}$
85. a. $D: \{-1, 0, 1, 2, 3, 4, 5\}$
b. $R: \{-2, -1, 0, 1, 2, 3, 4\}$
c. $f(2) = 1$
d. $f(-1) = 4$
86. a. $D: \{-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5\}$
b. $R: \{-1, 0, 1, 2, 3, 4, 5\}$
c. $f(2) = 0$
d. $f(-3) = 3, f(5) = 3$
87. a. $x \in [-5, 5]$
b. $y \in [-3, 4]$
c. $f(2) = -2$
d. when $y = 1, x = 0$ and $x = -4$.
88. a. $x \in [-3, 5]$
b. $y \in [-4, 5]$
c. $f(2) = -4$
d. when $y = -3, x = 1$ and $x = 3$.
89. a. $x \in [-3, \infty)$
b. $y \in (-\infty, 4]$
c. $f(2) = 2$
d. when $y = 2, x = 2$ and $x = -2$
90. a. $x \in [-5, \infty)$
b. $y \in [-2, \infty)$
c. $f(2) = -2$
d. when $y = -1, x = 1$ and $x = 3$

Chapter 2: Relations, Functions and Graphs

91. $W(H) = \frac{9}{2}H - 151$

a. $W(75) = \frac{9}{2}(75) - 151 = 186.5 \text{ lb}$

b. $W(72) = \frac{9}{2}(72) - 151 = 173 \text{ lb}$
 $210 - 173 = 37 \text{ lb}$

92. $C = \frac{5}{9}(F - 32)$

a. $C = \frac{5}{9}(41 - 32) = \frac{5}{9}(9) = 5^\circ\text{C}$

b. $C = \frac{5}{9}(F - 32)$
 $\frac{9}{5}C = F - 32$

$\frac{9}{5}C + 32 = F$

$\frac{9}{5}(5) + 32 = F$

$9 + 32 = F$

$41 = F$

They are the same result.

93. $A = \frac{1}{2}B + I - 1$

$\square PQR$

$P(-3, 1), Q(3, 9), R(7, 6)$

$m = \frac{9 - 1}{3 - (-3)} = \frac{4}{3}$

$y - 1 = \frac{4}{3}(x + 3)$

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

$y = \frac{4}{3}x + 5$

$(0, 5)$ lies on PQ;

Lattice points are points that join vertical and horizontal grids in a Cartesian coordinate system.

There are four lattice points on the boundary; three vertices and point $(0, 5)$, thus $B = 8$. There are 24 lattice points in the interior of the triangle, thus $I = 24$.

$A = \frac{1}{2}(8) + 24 - 1 = 25 \text{ units}^2$

94. a. $N(g) = 23g$

b. $g \in [0, 15]; N \in [0, 345]$

95. a. $N(g) = 2.5g$

b. $g \in [0, 5]; N \in [0, 12.5]$

96. a. $D \in [0, \infty)$

b. $V(6.25) = (6.25)^3 \approx 244 \text{ units}^3$

c. $V(2x^2) = (2x^2)^3 = 8x^6$

97. a. $D \in [0, \infty)$

b. $V(7.5) = 100\pi(7.5) = 750\pi$

c. $V\left(\frac{8}{\pi}\right) = 100\pi\left(\frac{8}{\pi}\right) = 800 \text{ cm}^3$

98. a. $c(t) = 12.50t + 19.50$

b. $c(3.5) = 12.50(3.5) + 19.50 = \63.25

c. $119.75 = 12.50t + 19.50$

$100.25 = 12.50t$

$8 \text{ hr} \approx t$

d. $150 = 12.50t + 19.50$

$130.5 = 12.50t$

$10.44 \text{ hr} = t$

$t \in [0, 10.44]; c \in [0, 150]$

99. a. $c(t) = 42.50t + 50$

b. $c(2.5) = 42.50(2.5) + 50 = \156.25

c. $262.50 = 42.50t + 50$

$212.50 = 42.50t$

$5 \text{ hr} = t$

d. $500 = 42.50t + 50$

$450 = 42.50t$

$10.6 \text{ hr} \approx t$

$t \in [0, 10.6]; c \in [0, 500]$

2.4 Exercises

100.a. Yes.

Each “x” is paired with exactly one “y”.

b. 9 P.M.

c. $3\frac{1}{2}$ m

d. 5 P.M. and 1 A.M.

101.a. Yes.

Each “x” is paired with exactly one “y”.

b. 10 P.M.

c. 0.9 m

d. 7 P.M. and 1 A.M.

102.a. Use (25,900) and (29,1100) for the 25th to 29th.

The average weight of change:

$$\frac{\square \text{weight}}{\square \text{time}} = \frac{1100 - 900}{29 - 25} = \frac{50}{1}; \text{ Positive;}$$

50 grams are gained each week.

b. Use (32,1600) and (36,2600) for the 32nd to 36th.

The average weight of change:

$$\frac{\square \text{weight}}{\square \text{time}} = \frac{2600 - 1600}{36 - 32} = \frac{250}{1};$$

The weight gain is five times greater in the later weeks.

103.a. Average rate of change from 1920 to 1940, use (20,3.2) and (40,2.2).

$$\frac{\square \text{fertility}}{\square \text{time}} = \frac{2.2 - 3.2}{40 - 20} = -\frac{1}{20}; \text{ Negative;}$$

Fertility is decreasing by one child every 20 years.

b. Average rate of change from 1940 to 1950, use (40,2.2).and (50,3.0).

$$\frac{\square \text{fertility}}{\square \text{time}} = \frac{3.0 - 2.2}{50 - 40} = \frac{0.8}{10}; \text{ Positive;}$$

Fertility is increasing by less than one child every 10 years.

c. from 1980 to 1990, use (80,1.8).and (90,2.0).

$$\frac{\square \text{fertility}}{\square \text{time}} = \frac{2.0 - 1.8}{90 - 80} = \frac{0.2}{10}; \text{ The}$$

fertility rate was increasing four times as fast from 1940 to 1950.

104.a. Father, 70 seconds

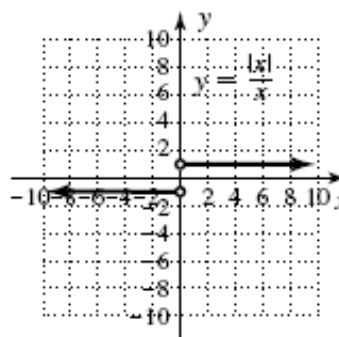
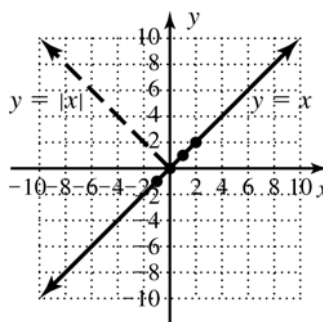
b. 50 meters

c. ≈ 40 seconds

d. 3 times since the graphs intersect three times.

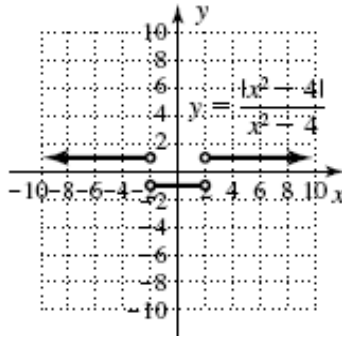
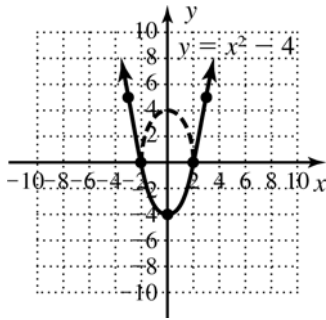
105.The y-values of the negative x integers would become positive.

All points would be in Quadrants I and III.



Chapter 2: Relations, Functions and Graphs

106. Negative outputs become positive.



107.a. $y = \frac{x-3}{x+2}, x \neq -2$

Domain: $x \in (-\infty, -2) \cup (-2, \infty)$;

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

$$xy + 2y = x - 3$$

$$xy - x = -2y - 3$$

$$x(y-1) = -2y-3$$

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

Range: $y \in (-\infty, 1) \cup (1, \infty)$

b. $y = x^2 - 3$

Domain: $x \in \mathbb{R}$;

$$y = x^2 - 3$$

$$y + 3 = x^2$$

$$\pm\sqrt{y+3} = x;$$

$$y + 3 \geq 0$$

$$y \geq -3$$

Range: $y \in [-3, \infty)$

$$108. m = \frac{3-6}{-5-2} = \frac{-3}{-7} = \frac{3}{7}$$

$$m = \frac{-4-4}{0-9} = \frac{-8}{-9} = \frac{8}{9}$$

The line through $(0, -4)$ and $(9, 4)$ has a steeper slope.

$$\begin{aligned} 109.a. \quad & \sqrt{24} + 6\sqrt{54} - \sqrt{6} \\ &= 2\sqrt{6} + 6 \cdot 3\sqrt{6} - \sqrt{6} \\ &= 2\sqrt{6} + 18\sqrt{6} - \sqrt{6} \\ &= 19\sqrt{6} \end{aligned}$$

$$\begin{aligned} b. \quad & (2 + \sqrt{3})(2 - \sqrt{3}) \\ &= 4 - 2\sqrt{3} + 2\sqrt{3} - 3 \\ &= 1 \end{aligned}$$

$$110. x^2 - 4x + 1 = 0$$

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

$$x = \frac{4 \pm \sqrt{16-4}}{2}$$

$$x = \frac{4 \pm \sqrt{12}}{2}$$

$$x = \frac{4 \pm 2\sqrt{3}}{2}$$

$$x = 2 \pm \sqrt{3}$$

$$111.a. x^3 - 3x^2 - 25x + 75$$

$$= (x^3 - 3x^2) - (25x - 75)$$

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

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

$$= (x-3)(x-5)(x+5)$$

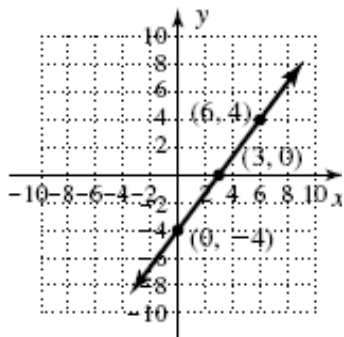
$$b. 2x^2 - 13x - 24 = (2x+3)(x-8)$$

$$c. 8x^3 - 125 = (2x-5)(4x^2 + 10x + 25)$$

Mid-Chapter Check

Chapter 2 Mid-Chapter Check

$$\begin{aligned} 1. \quad 4x - 3y &= 12 \\ -3y &= -4x + 12 \\ y &= \frac{4}{3}x - 4 \end{aligned}$$



$$2. \quad (-3, 8) \text{ and } (4, -10)$$

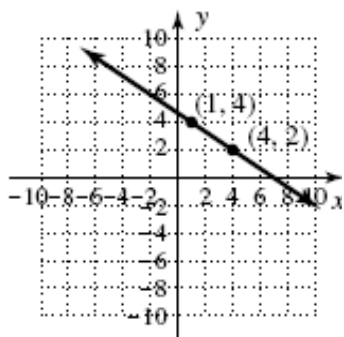
$$m = \frac{-10 - 8}{4 - (-3)} = \frac{-18}{7}$$

$$3. \quad m = \frac{-0.5 - (-2)}{2003 - 2002} = \frac{1.5}{1} = 1.5;$$

Positive, loss is decreasing, profit is increasing.

Data.com's loss decreases by 1.5 million dollars per year.

$$4. \quad (1, 4); m = -\frac{2}{3}$$



$$m = \frac{3}{2}; (1, 4)$$

$$y - y_1 = m(x - x_1)$$

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

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

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

5. $x = -3$; not a function. Input -3 is paired with more than one output.

$$6. \quad m = -\frac{4}{3}; y\text{-intercept } (0, 4)$$

$y = -\frac{4}{3}x + 4$; is a function. Each input is paired with only one output.

$$7. \quad a. h(2) = 0$$

$$b. x \in [-3, 5]$$

$$c. x = -1 \text{ when } h(x) = -3$$

$$d. y \in [-4, 5]$$

8. Rate of change from $x = 1$ to $x = 2$ is larger. It is steeper.

$$9. \quad m = \frac{3}{4}; (1, 2)$$

$$y - y_1 = m(x - x_1)$$

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

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

$$y = \frac{3}{4}x + \frac{5}{4}$$

$$F(p) = \frac{3}{4}p + \frac{5}{4}$$

For every 4000 pheasants, the fox population increases by 300.

$$F(20) = \frac{3}{4}(20) + \frac{5}{4} = 15 + 1.25 = 16.25$$

Fox population is 1625 when the pheasant population is 20,000.

$$10. \quad a. D = \{-3, -2, -1, 0, 1, 2, 3, 4\}$$

$$R = \{-3, -2, -1, 0, 1, 2, 3, 4\}$$

$$b. x \in [-3, 4]$$

$$y \in [-3, 4]$$

$$c. x \in (-\infty, \infty)$$

$$y \in (-\infty, \infty)$$

Chapter 2: Relations, Functions and Graphs

Chapter 2 Reinforcing Basic Concepts

1. $P_1(0,5); P_2(6,7)$

a. $m = \frac{7-5}{6-0} = \frac{2}{6} = \frac{1}{3}$; increasing

b. $y - 5 = \frac{1}{3}(x - 0)$

c. $y = \frac{1}{3}x + 5$

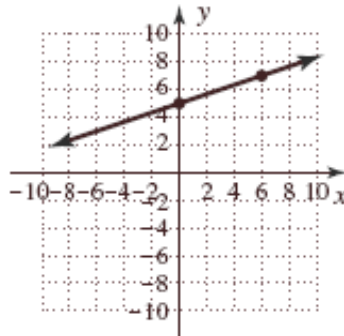
d. $y = \frac{1}{3}x + 5$

$$-\frac{1}{3}x + y = 5$$

$$x - 3y = -15$$

e. x-intercept: $(-15, 0)$ y-intercept: $(0, 5)$

$$\begin{array}{ll} x - 3(0) = -15 & 0 - 3y = -15 \\ x = -15 & -3y = -15 \\ & y = 5 \end{array}$$



2. $P_1(3,2) P_2(0,9)$

a. $m = \frac{9-2}{0-3} = \frac{7}{-3} = -\frac{7}{3}$; decreasing

b. $y - 9 = -\frac{7}{3}(x - 0)$

c. $y = -\frac{7}{3}x + 9$

d. $y = -\frac{7}{3}x + 9$

$$\frac{7}{3}x + y = 9$$

$$7x + 3y = 27$$

e. x-intercept: $\left(\frac{27}{7}, 0\right)$ y-intercept: $(0, 9)$

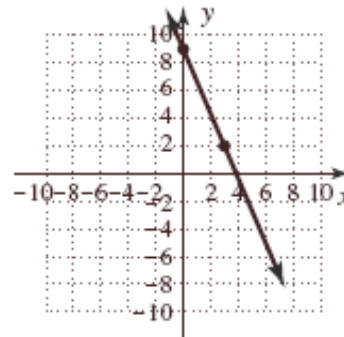
$$7x + 3(0) = 27$$

$$x = \frac{27}{7}$$

$$7(0) + 3y = 27$$

$$3y = 27$$

$$y = 9$$



Reinforcing Basic Concepts

3. $P_1(3,2); P_2(9,5)$

a. $m = \frac{5-2}{9-3} = \frac{3}{6} = \frac{1}{2}$; increasing

b. $y - 2 = \frac{1}{2}(x - 3)$

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

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

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

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

$x - 2y = -1$

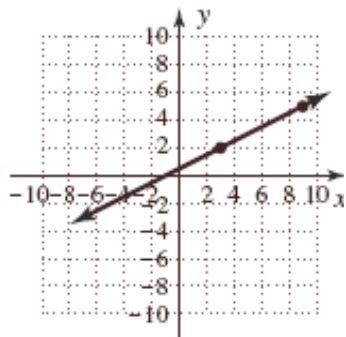
e. x-intercept: $(-1, 0)$ y-intercept: $(0, \frac{1}{2})$

$x - 2(0) = -1$

$x = -1$

$0 - 2y = -1$

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



4. $P_1(-5,-4); P_2(3,2)$

a. $m = \frac{2-(-4)}{3-(-5)} = \frac{6}{8} = \frac{3}{4}$; increasing

b. $y + 4 = \frac{3}{4}(x + 5)$

c. $y + 4 = \frac{3}{4}x + \frac{15}{4}$

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

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

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

$3x - 4y = 1$

e. x-intercept: $(\frac{1}{3}, 0)$

y-intercept: $(0, -\frac{1}{4})$

$3x - 4(0) = 1$

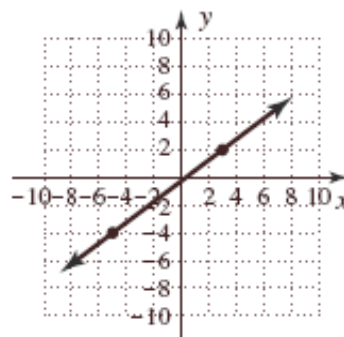
$3x = 1$

$x = \frac{1}{3}$

$3(0) - 4y = 1$

$-4y = 1$

$y = -\frac{1}{4}$



Chapter 2: Relations, Functions and Graphs

5. $P_1(-2,5); P_2(6,-1)$

a. $m = \frac{-1-5}{6-(-2)} = \frac{-6}{8} = -\frac{3}{4}$; decreasing

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

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

$y = -\frac{3}{4}x + \frac{7}{2}$

d. $y = -\frac{3}{4}x + \frac{7}{2}$

$\frac{3}{4}x + y = \frac{7}{2}$

$3x + 4y = 14$

e. x-intercept: $\left(\frac{14}{3}, 0\right)$ y-intercept: $\left(0, \frac{7}{2}\right)$

$3x + 4(0) = 14$

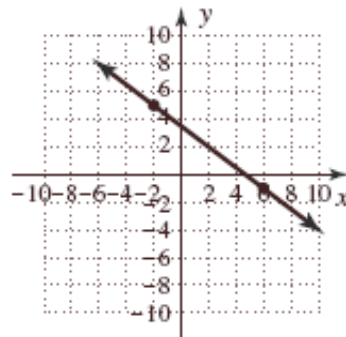
$3x = 14$

$x = \frac{14}{3}$

$3(0) + 4y = 14$

$4y = 14$

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



6. $P_1(2,-7); P_2(-8,-2)$

a. $m = \frac{-2-(-7)}{-8-2} = \frac{5}{-10} = -\frac{1}{2}$; decreasing

b. $y+7 = -\frac{1}{2}(x-2)$

c. $y+7 = -\frac{1}{2}x + 1$

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

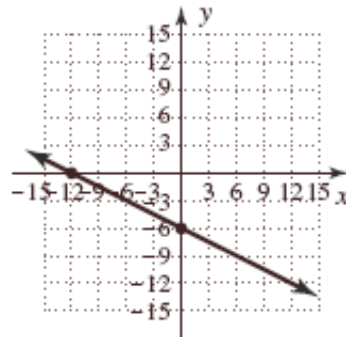
d. $y = -\frac{1}{2}x - 6$

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

$x + 2y = -12$

e. x-intercept: $(-12, 0)$ y-intercept: $(0, -6)$

$x + 2(0) = -12$ $0 + 2y = -12$
 $x = -12$ $y = -6$



2.5 Exercises

2.5 Technology Highlight

Exercise 1: $x \approx -2.87$, $x \approx 0.87$,

min : $y = -7$ at $(-1, -7)$, no max

Exercise 2: $x \approx -1.88$, $x \approx 0.35$, $x \approx 1.53$,

max : $y = 3$ at $(-1, 3)$, min : $y = -1$ at $(1, -1)$

Exercise 3: $x \approx 1.35$, $x \approx 6.65$,

min : $y = -7$ at $(4, -7)$, no max

Exercise 4: $x = -2$, $x = 2$,

min : $y = 0$ at $(2, 0)$,

max : $y \approx 9.48$ at $(-0.67, 9.48)$

Exercise 5: $x = -2$, $x = 0$, $x \approx 2.41$,

min : $y = -3.20$ at $(-1.47, -3.20)$,

min : $y \approx -9.51$ at $(1.67, -9.51)$,

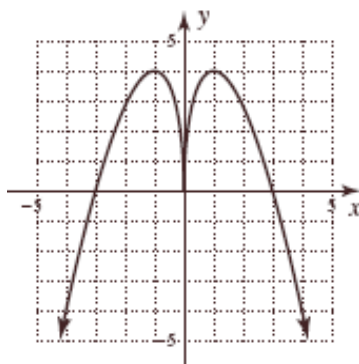
max : $y = 0$ at $(0, 0)$

Exercise 6: $x = -4$, $x = 0$,

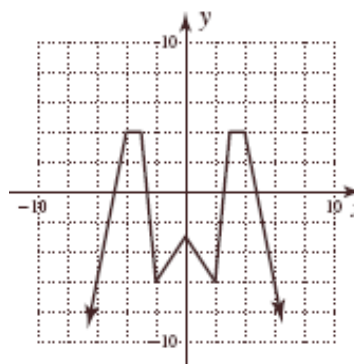
min : $y = -3.08$ at $(-2.67, -3.08)$

2.5 Exercises

1. Linear; bounce
2. Even; y; odd; origin
3. Increasing
4. Maximum
5. Answers will vary.
6. Answers will vary.
- 7.



8.



$$\begin{aligned}
 9. \quad f(x) &= -7|x| + 3x^2 + 5 \\
 f(k) &= -7|k| + 3(k)^2 + 5; \\
 f(-k) &= -7|-k| + 3(-k)^2 + 5 \\
 &= -7|k| + 3(k)^2 + 5 = f(k);
 \end{aligned}$$

Even

$$\begin{aligned}
 10. \quad p(x) &= 2x^4 - 6x + 1 \\
 p(k) &= 2(k)^4 - 6(k) + 1 \\
 &= 2k^4 - 6k + 1; \\
 p(-k) &= 2(-k)^4 - 6(-k) + 1 \\
 &= 2k^4 + 6k + 1 \\
 p(k) &\neq p(-k); \text{ Not even}
 \end{aligned}$$

$$\begin{aligned}
 11. \quad g(x) &= \frac{1}{3}x^4 - 5x^2 + 1 \\
 g(k) &= \frac{1}{3}(k)^4 - 5(k)^2 + 1 \\
 &= \frac{1}{3}k^4 - 5k^2 + 1; \\
 g(-k) &= \frac{1}{3}(-k)^4 - 5(-k)^2 + 1 \\
 &= \frac{1}{3}k^4 - 5k^2 + 1; \\
 g(k) &= g(-k) \\
 \text{Even}
 \end{aligned}$$

Chapter 2: Relations, Functions and Graphs

12. $q(x) = \frac{1}{x^2} - |x|$

$$q(k) = \frac{1}{(k)^2} - |k|$$

$$= \frac{1}{k^2} - |k|;$$

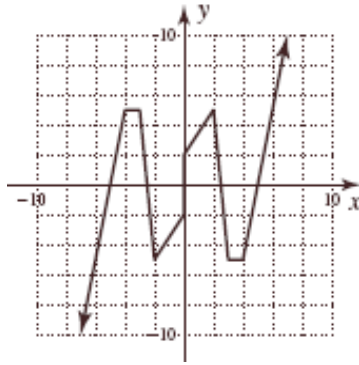
$$q(-k) = \frac{1}{(-k)^2} - |-k|$$

$$= \frac{1}{k^2} - |k|$$

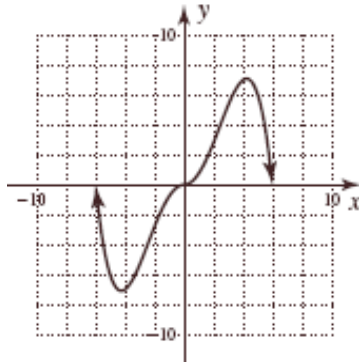
$$q(k) = q(-k)$$

Even

13.



14.



15. $f(x) = 4\sqrt[3]{x} - x$

$$f(k) = 4\sqrt[3]{k} - k$$

$$f(-k) = 4\sqrt[3]{-k} - (-k)$$

$$= -4\sqrt[3]{k} + k = -(4\sqrt[3]{k} - k);$$

$$f(k) = -f(-k)$$

Odd

16. $g(x) = \frac{1}{2}x^3 - 6x$

$$g(k) = \frac{1}{2}(k)^3 - 6(k)$$

$$= \frac{k^3}{2} - 6k;$$

$$g(-k) = \frac{1}{2}(-k)^3 - 6(-k)$$

$$= -\frac{k^3}{2} + 6k = -\left(\frac{k^3}{2} - 6k\right);$$

$$g(k) = -g(-k)$$

Odd

17. $p(x) = 3x^3 - 5x^2 + 1$

$$p(k) = 3(k)^3 - 5(k)^2 + 1$$

$$= 3k^3 - 5k^2 + 1$$

$$p(-k) = 3(-k)^3 - 5(-k)^2 + 1$$

$$= -3k^3 - 5k^2 + 1$$

$$p(k) \neq -p(-k); \text{ Not Odd}$$

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

$$q(k) = \frac{1}{k} - (k)$$

$$= \frac{1}{k} - k;$$

$$q(-k) = \frac{1}{-k} - (-k)$$

$$= -\frac{1}{k} + k = -\left(\frac{1}{k} - k\right);$$

$$q(k) = -q(-k); \text{ odd}$$

19. $w(x) = x^3 - x^2$

$$w(-x) = (-x)^3 - (-x)^2$$

$$= -x^3 - x^2; \text{ neither}$$

20. $q(x) = \frac{3}{4}x^2 + 3|x|$

$$q(-x) = \frac{3}{4}(-x)^2 + 3|-x|$$

$$= \frac{3}{4}x^2 + 3|x|; \text{ even}$$

2.5 Exercises

$$21. \quad 20. \quad p(x) = 2\sqrt[3]{x} - \frac{1}{4}x^3$$

$$p(-x) = 2\sqrt[3]{(-x)} - \frac{1}{4}(-x)^3$$

$$= -2\sqrt[3]{x} + \frac{1}{4}x^3 = -\left(2\sqrt[3]{x} - \frac{1}{4}x^3\right); \text{ odd}$$

$$22. \quad g(x) = x^3 + 7x$$

$$g(-x) = (-x)^3 + 7(-x)$$

$$= -x^3 - 7x = -(x^3 + 7x); \text{ odd}$$

$$23. \quad v(x) = x^3 + 3|x|$$

$$v(-x) = (-x)^3 + 3|-x|$$

$$= -x^3 + 3|x|; \text{ neither}$$

$$24. \quad f(x) = x^4 + 7x^2 - 30$$

$$f(-x) = (-x)^4 + 7(-x)^2 - 30$$

$$= x^4 + 7x^2 - 30; \text{ even}$$

$$25. \quad f(x) = x^3 - 3x^2 - x + 3$$

Verify Zeros: Let $f(x) = 0$

$$0 = x^2(x-3) - (x-3)$$

$$0 = (x-3)(x^2-1)$$

$$0 = (x-3)(x+1)(x-1)$$

Zeros: $(-1, 0), (1, 0), (3, 0)$

For $f(x) \geq 0$, $x \in [-1, 1] \cup [3, \infty)$

$$26. \quad f(x) = x^3 - 2x^2 - 4x + 8$$

Verify Zeros: Let $f(x) = 0$

$$0 = x^3 - 2x^2 - 4x + 8$$

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

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

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

Zeros: $(-2, 0), (2, 0)$

For $f(x) > 0$, $x \in (-2, 2) \cup (2, \infty)$

$$27. \quad f(x) = x^4 - 2x^2 + 1$$

Verify Zeros: Let $f(x) = 0$

$$0 = x^4 - 2x^2 + 1$$

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

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

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

For $f(x) > 0$, $x \in (-\infty, -1) \cup (-1, 1) \cup (1, \infty)$

$$28. \quad f(x) = x^3 + 2x^2 - 4x - 8$$

Verify Zeros: Let $f(x) = 0$

$$0 = x^3 + 2x^2 - 4x - 8$$

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

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

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

Zeros: $(-2, 0), (2, 0)$

For $f(x) \geq 0$, $x \in \{-2\} \cup [2, \infty)$

$$29. \quad p(x) = \sqrt[3]{x-1} - 1$$

$$p(x) \geq 0 \text{ for } x \in [2, \infty)$$

$$30. \quad q(x) = \sqrt{x+1} - 2$$

$$q(x) > 0 \text{ for } x \in (3, \infty)$$

$$31. \quad f(x) = (x-1)^3 - 1$$

$$f(x) \leq 0 \text{ for } x \in (-\infty, 2]$$

$$32. \quad g(x) = -(x+1)^3 - 1$$

$$g(x) < 0 \text{ for } x \in (-2, \infty)$$

$$33. \quad f(x) \uparrow: (-3, 1) \cup (4, 6)$$

$$f(x) \downarrow: (-\infty, -3), (1, 4)$$

Constant : None

$$34. \quad H(x) \uparrow: x \in (-2, 0) \cup (4, 5)$$

$$H(x) \downarrow: x \in (-\infty, -2)$$

Constant: $H(x) = -1: x \in (0, 4)$

$$35. \quad f(x) \uparrow: (1, 4)$$

$$f(x) \downarrow: (-2, 1) \cup (4, \infty)$$

Constant: $(-\infty, -2)$

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36. $g(x) \uparrow: (0,3) \cup (5,9)$
 $g(x) \downarrow: (3,5) \cup (9,\infty)$
 Constant: None
37. $p(x) = 0.5(x+2)^3$
 a. $p(x) \uparrow: x \in (-\infty, \infty)$
 $p(x) \downarrow$: None
 b. down, up
38. $q(x) = -\sqrt[3]{x+1}$
 a. $q(x) \uparrow$: None
 $q(x) \downarrow: x \in (-\infty, \infty)$
 b. up, down
39. $y = p(x)$
 a. $p(x) \uparrow: x \in (-3,0) \cup (3,\infty)$
 $p(x) \downarrow: x \in (-\infty,-3) \cup (0,3)$
 b. up, up
40. $y = q(x)$
 a. $q(x) \uparrow: x \in (-\infty,-2) \cup (1,6) \cup (8,\infty)$
 $q(x) \downarrow: x \in (-2,1) \cup (6,8)$
 b. down, up
41. $H(x) = -5|x-2| + 5$
 a. $x \in (-\infty, \infty)$
 $y \in (-\infty, 5]$
 b. (1, 0), (3, 0)
 c. $H(x) \geq 0: x \in [1,3]$
 $H(x) \leq 0: x \in (-\infty,1] \cup [3,\infty)$
 d. $H(x) \uparrow: x \in (-\infty,2)$
 $H(x) \downarrow: x \in (2,\infty)$
 e. local maximum: $y = 2$ at (2, 5)
42. $y = f(x)$
 a. $x \in (-\infty, \infty)$
 $y \in (-\infty, \infty)$
 b. (-3.5, 0), (3.5, 0), (0,0)
 c. $f(x) \geq 0: x \in [-3.5,0] \cup [3.5,\infty)$
 $f(x) \leq 0: x \in (-\infty,-3.5] \cup [0,3.5]$
 d. $f(x) \uparrow: x \in (-\infty,-2) \cup (2,\infty)$
 $f(x) \downarrow: x \in (-2,2)$
 e. local maximum: $y = 3$ at (-2, 3)
 local minimum: $y = -3$ at (2, -3)
43. $y = g(x)$
 a. $x \in (-\infty, \infty)$
 $y \in (-\infty, \infty)$
 b. (-1,0), (5, 0)
 c. $g(x) \geq 0: x \in [-1,\infty)$
 $g(x) \leq 0: x \in (-\infty,-1] \cup \{5\}$
 d. $g(x) \uparrow: x \in (-\infty,1) \cup (5,\infty)$
 $g(x) \downarrow: x \in (1,5)$
 e. local maximum: $y = 6$ at (1,6)
 local minimum: $y = 0$ at (5, 0)
44. $y = Y_1$
 a. $x \in [-4,\infty)$
 $y \in (-\infty, 3]$
 b. (-4, 0), (2, 0)
 c. $Y_1 \geq 0: x \in [-4,2]$
 $Y_1 \leq 0: x \in [2,\infty)$
 d. $Y_1 \uparrow: x \in (-4,-2)$
 $Y_1 \downarrow: x \in (-2,\infty)$
 e. local maximum: $y = 3$ at (-2, 3);
45. $y = Y_2$
 a. $x \in (-\infty, \infty)$
 $y \in (-\infty, 3]$
 b. (0, 0), (2, 0)
 c. $Y_2 \geq 0: x \in [0,2]$
 $Y_2 \leq 0: x \in (-\infty,0] \cup [2,\infty)$
 d. $Y_2 \uparrow: x \in (-\infty,1)$
 $Y_2 \downarrow: x \in (1,\infty)$
 e. local maximum: $y = 3$ at (1, 3)
46. $y = g(x)$
 a. $x \in (-\infty, 5]$
 $y \in (-\infty, 5]$
 b. $x = -5, -3, 1$
 c. $g(x) \geq 0: x \in [-5,-3] \cup [1,5]$;
 $g(x) \leq 0: x \in (-\infty,-5] \cup [-3,1]$
 d. $g(x) \uparrow: x \in (-\infty,-4) \cup (-1,2) \cup (4,5)$
 $g(x) \downarrow: x \in (-4,-1) \cup (2,4)$
 e. Local max: $y = 3$ at (-4, 3), $y = 4$ at (2, 4),

2.5 Exercises

Local min: $y = -4$ at $(-1, -4)$, $y = 1$ at $(4, 1)$,

47. $p(x) = (x+3)^3 + 1$

a. $x \in \mathbb{R}$, $y \in \mathbb{R}$

b. $x = -4$

c. $p(x) \geq 0 : x \in [-4, \infty)$;

$p(x) \leq 0 : x \in (-\infty, -4]$

d. $p(x) \uparrow : x \in (-\infty, -3) \cup (-3, \infty)$

$p(x) \downarrow$: never decreasing

e. Local max: none

Local min: none

48. $q(x) = |x-5| + 3$

a. $x \in (-\infty, \infty)$

$y \in [3, \infty)$

b. none

c. $q(x) \geq 0 : x \in (-\infty, \infty)$; $q(x) \leq 0 : q(x)$ is always positive.

d. $q(x) \uparrow : x \in (5, \infty)$

$g(x) \downarrow : x \in (-\infty, 5)$

e. Local max: none

Local min: $y = 3$ at $(5, 3)$

49. $y = \frac{1}{3}\sqrt{4x^2 - 36}$

a. $x \in (-\infty, -3] \cup [3, \infty)$

$y \in [0, \infty)$

b. $(-3, 0)$, $(3, 0)$

c. $f(x) \uparrow : x \in (3, \infty)$

$f(x) \downarrow : x \in (-\infty, -3)$

d. Even

50. $y = \sin(x)$

a. $y \in [-1, 1]$

b. $(-180, 0)$, $(0, 0)$, $(180, 0)$, $(360, 0)$

c. $y \uparrow : x \in (-90, 90) \cup (270, 360)$

$y \downarrow : x \in (-180, -90) \cup (90, 270)$

d. Minimum: $(-90, -1)$; $(270, -1)$

Maximum: $(90, 1)$

e. Odd

$y = \cos(x)$

a. $y \in [-1, 1]$

b. $(-90, 0)$, $(90, 0)$, $(270, 0)$

c. $y \uparrow : x \in (-180, 0) \cup (180, 360)$

$y \downarrow : x \in (0, 180)$

d. Minimum: $(-180, -1)$; $(180, -1)$

Maximum: $(0, 1)$; $(360, 1)$

e. Even

51. a. $x \in [0, 260]$

$y \in [0, 80]$

b. 80 feet

c. 120 feet

d. Yes

e. $(0, 120)$

f. $(120, 260)$

52. a. Increasing: $t \in (0, 1) \cup (3, 4) \cup (7, 10)$

b. Decreasing: $t \in (4, 7)$

c. Constant: $t \in (1, 3)$

d. Maximum: $(4, 12)$, $(10, 16)$

e. Minimum: $(7, -4)$

f. Positive: $t \in (0, 6)$, $(8, 10)$

g. Negative: $t \in (6, 8)$

h. Zero: $(6, 0)$, $(8, 0)$

53. $f(x) = x^{\frac{2}{3}} - 1$

a. $x \in (-\infty, \infty)$

$y \in [-1, \infty)$

b. $(-1, 0)$, $(1, 0)$

c. $f(x) \geq 0 : x \in (-\infty, -1] \cup [1, \infty)$

$f(x) < 0 : x \in (-1, 1)$

d. $f(x) \uparrow : x \in (0, \infty)$

$f(x) \downarrow : x \in (-\infty, 0)$

e. Minimum: $(0, -1)$

54. $h(x) = |x^2 - 4| - 5$

a. $x \in (-\infty, \infty)$

$y \in [-5, \infty)$

b. $(-3, 0)$, $(3, 0)$

c. $h(x) \geq 0 : x \in (-\infty, -3] \cup [3, \infty)$

$h(x) \leq 0 : x \in [-3, 3]$

d. $h(x) \uparrow : x \in (-2, 0) \cup (2, \infty)$

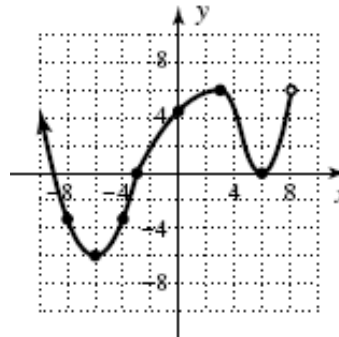
$h(x) \downarrow : x \in (-\infty, -2) \cup (0, 2)$

e. Maximum: $(0, -1)$

Minimum: $(-2, -5)$, $(2, -5)$

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58.



Zeros: $(-9, 0)$, $(-3, 0)$, $(6, 0)$

Min: $(-6, -6)$, $(6, 0)$

Max: $(3, 6)$

55. a. $D: t \in [72, 96]$

$R: I \in [7.25, 16]$

b. $I(t) \uparrow$ for $t \in (72, 74) \cup (77, 81) \cup (83,$

$84) \cup (93, 94)$

$I(t) \downarrow$ for $t \in (74, 75) \cup (81, 83) \cup (84, 86)$

$\cup (90, 93) \cup (94, 95)$

$I(t)$ constant for $t \in (75, 77) \cup (86, 90)$

$\cup (95, 96)$

c. Maximum: $(74, 9.25)$, $(81, 16)$ (global max), $(84, 13)$, $(94, 8.5)$

Minimum: $(72, 7.5)$, $(83, 12.75)$, $(93, 7.2)$

d. Increase: 1980 to 1981

Decrease: 1982 to 1983 or 1985 to 1986

56. a. $t \in [75, 102]$

$D \in [-300, 230]$

b. $D(t) \uparrow$ for

$t \in (76, 77) \cup (83, 84) \cup (86, 87) \cup (92, 100)$

$D(t) \downarrow$ for

$t \in (75, 76) \cup (77, 83) \cup (84, 86) \cup (89, 92) \cup (100, 102)$

$D(t)$ is constant for $t \in (87, 89)$

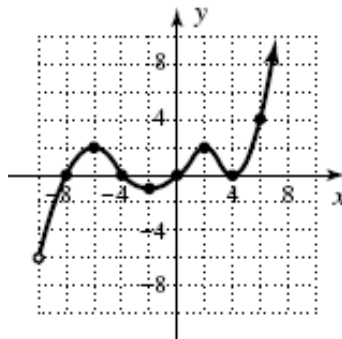
c. Maximum: $(75, -40)$, $(77, -50)$, $(84, -170)$, $(100, 240)$ (global maximum)

Minimum: $(76, -70)$, $(83, -210)$, $(86, -220)$, $(92, -300)$, $(102, -140)$

d. Increase: 1996 to 1997 or 1999 to 2000

Decrease: 2001 to 2002

57.



Zeros: $(-8, 0)$, $(-4, 0)$, $(0, 0)$, $(4, 0)$

Maximum: $(-6, 2)$, $(2, 2)$

Minimum: $(-2, -1)$, $(4, 0)$

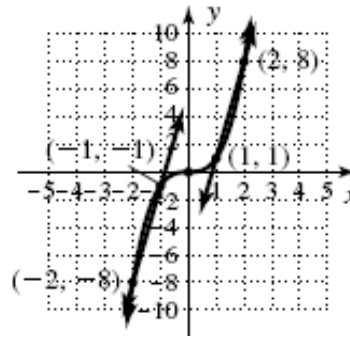
59. $f(x) = x^3$

a. $\frac{\Delta f}{\Delta x} = \frac{f(-1) - f(-2)}{-1 - (-2)} = \frac{-1 - (-8)}{1} = 7$

b. $\frac{\Delta f}{\Delta x} = \frac{f(2) - f(1)}{2 - 1} = \frac{8 - 1}{1} = 7$

c. They are the same.

d. Slopes of the lines are the same.



60. $f(x) = \sqrt[3]{x}$

a. Between $x = 0$ and $x = 1$

b. $\frac{\Delta f}{\Delta x} = \frac{f(1) - f(0)}{1 - 0} = \frac{1 - 0}{1} = 1$

$\frac{\Delta f}{\Delta x} = \frac{f(8) - f(7)}{8 - 7} = \frac{2 - 1.91}{1} = 0.09$

c. 11 times greater

2.5 Exercises

61. $h(t) = -16t^2 + 192t$

a. $h(1) = -16(1)^2 + 192(1) = 176$ ft

b. $h(2) = -16(2)^2 + 192(2) = 320$ ft

c. $\frac{\Delta h}{\Delta t} = \frac{h(2) - h(1)}{2 - 1} = \frac{320 - 176}{1}$
 $= 144$ ft/sec

d. $\frac{\Delta h}{\Delta t} = \frac{h(11) - h(10)}{11 - 10} = \frac{176 - 320}{1}$
 $= -144$ ft/sec

The arrow is going down.

62. $h(t) = -16t^2 + 96t$

a. $h(1) = -16(1)^2 + 96(1) = 80$ ft

$h(2) = -16(2)^2 + 96(2) = 128$ ft

b. $h(3) = -16(3)^2 + 96(3) = 144$ ft

c. Between $t = 1$ and $t = 2$; the rocket is decelerating.

d. $\frac{\Delta h}{\Delta t} = \frac{h(2) - h(1)}{2 - 1} = \frac{128 - 80}{1}$
 $= 48$ ft/sec;

$\frac{\Delta h}{\Delta t} = \frac{h(3) - h(2)}{3 - 2} = \frac{144 - 128}{1}$
 $= 16$ ft/sec

63. $v = \sqrt{2gs}$, $v = \sqrt{2(32)s} = 8\sqrt{s}$

a. $v = \sqrt{2(32)(5)} = \sqrt{320} = 17.89$ ft/sec ;

$v = \sqrt{2(32)(10)} = \sqrt{640} = 25.30$ ft/sec

b. $v = \sqrt{2(32)(15)} = \sqrt{960} = 30.98$ ft/sec ;

$v = \sqrt{2(32)(20)} = \sqrt{1280} = 35.78$ ft/sec

c. Between $s = 5$ and $s = 10$

d. $\frac{\Delta v}{\Delta s} = \frac{v(10) - v(5)}{10 - 5} = \frac{25.3 - 17.89}{5}$
 $= 1.482$ ft/sec;

$\frac{\Delta v}{\Delta s} = \frac{v(20) - v(15)}{20 - 15} = \frac{35.78 - 30.98}{5}$
 $= 0.96$ ft/sec

64. $T(h) = 0.8h^2 - 16h + 60$

a. $T(0) = 0.8(0)^2 - 16(0) + 60 = 60$
 60°F

b. $0 = 0.8h^2 - 16h + 60$

$0 = 8h^2 - 160h + 600$

$0 = 8(h^2 - 20h + 75)$

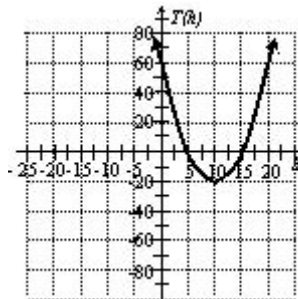
$0 = 8(h - 5)(h - 15)$

$h = 5$; $h = 15$

5 hours

c. $15 - 5 = 10$ hours

d. -20°F



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

$$\begin{aligned}\frac{\Delta f}{\Delta x} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{[2(x+h) - 3] - (2x - 3)}{h} \\ &= \frac{2x + 2h - 3 - 2x + 3}{h} \\ &= \frac{2h}{h} = 2\end{aligned}$$

66. $g(x) = 4x + 1$

$$\begin{aligned}\frac{g(x+h) - g(x)}{h} &= \frac{[4(x+h) + 1] - (4x + 1)}{h} \\ &= \frac{4x + 4h + 1 - 4x - 1}{h} \\ &= \frac{4h}{h} = 4\end{aligned}$$

Chapter 2: Relations, Functions and Graphs

67. $h(x) = x^2 + 3$

$$\begin{aligned}\frac{\Delta f}{\Delta x} &= \frac{h(x+h) - h(x)}{h} = \frac{[(x+h)^2 + 3] - (x^2 + 3)}{h} \\ &= \frac{x^2 + 2xh + h^2 + 3 - x^2 - 3}{h} \\ &= \frac{2xh + h^2}{h} = \frac{h(2x+h)}{h} = 2x+h\end{aligned}$$

68. $p(x) = x^2 - 2$

$$\begin{aligned}\frac{\Delta p}{\Delta x} &= \frac{p(x+h) - p(x)}{h} = \frac{[(x+h)^2 - 2] - (x^2 - 2)}{h} \\ &= \frac{x^2 + 2xh + h^2 - 2 - x^2 + 2}{h} \\ &= \frac{2xh + h^2}{h} = \frac{h(2x+h)}{h} = 2x+h\end{aligned}$$

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

$$\begin{aligned}\frac{\Delta g}{\Delta x} &= \frac{g(x+h) - g(x)}{h} \\ &= \frac{[(x+h)^2 + 2(x+h) - 3] - (x^2 + 2x - 3)}{h} \\ &= \frac{x^2 + 2xh + h^2 + 2x + 2h - 3 - x^2 - 2x + 3}{h} \\ &= \frac{2xh + h^2 + 2h}{h} = \frac{h(2x+h+2)}{h} = 2x+2+h\end{aligned}$$

70. $r(x) = x^2 - 5x + 2$

$$\begin{aligned}\frac{\Delta r}{\Delta x} &= \frac{r(x+h) - r(x)}{h} \\ &= \frac{[(x+h)^2 - 5(x+h) + 2] - (x^2 - 5x + 2)}{h} \\ &= \frac{x^2 + 2xh + h^2 - 5x - 5h + 2 - x^2 + 5x - 2}{h} \\ &= \frac{2xh + h^2 - 5h}{h} = \frac{h(2x+h-5)}{h} = 2x-5+h\end{aligned}$$

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

$$\begin{aligned}\frac{\Delta f}{\Delta x} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{\frac{2}{x+h} - \frac{2}{x}}{h} = \frac{\frac{2x - 2(x+h)}{x(x+h)}}{h} \\ &= \frac{\frac{2x - 2x - 2h}{x(x+h)}}{h} = \frac{\frac{-2h}{x(x+h)}}{h} = \frac{-2h}{x(x+h)} \cdot \frac{1}{h} = \frac{-2}{x(x+h)}\end{aligned}$$

72. $g(x) = \frac{-3}{x}$

$$\begin{aligned}\frac{\Delta g}{\Delta x} &= \frac{g(x+h) - g(x)}{h} \\ &= \frac{\frac{-3}{x+h} - \frac{-3}{x}}{h} = \frac{\frac{-3x + 3(x+h)}{x(x+h)}}{h} \\ &= \frac{\frac{-3x + 3x + 3h}{x(x+h)}}{h} = \frac{\frac{3h}{x(x+h)}}{h} = \frac{3h}{x(x+h)} \cdot \frac{1}{h} = \frac{3}{x(x+h)}\end{aligned}$$

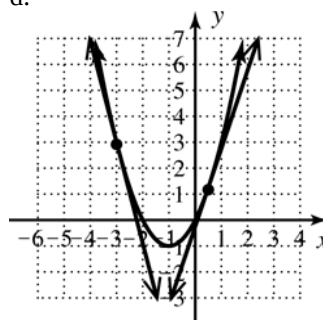
73. a. $g(x) = x^2 + 2x$

$$\begin{aligned}\frac{\Delta g}{\Delta x} &= \frac{g(x+h) - g(x)}{h} \\ &= \frac{[(x+h)^2 + 2(x+h)] - (x^2 + 2x)}{h} \\ &= \frac{x^2 + 2xh + h^2 + 2x + 2h - x^2 - 2x}{h} \\ &= \frac{2xh + h^2 + 2h}{h} = \frac{h(2x+h+2)}{h} = 2x+2+h\end{aligned}$$

b. For $[-3.0, -2.9]$, $x = -3.0$ and $h = 0.1$
Rate of change: $2(-3.0) + 2 + 0.1 = -3.9$

c. For $[0.50, 0.51]$, $x = 0.50$ and $h = 0.01$
Rate of change: $2(0.50) + 2 + 0.01 = 3.01$

d.



The rates of change have opposite signs, with the secant line to the left being more steep.

2.5 Exercises

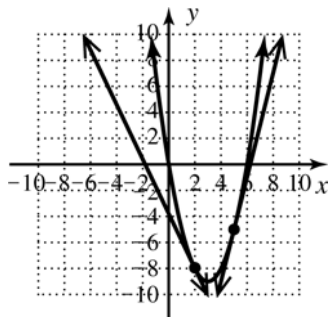
74. a. $h(x) = x^2 - 6x$

$$\begin{aligned}\frac{\Delta h}{\Delta x} &= \frac{h(x+h) - h(x)}{h} \\ &= \frac{[(x+h)^2 - 6(x+h)] - (x^2 - 6x)}{h} \\ &= \frac{x^2 + 2xh + h^2 - 6x - 6h - x^2 + 6x}{h} \\ &= \frac{2xh + h^2 - 6h}{h} = \frac{h(2x + h - 6)}{h} = 2x - 6 + h\end{aligned}$$

b. For $[1.9, 2.0]$, $x = 1.9$ and $h = 0.1$
Rate of change: $2(1.9) - 6 + 0.1 = -2.1$

c. For $[5.0, 5.01]$, $x = 5.0$ and $h = 0.01$
Rate of change: $2(5.0) - 6 + 0.01 = 4.01$

d.



The rates of change have opposite signs, with the secant line to the right being more steep.

75. a. $g(x) = x^3 + 1$

$$\begin{aligned}\frac{\Delta g}{\Delta x} &= \frac{g(x+h) - g(x)}{h} \\ &= \frac{[(x+h)^3 + 1] - (x^3 + 1)}{h} \\ &= \frac{x^3 + 3x^2h + 3xh^2 + h^3 + 1 - x^3 - 1}{h} \\ &= \frac{3x^2h + 3xh^2 + h^3}{h} \\ &= \frac{h(3x^2 + 3xh + h^2)}{h} = 3x^2 + 3xh + h^2\end{aligned}$$

b. For $[-2.1, -2]$, $x = -2.1$ and $h = 0.1$
Rate of change:

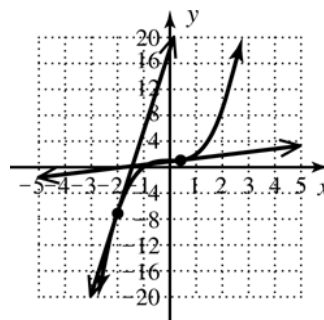
$$3(-2.1)^2 + 3(-2.1)(0.1) + (0.1)^2 = 12.61$$

c. For $[0.40, 0.41]$, $x = 0.40$ and $h = 0.01$

Rate of change:

$$3(0.40)^2 + 3(0.40)(0.01) + (0.01)^2 \approx 0.49$$

d.



Both lines have a positive slope, but the line at $x = -2$ is much steeper.

76. a. $r(x) = \sqrt{x}$

$$\begin{aligned}\frac{\Delta r}{\Delta x} &= \frac{r(x+h) - r(x)}{h} \\ &= \frac{\sqrt{x+h} - \sqrt{x}}{h} \\ &= \frac{\sqrt{x+h} - \sqrt{x}}{h} \cdot \frac{\sqrt{x+h} + \sqrt{x}}{\sqrt{x+h} + \sqrt{x}} \\ &= \frac{x+h-x}{h(\sqrt{x+h} + \sqrt{x})} = \frac{h}{h(\sqrt{x+h} + \sqrt{x})} \\ &= \frac{1}{\sqrt{x+h} + \sqrt{x}}\end{aligned}$$

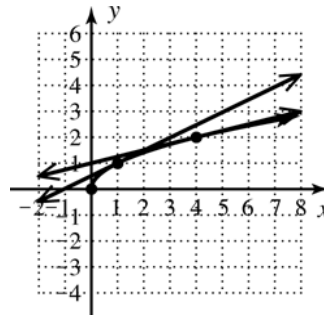
b. For $[1, 1.1]$, $x = 1$ and $h = 0.1$

Rate of change: $\frac{1}{\sqrt{1+0.1} + \sqrt{1}} \approx 0.49$

c. For $[4, 4.1]$, $x = 4$ and $h = 0.1$

Rate of change: $\frac{1}{\sqrt{4+0.1} + \sqrt{4}} \approx 0.25$

d.



Both lines have a positive slope, but the line at $x = 4$ is less steep.

77. $d(x) = 1.5\sqrt{x}$

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$$\begin{aligned}\frac{\Delta d}{\Delta x} &= \frac{d(x+h) - d(x)}{h} \\ &= \frac{1.5\sqrt{x+h} - 1.5\sqrt{x}}{h}\end{aligned}$$

a. For $[9, 9.01]$, $x = 9$ and $h = 0.01$

Rate of change:

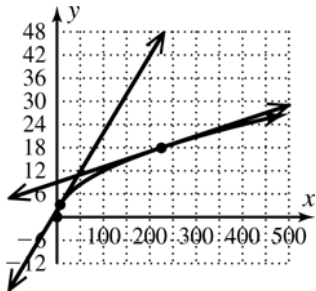
$$\frac{1.5\sqrt{9+0.01} - 1.5\sqrt{9}}{0.01} \approx 0.25$$

b. For $[225, 225.01]$, $x = 225$ and $h = 0.01$

Rate of change:

$$\frac{1.5\sqrt{225+0.01} - 1.5\sqrt{225}}{0.01} \approx 0.05$$

c.



As height increases, you can see farther, the sight distance is increasing much slower.

78. $P(x) = x^2$

$$\begin{aligned}\frac{\Delta P}{\Delta x} &= \frac{P(x+h) - P(x)}{h} \\ &= \frac{[(x+h)^2] - x^2}{h} \\ &= \frac{x^2 + 2xh + h^2 - x^2}{h} \\ &= \frac{2xh + h^2}{h} = \frac{h(2x+h)}{h} = 2x + h\end{aligned}$$

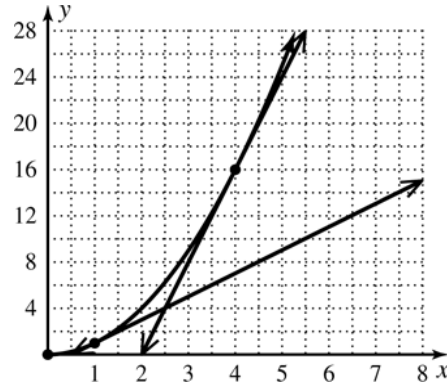
a. For $[1, 1.01]$, $x = 1$ and $h = 0.01$

Rate of change: $2(1) + 0.01 = 2.01$

b. For $[4, 4.01]$, $x = 4$ and $h = 0.01$

Rate of change: $2(4) + 0.01 = 8.01$

c.



The projected image grows at a faster rate, the farther you move away from the screen.

79. No; No; Answers will vary.

80. a. Daughter; her graph line reaches 400

meters before her mother's.

b. 20 meters; mother is at 380 meters when daughter reaches 400 meters.

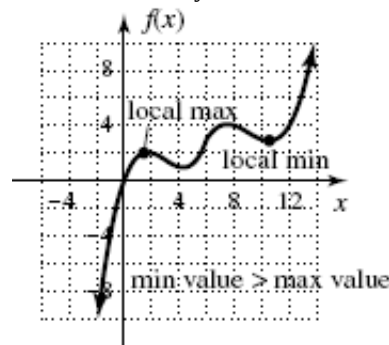
c. 10 seconds; daughter finishes in 65 seconds, mother finishes in 75 seconds.

d. Mother

e. 37 seconds; 0–30; 58–65

f. 28 seconds; 58 seconds – 38 seconds = 28 seconds

81. Answers will vary.



82. $h(-k) = h(k)$

$$\left[(-k)^{\frac{1}{3}}\right]^2 = \left(k^{\frac{1}{3}}\right)^2$$

$$(\sqrt[3]{-k})^2 = (\sqrt[3]{k})^2$$

$$(-\sqrt[3]{k})^2 = (\sqrt[3]{k})^2$$

$$(\sqrt[3]{k})^2 = (\sqrt[3]{k})^2$$

$h(x)$ is an even function.

2.6 Exercises

83. $x^2 - 8x - 20 = 0$

a. $(x-10)(x+2) = 0$

$x = 10; x = -2$

b. $(x^2 - 8x) - 20 = 0$

$(x^2 - 8x + 16) - 20 - 16 = 0$

$(x-4)^2 - 36 = 0$

$(x-4)^2 = 36$

$x-4 = \pm 6$

$x = 4 \pm 6$

$x = 10; x = -2$

c. $x = \frac{8 \pm \sqrt{(-8)^2 - 4(1)(-20)}}{2(1)}$

$x = \frac{8 \pm \sqrt{64+80}}{2}$

$x = \frac{8 \pm \sqrt{144}}{2}$

$x = \frac{8 \pm 12}{2}$

$x = 10; x = -2$

84. a. $\frac{3}{x+2} + \frac{3}{2-x}$

$\frac{3(2-x)}{(x+2)(2-x)} + \frac{3(x+2)}{(x+2)(2-x)}$

$\frac{6-3x+3x+6}{(x+2)(2-x)}$

Sum: $\frac{12}{4-x^2}$

b. $\frac{3}{x+2} \cdot \frac{3}{2-x}$

Product: $\frac{9}{4-x^2}$

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

86. $SA = 2\pi rh + 2\pi r^2$

$SA = 2\pi(12)(36) + 2\pi(12)^2$

$SA = 864\pi + 288\pi$

$SA = 1152\pi \text{ cm}^2;$

$V = \pi r^2 h$

$V = \pi(12)^2(36)$

$V = 5184\pi \text{ cm}^3$

2.6 Technology Highlight

Exercise 1: Shifted right 3 units; answers will vary.

Exercise 2: Shifted right 3 units; answers will vary.

2.6 Exercises

1. Stretch; compression

2. Translations; reflections

3. $(-5, -9)$; upward

4. $(4, 11)$; up; down

5. Answers will vary.

6. Answers will vary.

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

a. quadratic

b. up/up, Vertex $(-2, -4)$,
Axis of symmetry $x = -2$,
 x -intercepts $(-4, 0)$ and $(0, 0)$,
 y -intercept $(0, 0)$

c. D: $x \in \mathbb{R}$, R: $y \in [-4, \infty)$

8. $g(x) = -x^2 + 2x$

a. quadratic

b. down/down, Vertex $(1, 1)$,
Axis of symmetry $x = 1$,
 x -intercepts $(2, 0)$ and $(0, 0)$,
 y -intercept $(0, 0)$

c. D: $x \in \mathbb{R}$, R: $y \in (-\infty, 1]$

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9. $p(x) = x^2 - 2x - 3$
 - a. quadratic
 - b. up/up, Vertex (1,-4),
Axis of symmetry $x = 1$,
 x -intercepts (-1, 0) and (3,0),
 y -intercept (0,-3)
 - c. D: $x \in \square$, R: $y \in [-4, \infty)$
10. $q(x) = -x^2 + 2x + 8$
 - a. quadratic
 - b. down/down, Vertex (1,9),
Axis of symmetry $x = 1$,
 x -intercepts (-2, 0) and (4,0),
 y -intercept (0,8)
 - c. D: $x \in \square$, R: $y \in (-\infty, 9]$
11. $f(x) = x^2 - 4x - 5$
 - a. quadratic
 - b. up/up, Vertex (2,-9),
Axis of symmetry $x = 2$,
 x -intercepts (-1, 0) and (5,0),
 y -intercept (0,-5)
 - c. D: $x \in \square$, R: $y \in [-9, \infty)$
12. $g(x) = x^2 + 6x + 5$
 - a. quadratic
 - b. up/up, Vertex (-3,-4),
Axis of symmetry $x = -3$,
 x -intercepts (-5, 0) and (-1,0),
 y -intercept (0,5)
 - c. D: $x \in \square$, R: $y \in [-4, \infty)$
13. $p(x) = 2\sqrt{x+4} - 2$
 - a. square root
 - b. up to the right, Initial point (-3,-4),
 x -intercept (-3, 0),
 y -intercept (0,2)
 - c. D: $x \in [-4, \infty)$, R: $y \in [-2, \infty)$
14. $q(x) = -2\sqrt{x+4} + 2$
 - a. square root
 - b. down to the right, Initial point (-4,2),
 x -intercept (-3, 0),
 y -intercept (0,-2)
 - c. D: $x \in [-4, \infty)$, R: $y \in (-\infty, 2]$
15. $r(x) = -3\sqrt{4-x} + 3$
 - a. square root
 - b. down to the left, Initial point (4,3),
 x -intercept (3, 0),
 y -intercept (0,-3)
 - c. D: $x \in (-\infty, 4]$, R: $y \in (-\infty, 3]$
16. $p(x) = 2\sqrt{x+1} - 4$
 - a. square root
 - b. up to the right, Initial point (-1,-4),
 x -intercept (3, 0),
 y -intercept (0,-2)
 - c. D: $x \in [-1, \infty)$, R: $y \in [-4, \infty)$
17. $g(x) = 2\sqrt{4-x}$
 - a. square root
 - b. up to the left, Initial point (4,0),
 x -intercept (4, 0),
 y -intercept (0,4)
 - c. D: $x \in (-\infty, 4]$, R: $y \in [0, \infty)$
18. $h(x) = -2\sqrt{x+1} + 4$
 - a. square root
 - b. down to the right, Initial point (-1,4),
 x -intercept (3, 0),
 y -intercept (0,2)
 - c. D: $x \in [-1, \infty)$, R: $y \in (-\infty, 4]$
19. $p(x) = 2|x+1| - 4$
 - a. absolute value
 - b. up/up, Vertex (-1,-4),
Axis of symmetry $x = -1$,
 x -intercepts (-3, 0) and (1,0),
 y -intercept (0,-2)
 - c. D: $x \in \square$, R: $y \in [-4, \infty)$
20. $q(x) = -3|x-2| + 3$
 - a. absolute value
 - b. down/down, Vertex (2,3),
Axis of symmetry $x = 2$,
 x -intercepts (3, 0) and (1,0),
 y -intercept (0,-3)
 - c. D: $x \in \square$, R: $y \in (-\infty, 3]$

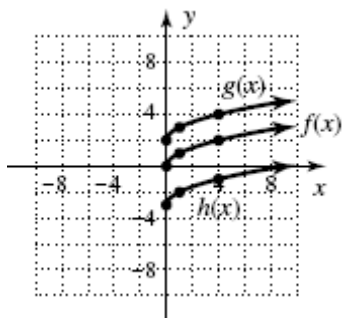
2.6 Exercises

21. $r(x) = -2|x+1|+6$
- absolute value
 - down/down, Vertex $(-1,6)$,
Axis of symmetry $x = -1$,
 x -intercepts $(-4, 0)$ and $(2,0)$,
 y -intercept $(0,4)$
 - D: $x \in \square$, R: $y \in (-\infty, 6]$
22. $f(x) = 3|x-2|-6$
- absolute value
 - up/up, Vertex $(2,-6)$,
Axis of symmetry $x = 2$,
 x -intercepts $(0, 0)$ and $(4,0)$,
 y -intercept $(0,0)$
 - D: $x \in \square$, R: $y \in [-6, \infty)$
23. $g(x) = -3|x|+6$
- absolute value
 - down/down, Vertex $(0,6)$,
Axis of symmetry $x = 0$,
 x -intercepts $(-2, 0)$ and $(2,0)$,
 y -intercept $(0,6)$
 - D: $x \in \square$, R: $y \in (-\infty, 6]$
24. $h(x) = 2|x+1|$
- absolute value
 - up/up, Vertex $(-1,0)$,
Axis of symmetry $x = -1$,
 x -intercept $(-1, 0)$,
 y -intercept $(0,2)$
 - D: $x \in \square$, R: $y \in [0, \infty)$
25. $f(x) = -(x-1)^3$
- cubic
 - up/down, Inflection point $(1,0)$,
 x -intercept $(1, 0)$,
 y -intercept $(0,1)$
 - D: $x \in \square$, R: $y \in \square$
26. $g(x) = (x+1)^3$
- cubic
 - down/up, Inflection point $(0,-1)$,
 x -intercept $(-1, 0)$,
 y -intercept $(0,1)$
 - D: $x \in \square$, R: $y \in \square$
27. $h(x) = x^3 + 1$
- cubic
 - down/up, Inflection point $(0,1)$,
 x -intercept $(-1, 0)$,
 y -intercept $(0,1)$
 - D: $x \in \square$, R: $y \in \square$
28. $p(x) = -\sqrt[3]{x} + 1$
- cube root
 - up/down, Inflection point $(0,1)$,
 x -intercept $(1, 0)$,
 y -intercept $(0,1)$
 - D: $x \in \square$, R: $y \in \square$
29. $q(x) = \sqrt[3]{x-1} - 1$
- cube root
 - down/up, Inflection point $(1,-1)$,
 x -intercept $(2, 0)$,
 y -intercept $(0,-2)$
 - D: $x \in \square$, R: $y \in \square$
30. $r(x) = -\sqrt[3]{x+1} - 1$
- cube root
 - up/down, Inflection point $(-1,-1)$,
 x -intercept $(-2, 0)$,
 y -intercept $(0,-2)$
 - D: $x \in \square$, R: $y \in \square$
31. Function family: Square root
 x -intercept: $(-3, 0)$
 y -intercept: $(0, 2)$
Initial point: $(-4, -2)$
End behavior: Up on right
32. Function family: Quadratic
 x -intercepts: $(-3, 0)$, $(1, 0)$
 y -intercept: $(0, 3)$
Vertex: $(-1, 4)$
End behavior: Down/down
33. Function family: Cubic
 x -intercept: $(-2, 0)$
 y -intercept: $(0, -2)$
Inflection point: $(-1, -1)$
End behavior: Up/down
34. Function family: Absolute Value
 x -intercepts: $(-1, 0)$, $(3, 0)$
 y -intercept: $(0, -2)$
Vertex: $(1, -4)$
End behavior: Up/up

Chapter 2: Relations, Functions and Graphs

35. $f(x) = \sqrt{x}$; $g(x) = \sqrt{x} + 2$; $h(x) = \sqrt{x} - 3$

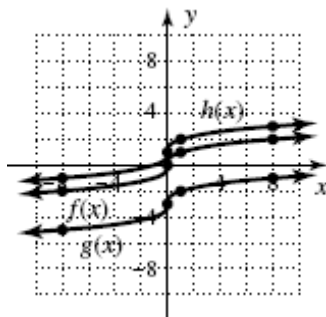
x	f(x)	g(x)	h(x)
0	0	2	-3
4	2	4	-1
9	3	5	0
16	4	6	1
25	5	7	2



From the parent graph $f(x) = \sqrt{x}$, $g(x)$ shifts up 2 units and $h(x)$ shifts down 3 units.

36. $f(x) = \sqrt[3]{x}$; $g(x) = \sqrt[3]{x} - 3$; $h(x) = \sqrt[3]{x} + 1$

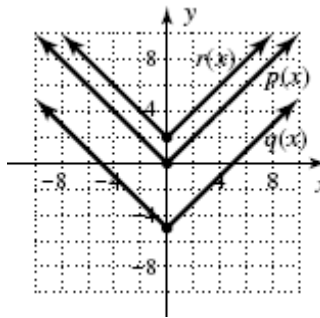
x	f(x)	g(x)	h(x)
0	0	-3	1
1	1	-2	2
8	2	-1	3
27	3	0	4
64	4	1	5



From the parent graph $f(x) = \sqrt[3]{x}$, $g(x)$ shifts down 3 units and $h(x)$ shifts up 1 unit.

37. $p(x) = |x|$; $q(x) = |x| - 5$; $r(x) = |x| + 2$

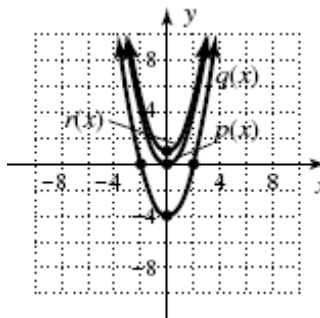
x	p(x)	q(x)	r(x)
-2	2	-3	4
-1	1	-4	3
0	0	-5	2
1	1	-4	3
2	2	-3	4



From the parent graph $p(x) = |x|$, $q(x)$ shifts down 5 units and $r(x)$ shifts up 2 units.

38. $p(x) = x^2$; $q(x) = x^2 - 4$; $r(x) = x^2 + 1$

x	p(x)	q(x)	h(x)
-2	4	0	5
-1	1	-3	2
0	0	-4	1
1	1	-3	2
2	4	0	5

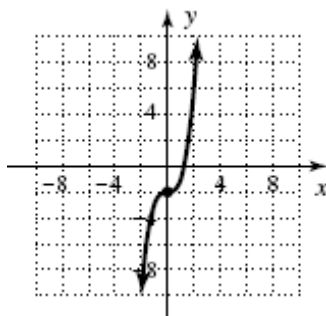


From the parent graph $p(x) = x^2$, $q(x)$ shifts down 4 units and $r(x)$ shifts up 1 unit.

2.6 Exercises

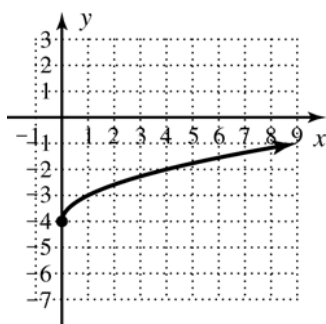
39. $f(x) = x^3 - 2$

Shifts down 2 units.



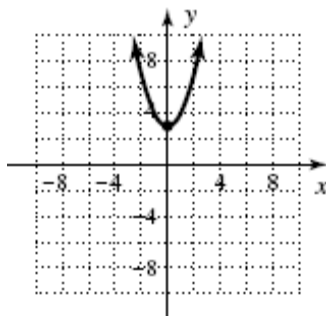
40. $g(x) = \sqrt{x} - 4$

Shifts down 4 units.



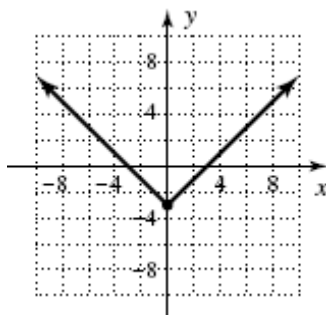
41. $h(x) = x^2 + 3$

Shifts up 3 units.



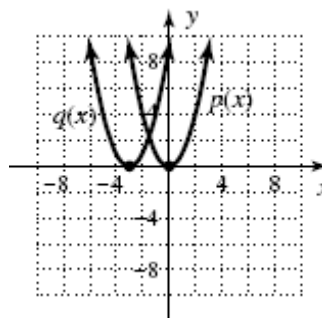
42. $Y_1 = |x| - 3$

Shifts down 3 units.



43. $p(x) = x^2$; $q(x) = (x+3)^2$

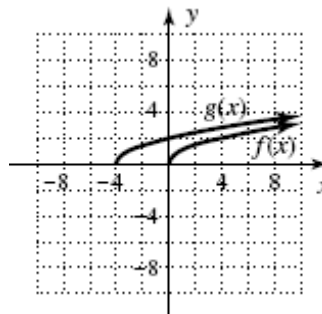
x	$p(x) = x^2$	$q(x) = (x+3)^2$
-5	25	4
-3	9	0
-1	1	4
1	1	16
3	9	36



From the parent graph $p(x) = x^2$, $q(x)$ shifts left 3 units.

44. $f(x) = \sqrt{x}$; $g(x) = \sqrt{x+4}$

x	$f(x) = \sqrt{x}$	$g(x) = \sqrt{x+4}$
0	0	2
1	1	$\sqrt{5}$
4	2	$2\sqrt{2}$
9	3	$\sqrt{13}$
16	4	$2\sqrt{5}$

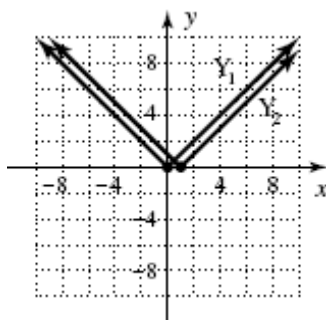


From the parent graph $f(x) = \sqrt{x}$, $g(x)$ shifts left 4 units.

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45. $Y_1 = |x|$; $Y_2 = |x-1|$

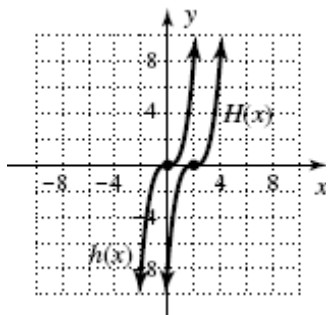
x	$Y_1 = x $	$Y_2 = x-1 $
-2	2	3
-1	1	2
0	0	1
1	1	0
2	2	1



From the parent graph $Y_1 = |x|$, Y_2 shifts right 1 unit.

46. $h(x) = x^3$; $H(x) = (x-2)^3$

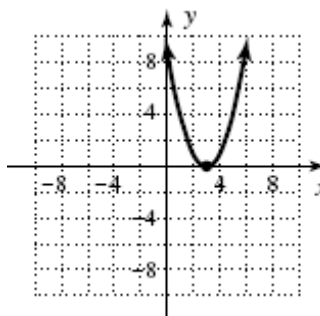
x	$h(x) = x^3$	$H(x) = (x-2)^3$
-2	-8	-64
-1	-1	-27
0	0	-8
1	1	-1
2	8	0



From the parent graph $h(x) = x^3$, $H(x)$ shifts right 2 units.

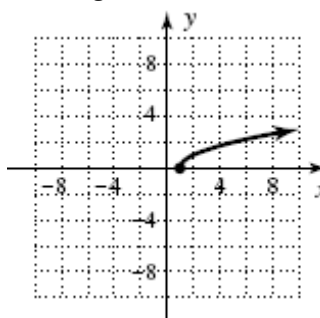
47. $p(x) = (x-3)^2$

Shifts right 3 units.



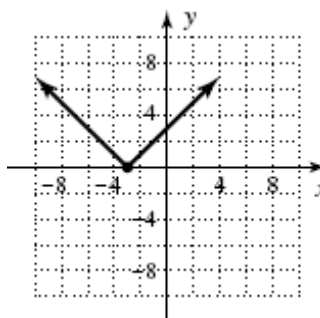
48. $Y_1 = \sqrt{x-1}$

Shifts right 1 unit.



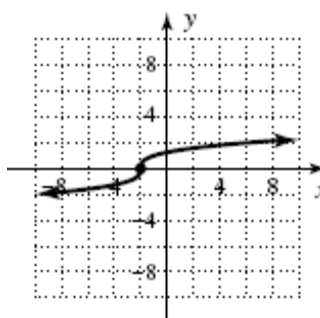
49. $h(x) = |x+3|$

Shifts left 3 units.



50. $f(x) = \sqrt[3]{x+2}$

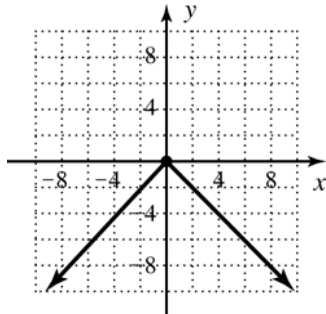
Shifts left 2 units.



2.6 Exercises

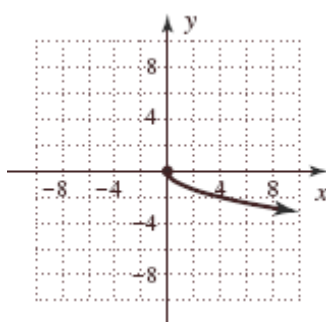
51. $g(x) = -|x|$

Reflects across the x -axis.



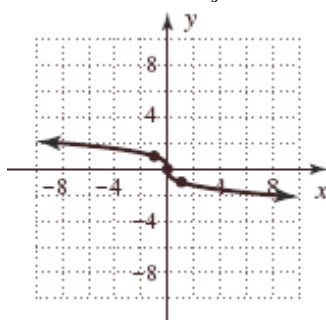
52. $Y_2 = -\sqrt{x}$

Reflects across the x -axis.



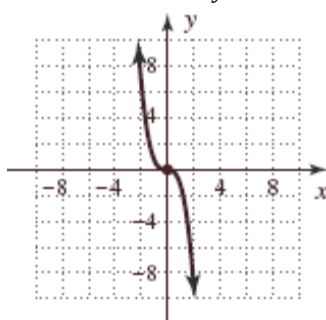
53. $f(x) = \sqrt[3]{-x}$

Reflects across the y -axis.



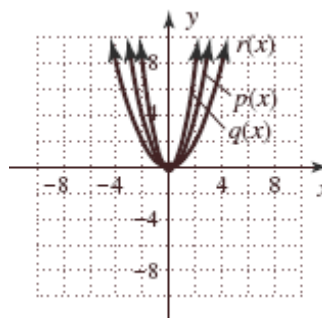
54. $g(x) = (-x)^3$

Reflects across the y -axis.



55. $p(x) = x^2$; $q(x) = 2x^2$; $r(x) = \frac{1}{2}x^2$

x	p(x)	q(x)	r(x)
-2	4	8	2
-1	1	2	1/2
0	0	0	0
1	1	2	1/2
2	4	8	2

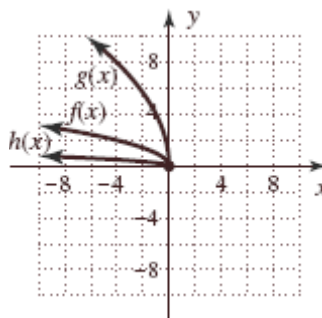


From the parent graph $p(x) = x^2$, $q(x)$ stretches upward and $r(x)$ compresses downward.

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

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

x	f(x)	g(x)	h(x)
-25	5	20	5/4
-16	4	16	1
-9	3	12	3/4
-4	2	8	1/2
-1	1	4	1/4

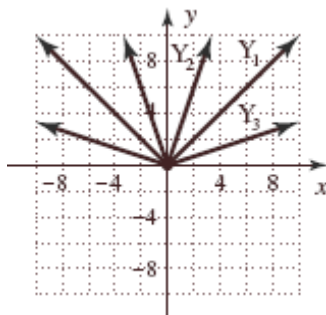


From the parent graph $f(x) = \sqrt{-x}$, $g(x)$ stretches upward and $h(x)$ compresses downward.

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57. $Y_1 = |x|$; $Y_2 = 3|x|$; $Y_3 = \frac{1}{3}|x|$

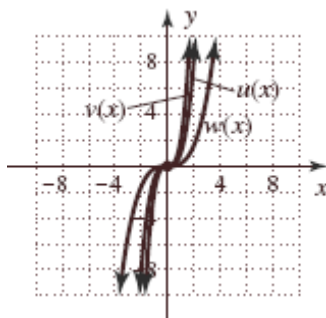
x	Y_1	Y_2	Y_3
-2	2	6	$2/3$
-1	1	3	$1/3$
0	0	0	0
1	1	3	$1/3$
2	2	6	$2/3$



From the parent graph $Y_1 = |x|$, Y_2 stretches upward and Y_3 compresses downward.

58. $u(x) = x^3$; $v(x) = 2x^3$; $w(x) = \frac{1}{5}x^3$

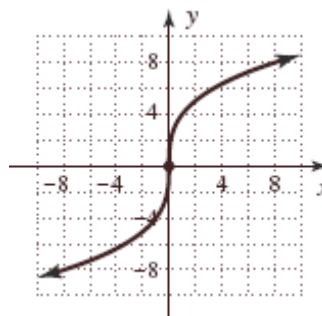
x	$u(x)$	$v(x)$	$w(x)$
-2	-8	-16	$-8/5$
-1	-1	-2	$-1/5$
0	0	0	0
1	1	2	$1/5$
2	8	16	$8/5$



From the parent graph $u(x) = x^3$, $v(x)$ stretches upward and $w(x)$ compresses downward.

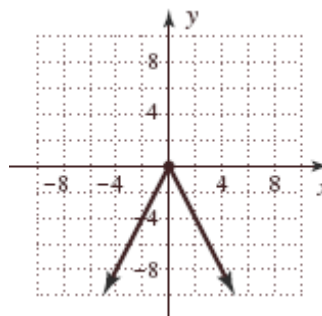
59. $f(x) = 4\sqrt[3]{x}$

Stretches upward and downward.



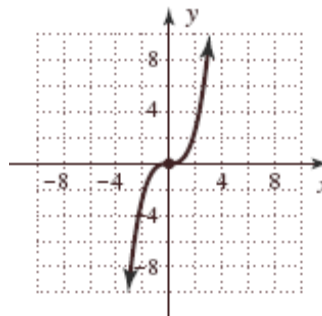
60. $g(x) = -2|x|$

Stretches upward; reflects over x -axis.



61. $p(x) = \frac{1}{3}x^3$

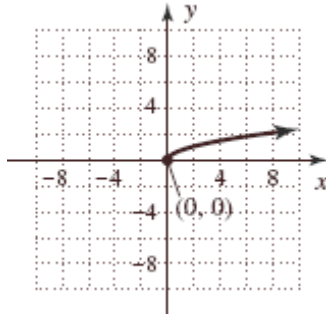
Compresses downward.



2.6 Exercises

62. $q(x) = \frac{3}{4}\sqrt{x}$

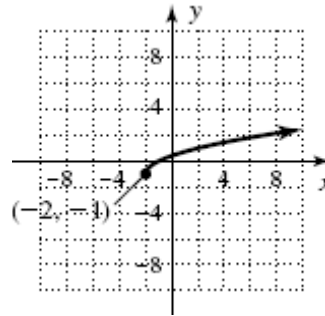
Compresses downward.



75. $f(x) = \sqrt{x+2} - 1$

Left 2, down 1

Initial point: $(-2, -1)$



63. $f(x) = \frac{1}{2}x^3; g$

64. $f(x) = -\frac{2}{3}x + 2; h$

65. $f(x) = -(x-3)^2 + 2; i$

66. $f(x) = -\sqrt[3]{x-1} - 1; d$

67. $f(x) = |x+4| + 1; e$

68. $f(x) = -\sqrt{x+6}; f$

69. $f(x) = -\sqrt{x+6} - 1; j$

70. $f(x) = x + 1; k$

71. $f(x) = (x-4)^2 - 3; l$

72. $f(x) = |x-2| - 5; b$

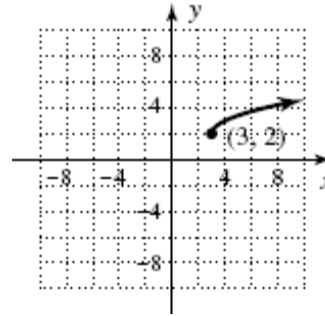
73. $f(x) = \sqrt{x+3} - 1; c$

74. $f(x) = -(x+3)^2 + 5; a$

76. $g(x) = \sqrt{x-3} + 2$

Right 3, up 2

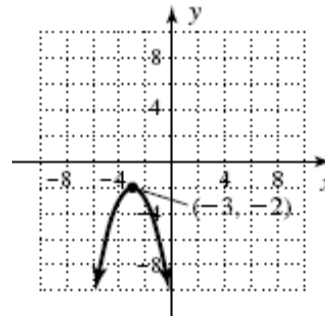
Initial point: $(3, 2)$



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

Left 3, reflected across x-axis, down 2

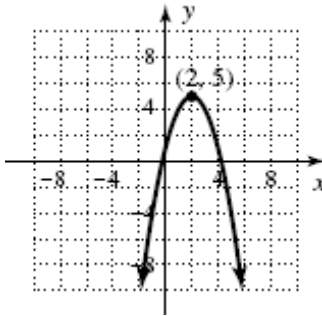
Vertex: $(-3, -2)$



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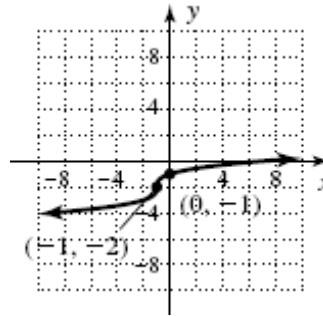
78. $H(x) = -(x-2)^2 + 5$

Right 2, reflected across x -axis, up 5
Vertex: (2, 5)



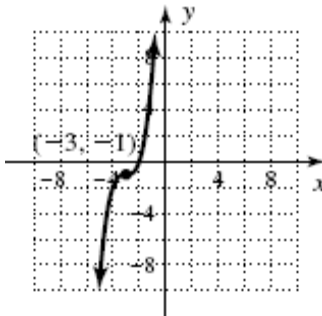
81. $Y_1 = \sqrt[3]{x+1} - 2$

Left 1, down 2
Inflection point: (-1, -2)



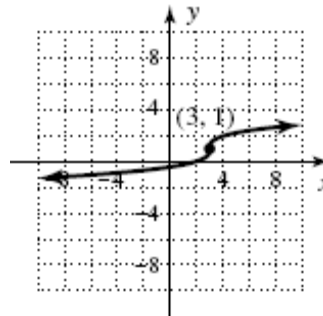
79. $p(x) = (x+3)^3 - 1$

Left 3, down 1
Inflection point: (-3, -1)



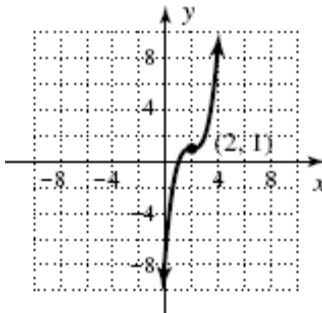
82. $Y_2 = \sqrt[3]{x-3} + 1$

Right 3, up 1
Inflection point: (3, 1)



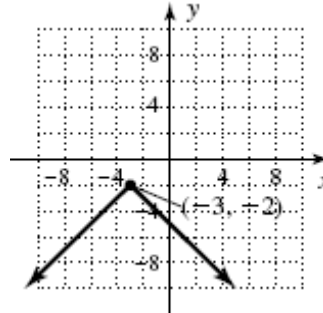
80. $q(x) = (x-2)^3 + 1$

Right 2, up 1
Inflection point: (2, 1)



83. $f(x) = -|x+3| - 2$

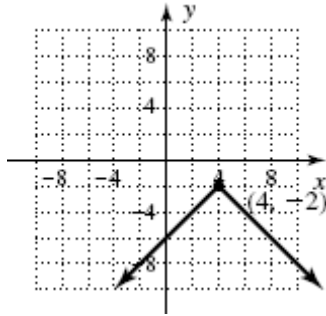
Left 3, reflected across x -axis, down 2
Vertex: (-3, -2)



2.6 Exercises

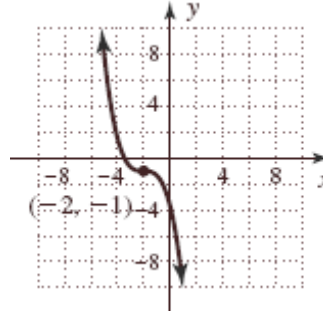
84. $g(x) = -|x-4| - 2$

Right 4, reflected across x -axis, down 2
Vertex: (4, -2)



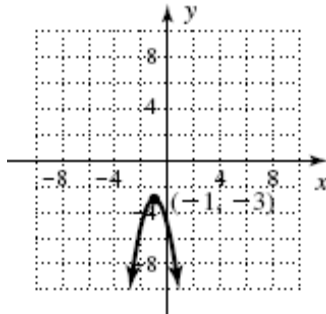
87. $p(x) = -\frac{1}{3}(x+2)^3 - 1$

Left 2, compressed vertically, reflected across x -axis, down 1
Inflection point: (-2, -1)



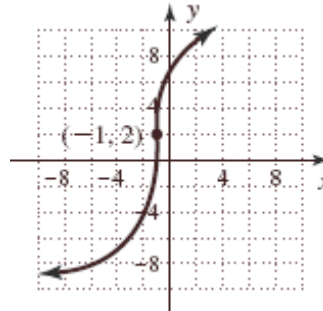
85. $h(x) = -2(x+1)^2 - 3$

Left 1, stretched vertically, reflected across x -axis, down 3
Vertex: (-1, -3)



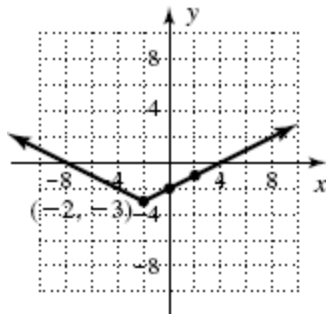
88. $q(x) = 5\sqrt[3]{x+1} + 2$

Left 1, stretched vertically, up 2
Inflection point: (-1, 2)



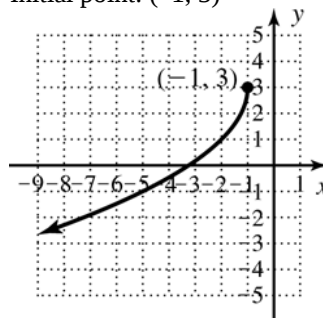
86. $H(x) = \frac{1}{2}|x+2| - 3$

Left 2, compressed vertically, down 3
Vertex: (-2, -3)



89. $Y_1 = -2\sqrt{-x-1} + 3$

Reflected across y -axis, left 1, reflected across x -axis, stretched vertically, up 3
Initial point: (-1, 3)

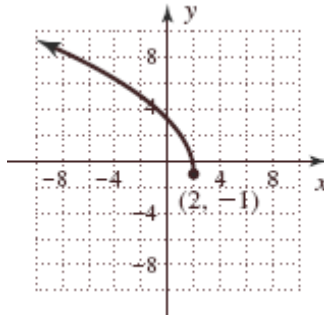


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90. $Y_2 = 3\sqrt{-x+2} - 1$

Reflected across y -axis, right 2, stretched vertically, down 1

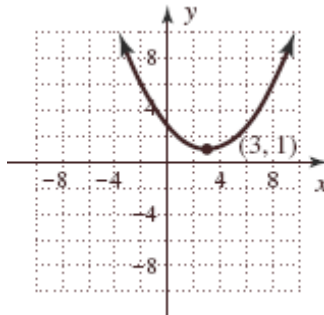
Initial point: $(2, -1)$



91. $h(x) = \frac{1}{5}(x-3)^2 + 1$

Right 3, compressed vertically, up 1

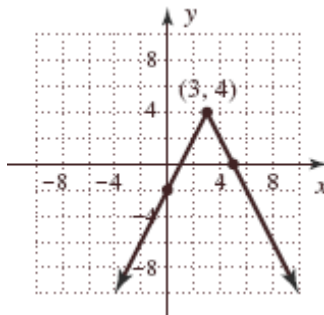
Vertex: $(3, 1)$



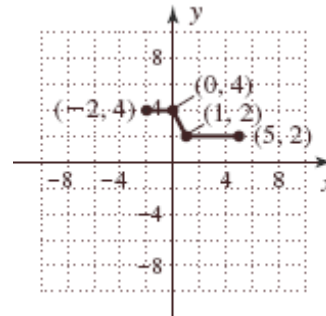
92. $H(x) = -2|x-3| + 4$

Right 3, reflected across x -axis, stretched vertically, up 4

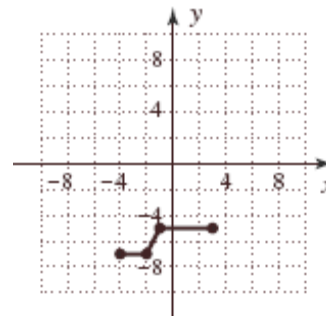
Vertex: $(3, 4)$



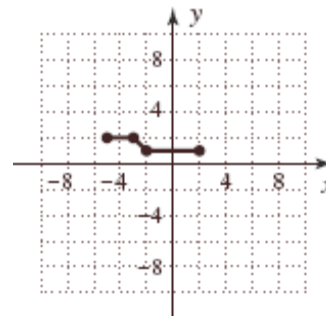
93. a. $f(x-2)$



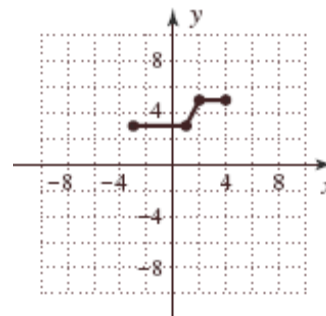
b. $-f(x) - 3$



c. $\frac{1}{2}f(x+1)$

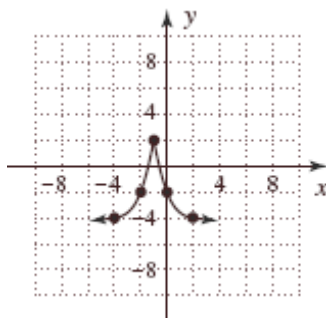


d. $f(-x) + 1$

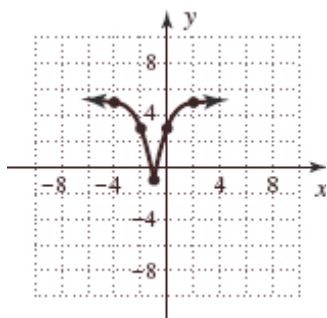


2.6 Exercises

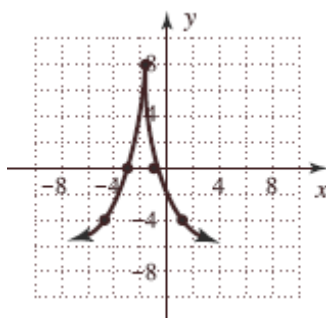
94. a. $g(x) - 2$



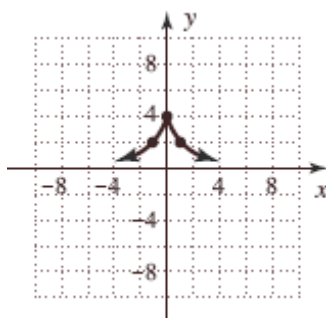
b. $-g(x) + 3$



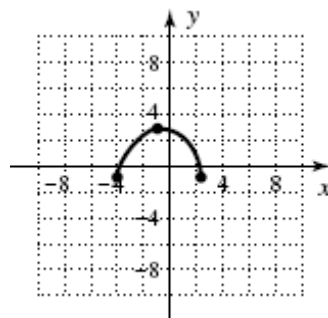
c. $2g(x + 1)$



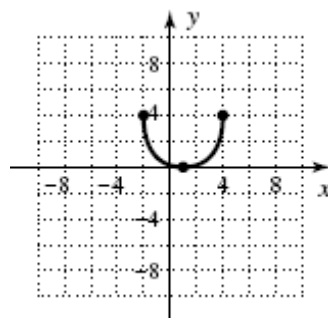
d. $\frac{1}{2}g(x - 1) + 2$



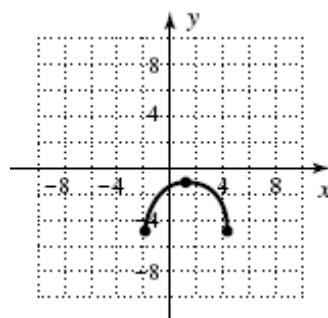
95. a. $h(x) + 3$



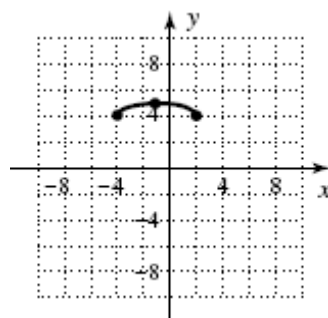
b. $-h(x - 2)$



c. $h(x - 2) - 1$

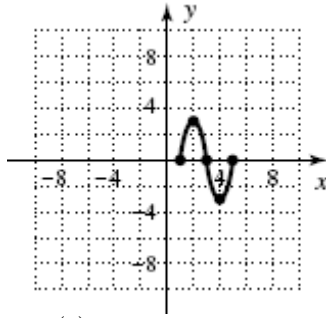


d. $\frac{1}{4}h(x) + 5$

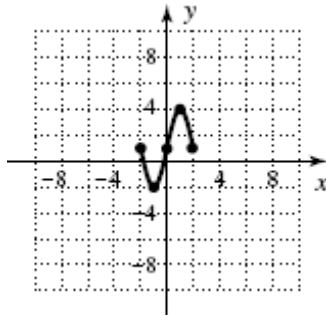


Chapter 2: Relations, Functions and Graphs

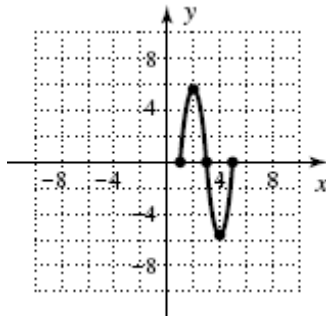
96. a. $H(x-3)$



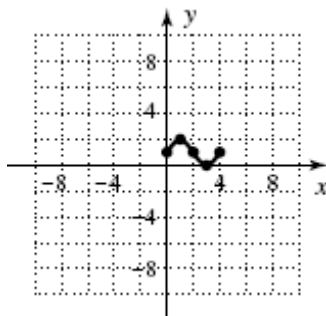
b. $-H(x)+1$



c. $2H(x-3)$



d. $\frac{1}{3}H(x-2)+1$



97. Vertex: (2, 0)

Point: (0, -4)

$$y = a(x-h)^2 + k$$

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

$$-4 = 4a$$

$$-1 = a;$$

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

98. Vertex: (0, -4)

Point: (-5, 6)

$$y = a(x-h)^2 + k$$

$$6 = a(-5-0)^2 - 4$$

$$6 = 25a - 4$$

$$10 = 25a$$

$$\frac{2}{5} = a;$$

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

99. Node: (-3, 0)

Point: (6, 4.5)

$$y = a\sqrt{x-h} + k$$

$$4.5 = a\sqrt{6-(-3)} + 0$$

$$4.5 = 3a$$

$$1.5 = a;$$

$$y = 1.5\sqrt{x+3}$$

100. Initial point: (-4, 5)

Point: (5, -1)

$$y = a\sqrt{x-h} + k$$

$$-1 = a\sqrt{5-(-4)} + 5$$

$$-6 = 3a$$

$$-2 = a;$$

$$y = -2\sqrt{x+4} + 5$$

101. Vertex: (-4, 0)

Point: (1, 4)

$$y = a|x-h| + k$$

$$4 = a|1+4| + 0$$

$$4 = 5a$$

$$\frac{4}{5} = a;$$

$$y = \frac{4}{5}|x+4|$$

2.6 Exercises

102. Vertex: (3, 7)

Point: (0, -2)

$$y = a|x - h| + k$$

$$-2 = a|0 - 3| + 7$$

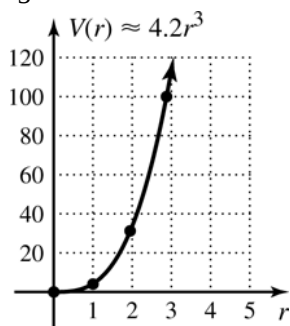
$$-9 = 3a$$

$$-3 = a;$$

$$y = -3|x - 3| + 7$$

103. $V = \frac{4}{3}\pi r^3$

$$\frac{4}{3}\pi \approx 4.2$$



Volume estimate: 70 in³

$$V = \frac{4}{3}\pi r^3$$

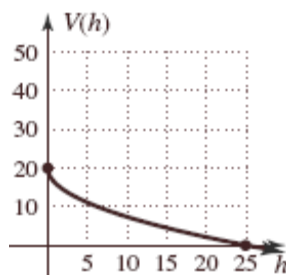
$$V = \frac{4}{3}\pi(2.5)^3$$

$$V = \frac{4}{3}\pi(15.625) \approx 65.4 \text{ in}^3$$

Yes

104. $V(h) = -4\sqrt{h} + 20$

h	$V(h) = -4\sqrt{h} + 20$
1	$V(1) = -4\sqrt{1} + 20 = -4 + 20 = 16$
4	$V(4) = -4\sqrt{4} + 20 = -8 + 20 = 12$
9	$V(9) = -4\sqrt{9} + 20 = -12 + 20 = 8$
16	$V(16) = -4\sqrt{16} + 20 = -16 + 20 = 4$
25	$V(25) = -4\sqrt{25} + 20 = -20 + 20 = 0$



Velocity estimate: 9 ft/sec

$$V(7) = -4\sqrt{7} + 20 \approx 9.4 \text{ ft/sec}$$

Answers are close.

$$5 = -4\sqrt{h} + 20$$

$$-15 = -4\sqrt{h}$$

$$3.75 = \sqrt{h}$$

$$14.0625 = h$$

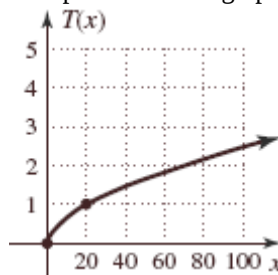
At 5 ft/sec, the water level is about 14 feet.

105. $T(x) = \frac{1}{4}\sqrt{x}$

The graph can be obtained from $y = \sqrt{x}$ if it is compressed vertically.

$$T(81) = \frac{1}{4}\sqrt{81} = \frac{1}{4}(9) = 2.25 \text{ sec}$$

This point is on the graph.

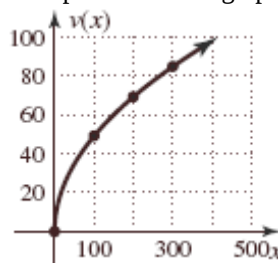


106. $v(x) = 4.9\sqrt{x}$

The graph can be obtained from $y = \sqrt{x}$ if it is stretched vertically.

$$v(225) = 4.9\sqrt{225} = 73.5 \text{ mph}$$

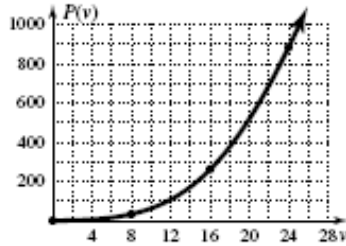
This point is on the graph.



Chapter 2: Relations, Functions and Graphs

107. $P(v) = \frac{8}{125}v^3$

- a. The graph can be obtained from $y = v^3$ if it is compressed vertically.
b.



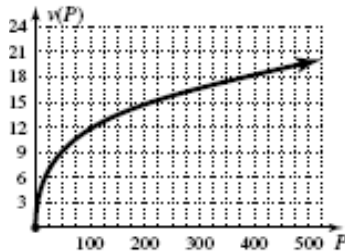
$$P(15) = \frac{8}{125}(15)^3 = 216 \text{ watts}$$

- c. About 15.6, 161.5, Power increases dramatically at higher windspeeds.

108. $v(P) = \left(\frac{5}{2}\right)\sqrt[3]{P}$

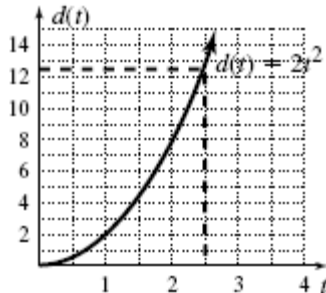
Stretched vertically

$$v(343) = \left(\frac{5}{2}\right)\sqrt[3]{343} = \frac{5}{2}(7) = 17.5 \text{ mph}$$



109. $d(t) = 2t^2$

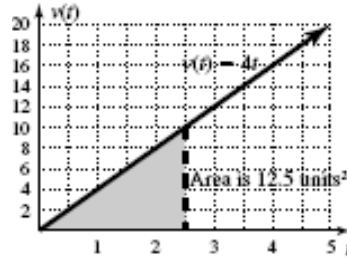
- a. Vertical stretch by a factor of 2



- b. $d(2.5) = 2(2.5)^2 = 2(6.25) = 12.5 \text{ ft}$
c. 5, 13, distance fallen per unit time increases very fast.

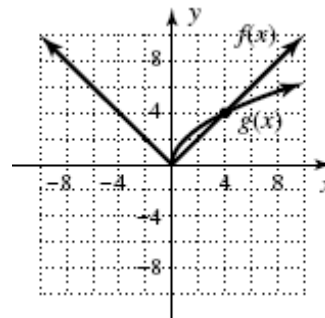
110. $v(t) = 4t$

Vertical stretch by a factor of 4.



$$v(2.5) = 4(2.5) = 10 \text{ ft/sec}$$

111. $f(x) = |x|$ and $g(x) = 2\sqrt{x}$



Interval: $x \in (0, 4)$

$$x = 1$$

$$f(1) = |1| = 1 \text{ and } g(1) = 2\sqrt{1} = 2$$

$$g(h) > f(h)$$

Interval: $x \in (4, \infty)$

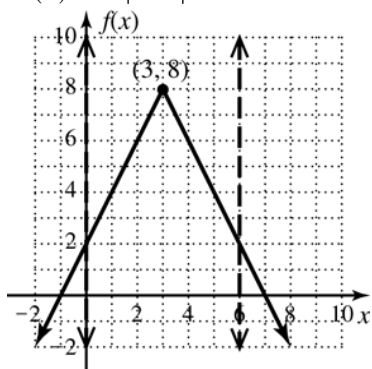
$$x = 9$$

$$f(9) = |9| = 9 \text{ and } g(9) = 2\sqrt{9} = 6$$

$$g(k) < f(k)$$

2.6 Exercises

112. $f(x) = -2|x-3| + 8$



$A = \text{Area of rectangle} + \text{Area of triangular segment}$

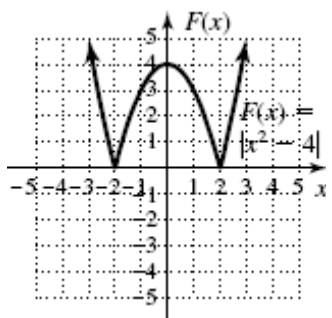
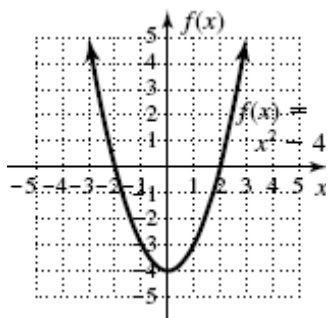
$$A = lw + \frac{1}{2}ab$$

$$A = 2(6-0) + \frac{1}{2}(6-0)(8-2)$$

$$A = 30 \text{ units}^2$$

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

$$F(x) = |x^2 - 4|$$



Any points in QIII and IV will be reflected across the x -axis and thus move to QI and II.

114. $(-13, 9)$ and $(7, -12)$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$d = \sqrt{(7 + 13)^2 + (-12 - 9)^2}$$

$$d = \sqrt{(20)^2 + (-21)^2}$$

$$d = \sqrt{400 + 441}$$

$$d = \sqrt{841} = 29 \text{ miles}$$

$$M = \frac{y_2 - y_1}{x_2 - x_1} = \frac{-12 - 9}{7 + 13} = \frac{-21}{20}$$

115. $P = 32 + 32 + 38 + 24 + 6 + 8 = 140 \text{ in.}$

$$A = 32(32) + 24(6) = 1024 + 144 = 1168 \text{ in}^2$$

116. $\frac{2}{3}x + \frac{1}{4} = \frac{1}{2}x - \frac{7}{12}$

$$12\left(\frac{2}{3}x + \frac{1}{4} = \frac{1}{2}x - \frac{7}{12}\right)$$

$$8x + 3 = 6x - 7$$

$$2x = -10$$

$$x = -5$$

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

Quadratic, opens upward, Vertex $(4, 3)$

$$f(x) \downarrow: (-\infty, 4);$$

$$f(x) \uparrow: (4, \infty)$$

Chapter 2: Relations, Functions and Graphs

2.7 Technology Highlight

Exercise 1: They are approaching 4; not defined.

Exercise 2: $Y_1 = 4$, Y_2 has a rounding error.

Calculator is rounding to 4; No.

2.7 Exercises

- Continuous
- Domain
- Smooth
- Open
- Each piece must be continuous on the corresponding interval, and the function values at the endpoints of each interval must be equal. Answers will vary.
- Answers will vary.

$$7. \quad a. \quad f(x) = \begin{cases} x^2 - 6x + 10 & 0 \leq x \leq 5 \\ \frac{3}{2}x - \frac{5}{2} & 5 < x \leq 9 \end{cases}$$

b. $y \in [1, 11]$

$$8. \quad a. \quad f(x) = \begin{cases} -1.5|x-5| + 10 & 1 \leq x < 7 \\ -\sqrt{x-7} + 5 & x \geq 7 \end{cases}$$

b. $y \in (-\infty, 10]$

$$9. \quad h(x) = \begin{cases} -2 & x < -2 \\ |x| & -2 \leq x < 3 \\ 5 & x \geq 3 \end{cases}$$

$$h(-5) = -2;$$

$$h(-2) = |-2| = 2;$$

$$h\left(-\frac{1}{2}\right) = \left|-\frac{1}{2}\right| = \frac{1}{2};$$

$$h(0) = |0| = 0;$$

$$h(2.999) = |2.999| = 2.999;$$

$$h(3) = 5$$

$$10. \quad H(x) = \begin{cases} 2x+3 & x < 0 \\ x^2+1 & 0 \leq x < 2 \\ 5 & x \geq 2 \end{cases}$$

$$H(-3) = 2(-3) + 3 = -6 + 3 = -3;$$

$$H\left(\frac{-3}{2}\right) = 2\left(\frac{-3}{2}\right) + 3 = -3 + 3 = 0;$$

$$H(-0.001) = 2(-0.001) + 3 = 2.998;$$

$$H(1) = (1)^2 + 1 = 2;$$

$$H(2) = \text{not defined};$$

$$H(3) = 5$$

$$11. \quad p(x) = \begin{cases} 5 & x < -3 \\ x^2 - 4 & -3 \leq x \leq 3 \\ 2x + 1 & x > 3 \end{cases}$$

$$p(-5) = 5;$$

$$p(-3) = (-3)^2 - 4 = 9 - 4 = 5;$$

$$p(-2) = (-2)^2 - 4 = 4 - 4 = 0;$$

$$p(0) = (0)^2 - 4 = 0 - 4 = -4;$$

$$p(3) = (3)^2 - 4 = 9 - 4 = 5;$$

$$p(5) = 2(5) + 1 = 10 + 1 = 11$$

$$12. \quad q(x) = \begin{cases} -x-3 & x < -1 \\ 2 & -1 \leq x < 2 \\ -\frac{1}{2}x^2 + 3x - 2 & x \geq 2 \end{cases}$$

$$q(-3) = -(-3) - 3 = 3 - 3 = 0;$$

$$q(-1) = 2;$$

$$q(0) = 2;$$

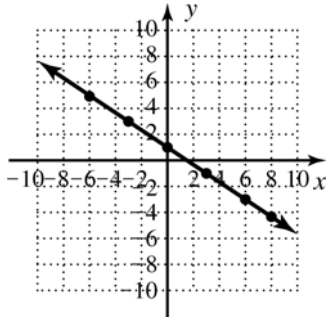
$$q(1.999) = 2;$$

$$q(2) = -\frac{1}{2}(2)^2 + 3(2) - 2 = -2 + 6 - 2 = 2;$$

$$q(4) = -\frac{1}{2}(4)^2 + 3(4) - 2 = -8 + 12 - 2 = 2$$

2.7 Exercises

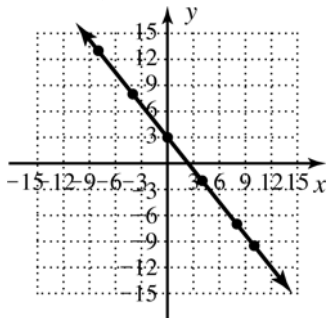
$$13. p(x) = \begin{cases} x+2 & -6 \leq x \leq 2 \\ 2|x-4| & x > 2 \end{cases}$$



$$D: x \in [-6, \infty)$$

$$R: y \in [-4, \infty)$$

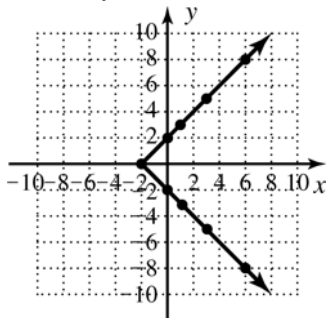
$$14. q(x) = \begin{cases} \sqrt{x+4} & -4 \leq x \leq 0 \\ |x-2| & 0 < x \leq 7 \end{cases}$$



$$D: x \in [-4, 7]$$

$$R: y \in [0, 5]$$

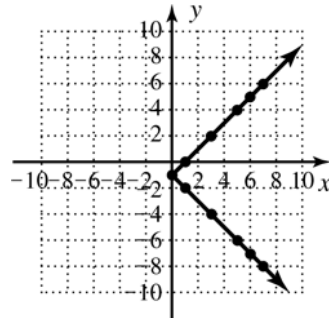
$$15. g(x) = \begin{cases} -(x-1)^2 + 5 & -2 \leq x \leq 4 \\ 2x-12 & x > 4 \end{cases}$$



$$D: x \in [-2, \infty)$$

$$R: y \in [-4, \infty)$$

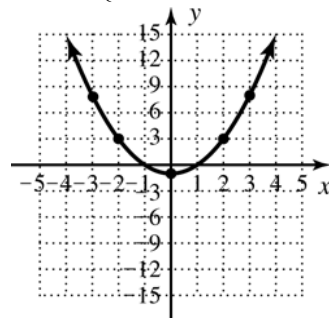
$$16. h(x) = \begin{cases} \frac{1}{2}x+1 & x \leq 0 \\ (x-2)^2 - 3 & 0 < x \leq 5 \end{cases}$$



$$D: x \in (-\infty, 5]$$

$$R: y \in (-\infty, 6]$$

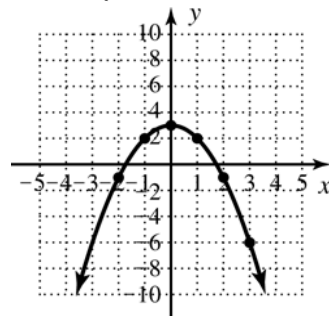
$$17. p(x) = \begin{cases} \frac{1}{2}x+1 & x \neq 4 \\ 2 & x = 4 \end{cases}$$



$$D: x \in (-\infty, \infty)$$

$$R: y \in (-\infty, 3) \cup (3, \infty)$$

$$18. q(x) = \begin{cases} \frac{1}{2}(x-1)^3 - 1 & x \neq 3 \\ -2 & x = 3 \end{cases}$$

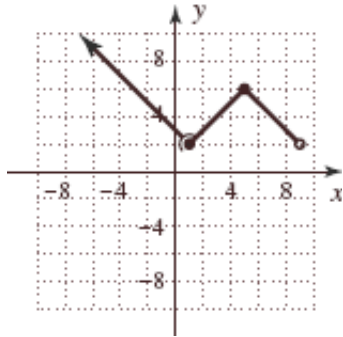


$$D: x \in (-\infty, \infty)$$

$$R: y \in (-\infty, 3) \cup (3, \infty)$$

Chapter 2: Relations, Functions and Graphs

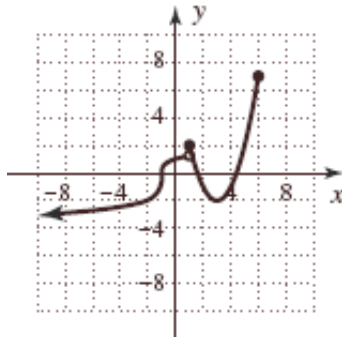
19. $H(x) = \begin{cases} -x+3 & x < 1 \\ -|x-5|+6 & 1 \leq x < 9 \end{cases}$



$D: x \in (-\infty, 9)$

$R: y \in [2, \infty)$

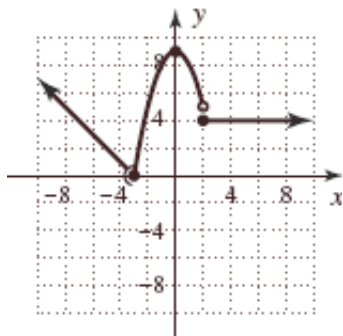
20. $w(x) = \begin{cases} \sqrt[3]{x+1} & x < 1 \\ (x-3)^2 - 2 & 1 \leq x \leq 6 \end{cases}$



$D: x \in (-\infty, 6]$

$R: y \in (-\infty, 7]$

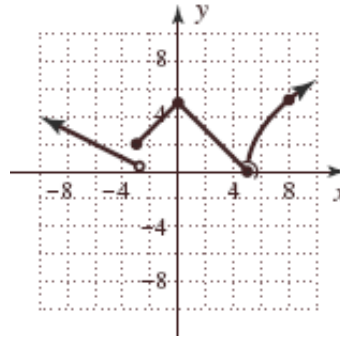
21. $f(x) = \begin{cases} -x-3 & x < -3 \\ 9-x^2 & -3 \leq x < 2 \\ 4 & x \geq 2 \end{cases}$



$D: x \in (-\infty, \infty)$

$R: y \in [0, \infty)$

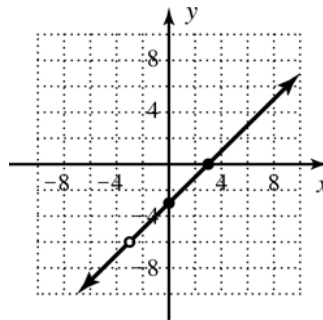
22. $h(x) = \begin{cases} -\frac{1}{2}x-1 & x < -3 \\ -|x|+5 & -3 \leq x \leq 5 \\ 3\sqrt{x-5} & x > 5 \end{cases}$



$D: x \in (-\infty, \infty)$

$R: y \in [0, \infty)$

23. $f(x) = \begin{cases} \frac{x^2-9}{x+3} & x \neq -3 \\ c & x = -3 \end{cases}$



$D: x \in (-\infty, \infty)$

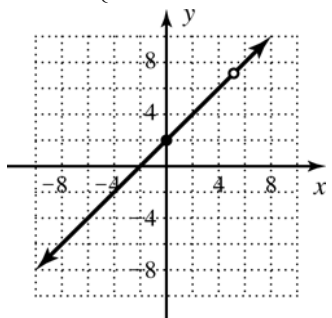
$R: y \in (-\infty, -6) \cup (-6, \infty)$

Discontinuity at $x = -3$

Redefine $f(x) = -6$ at $x = -3$; $c = -6$

2.7 Exercises

$$24. f(x) = \begin{cases} \frac{x^2 - 3x - 10}{x - 5} & x \neq 5 \\ c & x = 5 \end{cases}$$



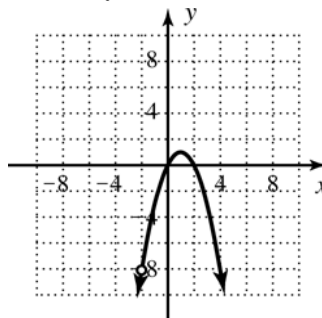
$$D: x \in (-\infty, \infty)$$

$$R: y \in (-\infty, 7) \cup (7, \infty)$$

Discontinuity at $x = 5$

Redefine $f(x) = 7$ at $x = 5$; $c = 7$

$$26. f(x) = \begin{cases} \frac{4x - x^3}{x + 2} & x \neq -2 \\ c & x = -2 \end{cases}$$



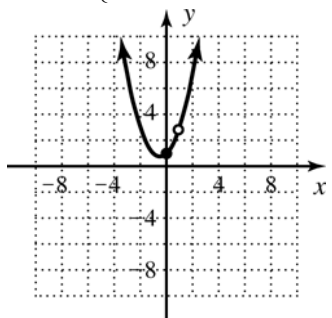
$$D: x \in (-\infty, \infty)$$

$$R: y \in (-\infty, 1]$$

Discontinuity at $x = -2$

Redefine $f(x) = -8$ at $x = -2$; $c = -8$

$$25. f(x) = \begin{cases} \frac{x^3 - 1}{x - 1} & x \neq 1 \\ c & x = 1 \end{cases}$$



$$D: x \in (-\infty, \infty)$$

$$R: y \in [0.75, \infty)$$

Discontinuity at $x = 1$

Redefine $f(x) = 3$ at $x = 1$; $c = 3$

27. Left line contains the points $(-4, -3)$ and $(2, 0)$.

$$m = \frac{0 - (-3)}{2 - (-4)} = \frac{1}{2};$$

$$y - 0 = \frac{1}{2}(x - 2)$$

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

Right line contains the points $(2, 0)$ and $(3, 3)$.

$$m = \frac{3 - 0}{3 - 2} = 3;$$

$$y - 0 = 3(x - 2)$$

$$y = 3x - 6;$$

$$f(x) = \begin{cases} \frac{1}{2}x - 1 & -4 \leq x < 2 \\ 3x - 6 & x \geq 2 \end{cases}$$

28. Left line contains the points $(-4, 2)$ and $(-2, 0)$.

$$m = \frac{0 - 2}{-2 - (-4)} = -1;$$

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

$$y = -x - 2;$$

The second equation is an absolute value function with vertex $(1, 3)$ and reflected across the x -axis.

$$g(x) = \begin{cases} -x - 2 & x \leq -2 \\ -|x - 1| + 3 & -2 \leq x \leq 5 \end{cases}$$

Chapter 2: Relations, Functions and Graphs

29. The first equation is a quadratic with vertex $(-1, -4)$, opening up.

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

$$y = x^2 + 2x - 3;$$

The line is bounded by $(1, 2)$ and contains $(4, 5)$.

$$m = \frac{5-2}{4-1} = 1$$

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

$$y = x + 1;$$

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

30. The first equation is a horizontal line:

$$y = -2;$$

The second equation is a line with slope 1 and y -intercept $(0, 0)$. $y = x$;

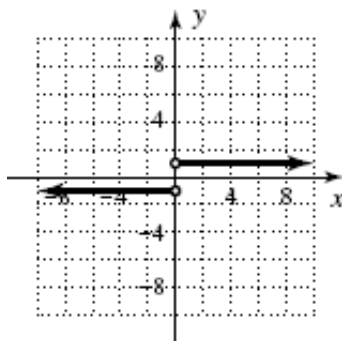
The third equation is a square root function with the vertex $(1, 1)$. $y = \sqrt{x-1} + 1$;

$$q(x) = \begin{cases} -2 & x \leq -1 \\ x & -1 \leq x \leq 1 \\ \sqrt{x-1} + 1 & x > 1 \end{cases}$$

31. $|x| = \begin{cases} -x & x < 0 \\ x & x \geq 0 \end{cases}$

$$f(x) = \frac{|x|}{x}$$

Graph is discontinuous at $x = 0$.



If $x < 0$, $f(x) = -1$.

If $x > 0$, $f(x) = 1$.

32.

$$f(x) = \begin{cases} -|x-2|+1 & 1 \leq x < 3 \\ -|x-4|+1 & 3 \leq x < 5 \\ -|x-2k|+1 & 2k-1 \leq x < 2k+1 \text{ for } k \in \mathbb{N} \end{cases}$$

Answers will vary.

$$33. \text{ a. } S(t) = \begin{cases} -t^2 + 6t & 0 \leq t \leq 5 \\ 500 & t > 5 \end{cases}$$

$$\text{b. } S(t) \in [0, 9]$$

$$34. \text{ a. } f(t) = \begin{cases} -0.13t^2 + 8.1t + 208 & 4 \leq t \leq 38 \\ -5.75|t-46| + 374 & 38 < t < 54 \\ -2.45x + 460 & t \geq 54 \end{cases}$$

$$\text{b. } f(t) \in [0, 374]$$

$$35. \text{ P}(t) = \begin{cases} -0.03t^2 + 1.28t + 1.68 & 0 \leq t \leq 30 \\ 1.89t - 43.5 & t > 30 \end{cases}$$

$$\text{a. } P(5) = -0.03(5)^2 + 1.28(5) + 1.68 = 7.33$$

$$P(15) = -0.03(15)^2 + 1.28(15) + 1.68 = 14.13$$

$$P(25) = -0.03(25)^2 + 1.28(25) + 1.68 = 14.93$$

$$P(35) = 1.89(35) - 43.5 = 22.65$$

$$P(45) = 1.89(45) - 43.5 = 41.55$$

$$P(55) = 1.89(55) - 43.5 = 60.45$$

- b. Each piece gives a slightly different value due to rounding of coefficients in each model. At $t = 30$ we use the "first" piece: $P(30) = 13.08$.

$$36. \begin{cases} 0.047t^2 - 0.38t + 1.9 & 0 \leq t < 8 \\ -0.075t^2 + 1.495t - 5.265 & 8 \leq t \leq 11 \\ 0.133t + 0.685 & t > 11 \end{cases}$$

$$\text{a. } A(3) = 0.047(3)^2 - 0.38(3) + 1.9 = 1.183$$

$$A(9) = -0.075(9)^2 + 1.495(9) - 5.265 = 2.115$$

$$A(15) = 0.133(15) + 0.685 = 2.68$$

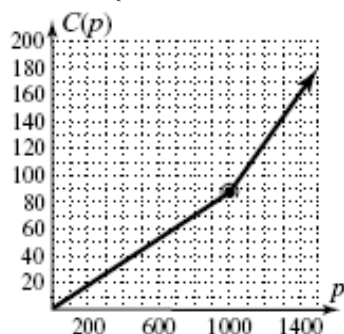
$$A(25) = 0.133(25) + 0.685 = 4.01$$

$$\text{b. } A(4) = 0.047(4)^2 - 0.38(4) + 1.9 = 1.1$$

About 1.1 billion barrels

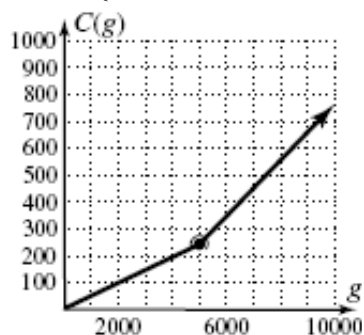
2.7 Exercises

$$37. C(h) = \begin{cases} 0.09h & 0 \leq h \leq 1000 \\ 0.18h - 90 & h > 1000 \end{cases}$$



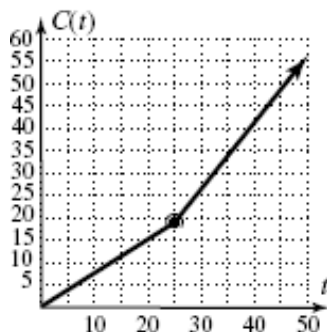
$$C(1200) = 0.18(1200) - 90 = 216 - 90 = \$126$$

$$38. C(w) = \begin{cases} 0.05w & 0 \leq w \leq 5000 \\ 0.10w - 250 & w > 5000 \end{cases}$$



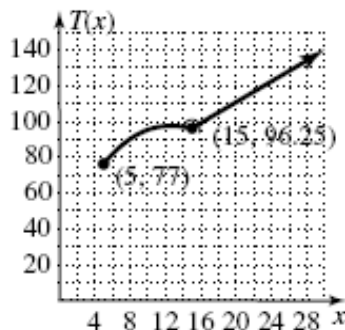
$$C(9500) = 0.10(9500) - 250 \\ = 950 - 250 = \$700$$

$$39. C(t) = \begin{cases} 0.75t & 0 \leq t \leq 25 \\ 1.5t - 18.75 & t > 25 \end{cases}$$



$$C(45) = 1.5(45) - 18.75 = \$48.75$$

$$40. T(x) = \begin{cases} -0.21x^2 + 6.1x + 52 & 5 \leq x \leq 15 \\ 4.53x + 28.3 & x > 15 \end{cases}$$



$$f(10) = -0.21(10)^2 + 6.1(10) + 52 = 92$$

92,000 births;

$$f(20) = 4.53(20) + 28.3 = 118.9$$

$\approx 119,000$ births;

$$f(25) = 4.53(25) + 28.3 = 141.55$$

$\approx 142,000$ births;

$$f(30) = 4.53(30) + 28.3 = 164.2$$

$\approx 164,000$ births

$$41. S(t) = \begin{cases} -1.35t^2 + 31.9t + 152 & 0 \leq t \leq 12 \\ 2.5t^2 - 80.6t + 950 & 12 < t \leq 22 \end{cases}$$

$$S(25) = 2.5(25)^2 - 80.6(25) + 950$$

$$= 2.5(625) - 2015 + 950 = 497.5$$

$\approx \$498$ billion;

$$S(28) = 2.5(28)^2 - 80.6(28) + 950$$

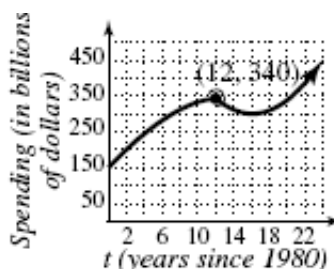
$$= 2.5(784) - 2256.8 + 950 = 653.2$$

$\approx \$653$ billion;

$$S(30) = 2.5(30)^2 - 80.6(30) + 950$$

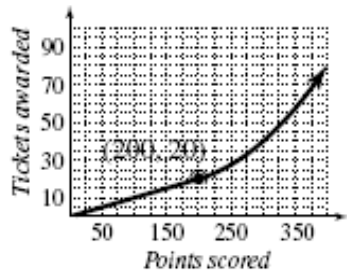
$$= 2.5(900) - 2418 + 950 = 782$$

$\approx \$782$ billion



Chapter 2: Relations, Functions and Graphs

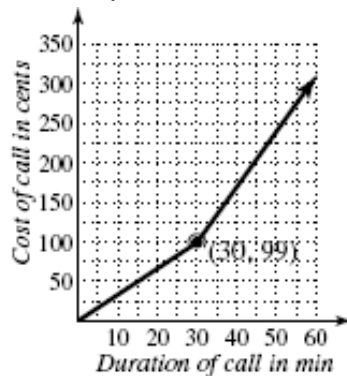
$$42. T(x) = \begin{cases} \frac{x}{10} & 0 \leq x \leq 200 \\ 0.001x^2 - 0.3x + 40 & x > 200 \end{cases}$$



$$T(390) = 0.001(390)^2 - 0.3(390) + 40 \\ = 75 \text{ tickets}$$

$$43. C(m) = \begin{cases} 3.3m & 0 \leq m \leq 30 \\ 3.3(30) + 7(m - 30) & m > 30 \end{cases}$$

$$C(m) = \begin{cases} 3.3m & 0 \leq m \leq 30 \\ 7m - 111 & m > 30 \end{cases}$$

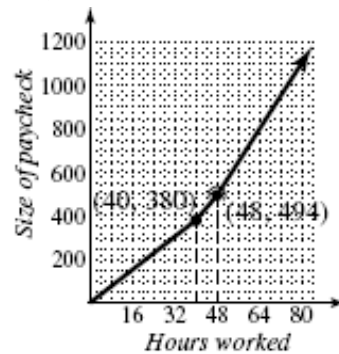


$$C(46) = 7(46) - 111 = \$2.11$$

$$44. W(h)$$

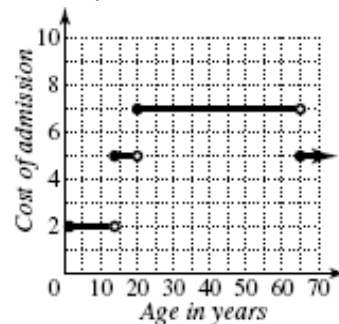
$$= \begin{cases} 9.50h & 0 \leq h \leq 40 \\ 9.50(40) + 14.25(h - 40) & 41 \leq h \leq 48 \\ 9.50(40) + 14.25(8) + 19.00(h - 48) & 48 < h < 84 \end{cases}$$

$$= \begin{cases} 9.50h & 0 \leq h \leq 40 \\ 14.25h - 190 & 40 < h \leq 48 \\ 19h - 418 & 48 < h < 84 \end{cases}$$



$$W(54) = 19(54) - 418 = \$608$$

$$45. C(a) = \begin{cases} 0 & a < 2 \\ 2 & 2 \leq a < 13 \\ 5 & 13 \leq a < 20 \\ 7 & 20 \leq a < 65 \\ 5 & a \geq 65 \end{cases}$$



One grandparent:

$$C(70) = 5 ;$$

Two adults:

$$C(44) = 7; C(45) = 7 ;$$

Three teenagers:

$$3 \cdot 5 = 15 ;$$

Two children:

$$2 \cdot 2 = 4 ;$$

One infant: 0

$$\text{Total Cost: } 5 + 7 + 7 + 15 + 4 + 0 = \$38$$

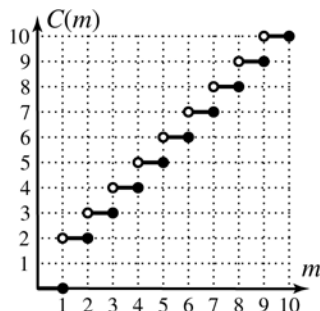
2.7 Exercises

46. a. $A(t) = \lfloor t \rfloor$
 b. $0 \leq t < 123$
 c. 36 years
 d. 36 years
 e. 37 years
 f. 37 years

47. a. $C(w) = 17\lceil w-1 \rceil + 80$
 For an envelope weighing between 0 and 1 oz, the cost is \$0.80. Each step interval increases by 0.17.
 b. $0 < w \leq 13$
 c. 80 cents
 d. 165 cents
 e. 165 cents
 f. 165 cents
 g. 182 cents

48. a. $C(m) = \begin{cases} 0 & 0 < m \leq 1 \\ \lceil m \rceil & m > 1 \end{cases}$

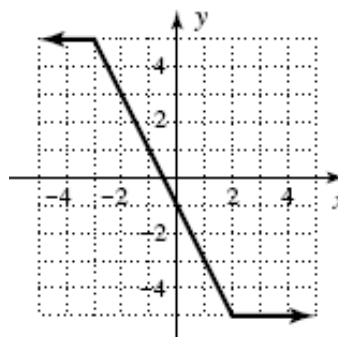
b.



- c. 2 min 3 sec $\rightarrow$ 3;
 13 min 46 sec $\rightarrow$ 14;
 1 min 5 sec $\rightarrow$ 2;
 3 min 59 sec $\rightarrow$ 4;
 8 min 2 sec $\rightarrow$ 9;
 $3+14+2+4+9=32$ min
 Yes, free 30 min has been exceeded.
 d. $2+13+1+3+8=27$ min;
 $3+46+5+59+2=115$ sec;
 27 min 115 sec = 28 min 55 sec

49. $h(x) = |x-2| - |x+3|$

x	$h(x) = x-2 - x+3 $
-5	$h(-5) = -5-2 - -5+3 = 7-2=5$
-4	$h(-4) = -4-2 - -4+3 = 6-1=5$
-3	$h(-3) = -3-2 - -3+3 = 5-0=5$
-2	$h(-2) = -2-2 - -2+3 = 4-1=3$
-1	$h(-1) = -1-2 - -1+3 = 3-2=1$
0	$h(0) = 0-2 - 0+3 = 2-3=-1$
1	$h(1) = 1-2 - 1+3 = 1-4=-3$
2	$h(2) = 2-2 - 2+3 = 0-5=-5$
3	$h(3) = 3-2 - 3+3 = 1-6=-5$
4	$h(4) = 4-2 - 4+3 = 2-7=-5$
5	$h(5) = 5-2 - 5+3 = 3-8=-5$



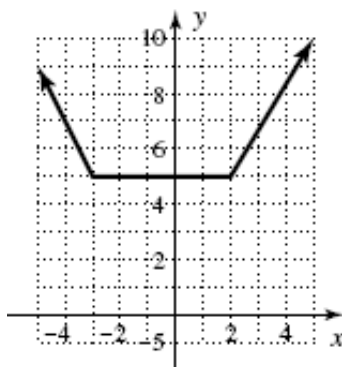
The function is continuous.

$$h(x) = \begin{cases} 5 & x \leq -3 \\ -2x-1 & -3 < x < 2 \\ -5 & x \geq 2 \end{cases}$$

Chapter 2: Relations, Functions and Graphs

50. $H(x) = |x-2| + |x+3|$

x	$H(x) = x-2 + x+3 $
-5	$H(-5) = -5-2 + -5+3 = 7+2=9$
-4	$H(-4) = -4-2 + -4+3 = 6+1=7$
-3	$H(-3) = -3-2 + -3+3 = 5+0=5$
-2	$H(-2) = -2-2 + -2+3 = 4+1=5$
-1	$H(-1) = -1-2 + -1+3 = 3+2=5$
0	$H(0) = 0-2 + 0+3 = 2+3=5$
1	$H(1) = 1-2 + 1+3 = 1+4=5$
2	$H(2) = 2-2 + 2+3 = 0+5=5$
3	$H(3) = 3-2 + 3+3 = 1+6=7$
4	$H(4) = 4-2 + 4+3 = 2+7=9$
5	$H(5) = 5-2 + 5+3 = 3+8=11$



The function is continuous.

$$h(x) = \begin{cases} -2x-1 & x < -3 \\ 5 & -3 \leq x \leq 2 \\ 2x+1 & x > 2 \end{cases}$$

51. $Y_1 = \frac{x+2}{x+2}$, $Y_2 = \frac{|x+2|}{x+2}$

Y_1 has a removable discontinuity at $x = -2$.

Y_2 is discontinuous at $x = -2$.

52. $f(x) = \begin{cases} x^2 & x < 1 \\ 4x-3 & 1 \leq x \leq 3 \\ 2x+3 & x > 3 \end{cases}$

53. $\frac{3}{x-2} + 1 = \frac{30}{x^2-4}$

$$\left(\frac{3}{x-2} + 1 = \frac{30}{(x-2)(x+2)} \right) (x-2)(x+2)$$

$$3(x+2) + 1(x-2)(x+2) = 30$$

$$3x+6 + x^2-4 = 30$$

$$x^2 + 3x - 28 = 0$$

$$(x+7)(x-4) = 0$$

$x = -7$; $x = 4$

54. $\frac{x^3+3x^2-4x-12}{x-3} \cdot \frac{2x-6}{x^2+5x+6} \div \frac{3x-6}{1}$

$$= \frac{x^2(x+3)-4(x+3)}{x-3} \cdot \frac{2(x-3)}{(x+2)(x+3)} \div \frac{3(x-2)}{1}$$

$$= \frac{(x+3)(x^2-4)}{x-3} \cdot \frac{2(x-3)}{(x+2)(x+3)} \div \frac{3(x-2)}{1}$$

$$= \frac{(x+3)(x+2)(x-2)}{x-3} \cdot \frac{2(x-3)}{(x+2)(x+3)} \cdot \frac{1}{3(x-2)}$$

$$= \frac{2}{3}$$

55. a. $a^2 + b^2 = c^2$

$$8^2 + b^2 = 12^2$$

$$64 + b^2 = 144$$

$$b^2 = 80$$

$$b = 4\sqrt{5} \text{ cm}$$

b. $A = \frac{1}{2}bh$

$$A = \frac{1}{2}(4\sqrt{5})(8)$$

$$A = 16\sqrt{5} \text{ cm}^2$$

c. $V = \left(\frac{bh}{2} \right)h$

$$V = (16\sqrt{5})(20) = 320\sqrt{5} \text{ cm}^3$$

2.8 Exercises

56. $3x + 4y = 8$
 $4y = -3x + 8$
 $y = -\frac{3}{4}x + 2$
 $m = -\frac{3}{4}$, slope of a line perpendicular to the
 given line is $\frac{4}{3}$.
 Slope $\frac{4}{3}$ passing through $(0, -2)$:
 $y = \frac{4}{3}x - 2$

2.8 Technology Highlight

Exercise 1: $Y_1 = \sqrt{x}$ and $Y_2 = x + 7$
 Yes, graph shifts 7 units to the left.

Exercise 2: $Y_1 = x^3$ and
 $Y_2 = x - 1$
 Yes, the basic function $f(x) = |x|$ shifts 1
 unit right.

2.8 Exercises

- $(f + g)(x)$; $A \cap B$
- $(f \cdot g)(5)$; $f(5) \cdot g(5)$
- Intersection; $g(x)$
- Composition; $g(x)$; $f(x)$; $f[g(x)]$
- Answers will vary.
- Answers will vary.
- Domain:
 $f(x) = 2x^2 - x - 3$; $x \in \square$;
 $g(x) = x^2 + 5x$; $x \in \square$;
 $h(x) = f(x) - g(x)$; $x \in \square$
 $h(-2) = f(-2) - g(-2)$
 - $= 2(-2)^2 - (-2) - 3 - ((-2)^2 + 5(-2))$
 $= 7 - (-6) = 13$

- Domain:
 $f(x) = 2x^2 - 18$; $x \in \square$;
 $g(x) = -3x - 7$; $x \in \square$;
 $h(x) = f(x) + g(x)$; $x \in \square$
 - $h(5) = f(5) + g(5)$
 $= 2(5)^2 - 18 + (-3(5) - 7)$
 $= 32 + (-22) = 10$
9. $h(x) = f(x) - g(x)$
- $h(x) = 2x^2 - x - 3 - (x^2 + 5x)$
 $= 2x^2 - x - 3 - x^2 - 5x$
 $= x^2 - 6x - 3$
 - $h(-2) = (-2)^2 - 6(-2) - 3 = 13$
 - Same result
10. $h(x) = f(x) + g(x)$
- $h(x) = 2x^2 - 18 + (-3x - 7)$
 $= 2x^2 - 18 - 3x - 7$
 $= 2x^2 - 3x - 25$
 - $h(5) = 2(5)^2 - 3(5) - 25 = 10$
 - Same result
11. a. Domain of $f(x) = \sqrt{x - 3}$
 $x - 3 \geq 0$
 $x \geq 3$; $[3, \infty)$
 Domain of $g(x)$: $x \in \square$;
 Domain of $h(x)$: $x \in [3, \infty)$
- $h(x) = (f + g)(x)$
 $= f(x) + g(x)$
 $= \sqrt{x - 3} + 2x^3 - 54$
 - $h(4) = \sqrt{4 - 3} + 2(4)^3 - 54 = 75$;
 $h(2) = \sqrt{2 - 3} + 2(2)^3 - 54$
 $= \sqrt{-1} + 16 - 54$
 $\sqrt{-1}$ is not a real number;
 2 is not in the domain of $h(x)$.

Chapter 2: Relations, Functions and Graphs

12. a. Domain of $f(x): x \in \mathbb{R}$;
 Domain of $g(x) = \sqrt{2x-5}$
 $2x-5 \geq 0$
 $x \geq \frac{5}{2}; x \in \left[\frac{5}{2}, \infty\right)$
 Domain of $h(x): x \in \left[\frac{5}{2}, \infty\right)$
- b. $h(x) = (f - g)(x)$
 $= f(x) - g(x)$
 $= 4x^2 - 2x + 3 - \sqrt{2x-5}$
- c. $h(7) = 4(7)^2 - 2(7) + 3 - \sqrt{2(7)-5}$
 $h(7) = 196 - 14 + 3 - \sqrt{9} = 182;$
 $h(2) = 4(2)^2 - 2(2) + 3 - \sqrt{2(2)-5}$
 $= 16 - 4 + 3 - \sqrt{-1}$
 $\sqrt{-1}$ is not a real number;
 2 is not in the domain of $h(x)$.
13. a. Domain of $p(x) = \sqrt{x+5}$
 $x+5 \geq 0$
 $x \geq -5; x \in [-5, \infty)$
 Domain of $q(x) = \sqrt{3-x}$
 $3-x \geq 0$
 $-x \geq -3$
 $x \leq 3; x \in (-\infty, 3]$
 Domain of $r(x): x \in [-5, 3]$
- b. $r(x) = (p + q)(x)$
 $= p(x) + q(x)$
 $= \sqrt{x+5} + \sqrt{3-x}$
- c. $r(2) = \sqrt{2+5} + \sqrt{3-2} = \sqrt{7} + 1$
 $r(4) = \sqrt{4+5} + \sqrt{3-4} = \sqrt{9} + \sqrt{-1}$
 $\sqrt{-1}$ is not a real number;
 4 is not in the domain of $r(x)$.
14. a. Domain of $p(x) = \sqrt{6-x}$
 $6-x \geq 0$
 $-x \geq -6$
 $x \leq 6; x \in (-\infty, 6]$
 Domain of $q(x) = \sqrt{x+2}$
 $x+2 \geq 0$
 $x \geq -2; x \in [-2, \infty)$
 Domain of $r(x): x \in [-2, 6]$
- b. $r(x) = (p - q)(x)$
 $= p(x) - q(x)$
 $= \sqrt{6-x} - \sqrt{x+2}$
- c. $r(-3) = \sqrt{6-(-3)} - \sqrt{-3+2}$
 $= \sqrt{9} + \sqrt{-1}$
 $\sqrt{-1}$ is not a real number;
 -3 is not in the domain of $r(x)$.
 $r(2) = \sqrt{6-2} - \sqrt{2+2} = 0$
15. a. Domain of $f(x) = \sqrt{x+4}$
 $x+4 \geq 0$
 $x \geq -4; x \in [-4, \infty)$
 Domain of $g(x) = 2x+3: x \in \mathbb{R}$
 Domain of $h(x): x \in [-4, \infty)$
- b. $h(x) = (f \cdot g)(x)$
 $= f(x) \cdot g(x)$
 $= \sqrt{x+4}(2x+3)$
- c. $h(-4) = \sqrt{-4+4}(2(-4)+3) = 0;$
 $h(21) = \sqrt{21+4}(2(21)+3) = 225$
16. a. Domain of $f(x) = -3x+5: x \in \mathbb{R}$
 Domain of $g(x) = \sqrt{x-7}$
 $x-7 \geq 0$
 $x \geq 7; x \in [7, \infty)$
 Domain of $h(x): x \in [7, \infty)$
- b. $h(x) = (f \cdot g)(x)$
 $= f(x) \cdot g(x)$
 $= (-3x+5)\sqrt{x-7}$
- c. $h(8) = (-3(8)+5)\sqrt{8-7} = -19(1) = -19;$
 $h(11) = (-3(11)+5)\sqrt{11-7} = -28(2) = -56$

2.8 Exercises

17. a. Domain of $p(x) = \sqrt{x+1}$
 $x+1 \geq 0$
 $x \geq -1; x \in [-1, \infty)$
 Domain of $q(x) = \sqrt{7-x}$
 $7-x \geq 0$
 $-x \geq -7$
 $x \leq 7; x \in (-\infty, 7]$
 Domain of $r(x): x \in [-1, 7]$
- b. $r(x) = (p \cdot q)(x)$
 $= p(x) \cdot q(x)$
 $= \sqrt{x+1} \cdot \sqrt{7-x}$
 $= \sqrt{-x^2 + 6x + 7}$
- c. $r(15) = \sqrt{-(15)^2 + 6(15) + 7} = \sqrt{-128}$
 $\sqrt{-128}$ is not a real number;
 15 is not in the domain of $r(x)$.
 $r(3) = \sqrt{-(3)^2 + 6(3) + 7} = \sqrt{16} = 4$
18. a. Domain of $p(x) = \sqrt{4-x}$
 $4-x \geq 0$
 $-x \geq -4$
 $x \leq 4; x \in (-\infty, 4]$
 Domain of $q(x) = \sqrt{x+4}$
 $x+4 \geq 0$
 $x \geq -4; x \in [-4, \infty)$
 Domain of $r(x): x \in [-4, 4]$
- b. $r(x) = (p \cdot q)(x)$
 $= p(x) \cdot q(x)$
 $= \sqrt{4-x} \cdot \sqrt{x+4}$
 $= \sqrt{16-x^2}$
- c. $r(-5) = \sqrt{16-(-5)^2} = \sqrt{-9}$
 $\sqrt{-9}$ is not a real number;
 -5 is not in the domain of $r(x)$.
 $r(-3) = \sqrt{16-(-3)^2} = \sqrt{7}$
19. a. Domain of $f(x) = x^2 - 16: x \in \mathbb{R}$
 Domain of $g(x) = x + 4: x \in \mathbb{R}$
 Domain of $h(x) = \frac{x^2 - 16}{x + 4}, x \neq -4$
 $x \in (-\infty, -4) \cup (-4, \infty)$
- b. $h(x) = \frac{f}{g}(x) = \frac{x^2 - 16}{x + 4}$
 $h(x) = \frac{(x+4)(x-4)}{x+4} = x-4; x \neq -4$
20. a. Domain of $f(x) = x^2 - 49: x \in \mathbb{R}$
 Domain of $g(x) = x - 7: x \in \mathbb{R}$
 Domain of $h(x) = \frac{x^2 - 49}{x - 7}, x \neq 7$
 $x \in (-\infty, 7) \cup (7, \infty)$
- b. $h(x) = \frac{f}{g}(x) = \frac{x^2 - 49}{x - 7}$
 $h(x) = \frac{(x+7)(x-7)}{x-7} = x+7; x \neq 7$
21. a. Domain of
 $f(x) = x^3 + 4x^2 - 2x - 8: x \in \mathbb{R}$
 Domain of $g(x) = x + 4, x \in \mathbb{R}$
 Domain of
 $h(x) = \frac{x^3 + 4x^2 - 2x - 8}{x + 4}, x \neq -4$
 $x \in (-\infty, -4) \cup (-4, \infty)$
- b. $h(x) = \frac{f}{g}(x) = \frac{x^3 + 4x^2 - 2x - 8}{x + 4}$
 $h(x) = \frac{x^2(x+4) - 2(x+4)}{x+4}$
 $= \frac{(x+4)(x^2 - 2)}{x+4} = x^2 - 2; x \neq -4$
22. a. Domain of
 $f(x) = x^3 - 5x^2 + 2x - 10: x \in \mathbb{R}$
 Domain of $g(x) = x - 5: x \in \mathbb{R}$
 Domain of
 $h(x) = \frac{x^3 - 5x^2 + 2x - 10}{x - 5}, x \neq 5$
 $x \in (-\infty, 5) \cup (5, \infty)$
- b. $h(x) = \frac{f}{g}(x) = \frac{x^3 - 5x^2 + 2x - 10}{x - 5}$
 $h(x) = \frac{x^2(x-5) + 2(x-5)}{x-5}$
 $= \frac{(x-5)(x^2 + 2)}{x-5} = x^2 + 2; x \neq 5$

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23. a. Domain of $f(x) = x^3 - 7x^2 + 6x : x \in \mathbb{R}$

Domain of $g(x) = x - 1 : x \in \mathbb{R}$

Domain of

$$h(x) = \frac{x^3 - 7x^2 + 6x}{x - 1}, x \neq 1$$

$$x \in (-\infty, 1) \cup (1, \infty)$$

b. $h(x) = \frac{f}{g}(x) = \frac{x^3 - 7x^2 + 6x}{x - 1}$

$$h(x) = \frac{x(x^2 - 7x + 6)}{x - 1}$$

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

$$= x^2 - 6x; x \neq 1$$

24. a. Domain of $f(x) = x^3 - 1 : x \in \mathbb{R}$

Domain of $g(x) = x - 1 : x \in \mathbb{R}$

Domain of $h(x) = \frac{x^3 - 1}{x - 1}, x \neq 1$

$$x \in (-\infty, 1) \cup (1, \infty)$$

b. $h(x) = \frac{f}{g}(x) = \frac{x^3 - 1}{x - 1}$

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

$$= x^2 + x + 1; x \neq 1$$

25. a. Domain of $f(x) = x + 1 : x \in \mathbb{R}$

Domain of $g(x) = x - 5 : x \in \mathbb{R}$

Domain of

$$h(x) = \frac{x + 1}{x - 5}, x \neq 5$$

$$x \in (-\infty, 5) \cup (5, \infty)$$

b. $h(x) = \frac{f}{g}(x) = \frac{x + 1}{x - 5}; x \neq 5$

26. a. Domain of $f(x) = x + 3 : x \in \mathbb{R}$

Domain of $g(x) = x - 7 : x \in \mathbb{R}$

Domain of

$$h(x) = \frac{x + 3}{x - 7}, x \neq 7$$

$$x \in (-\infty, 7) \cup (7, \infty)$$

b. $h(x) = \frac{f}{g}(x) = \frac{x + 3}{x - 7}; x \neq 7$

27. a. Domain of $p(x) = 2x - 3 : x \in \mathbb{R}$

Domain of $q(x) = \sqrt{-2 - x},$

$$-2 - x \geq 0$$

$$-x \geq 2$$

$$x \leq -2; x \in (-\infty, -2]$$

Domain of $r(x) = \frac{2x - 3}{\sqrt{-2 - x}},$

$$-2 - x > 0$$

$$-x > 2$$

$$x < -2; x \in (-\infty, -2)$$

b. $r(x) = \frac{p}{q}(x) = \frac{2x - 3}{\sqrt{-2 - x}}$

c. $r(6) = \frac{2(6) - 3}{\sqrt{-2 - 6}} = \frac{9}{\sqrt{-8}}$

$$\sqrt{-8} \text{ is not a real number;}$$

6 is not in the domain of $r(x)$.

$$r(-6) = \frac{2(-6) - 3}{\sqrt{-2 + 6}} = \frac{-15}{\sqrt{4}} = -\frac{15}{2}$$

28. a. Domain of $p(x) = 1 - x : x \in \mathbb{R}$

Domain of $q(x) = \sqrt{3 - x},$

$$3 - x \geq 0$$

$$-x \geq -3$$

$$x \leq 3; x \in (-\infty, 3]$$

Domain of $r(x) = \frac{1 - x}{\sqrt{3 - x}},$

$$3 - x > 0$$

$$-x > -3$$

$$x < 3; x \in (-\infty, 3)$$

b. $r(x) = \frac{p}{q}(x) = \frac{1 - x}{\sqrt{3 - x}}$

c. $r(6) = \frac{1 - 6}{\sqrt{3 - 6}} = \frac{-5}{\sqrt{-3}}$

$$\sqrt{-3} \text{ is not a real number;}$$

6 is not in the domain of $r(x)$.

$$r(-6) = \frac{1 - (-6)}{\sqrt{3 + 6}} = \frac{7}{\sqrt{9}} = \frac{7}{3}$$

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29. a. Domain of $p(x) = x - 5: x \in \square$

$$\text{Domain of } q(x) = \sqrt{x-5},$$

$$x-5 \geq 0$$

$$x \geq 5; x \in [5, \infty)$$

$$\text{Domain of } r(x) = \frac{x-5}{\sqrt{x-5}},$$

$$x-5 > 0$$

$$x > 5; x \in (5, \infty)$$

b. $r(x) = \frac{p}{q}(x) = \frac{x-5}{\sqrt{x-5}}$

c. $r(6) = \frac{6-5}{\sqrt{6-5}} = \frac{1}{\sqrt{1}} = 1$

$$r(-6) = \frac{-6-5}{\sqrt{-6-5}} = \frac{-11}{\sqrt{-11}}$$

$$\sqrt{-11} \text{ is not a real number;}$$

$$-6 \text{ is not in the domain of } r(x).$$

30. a. Domain of $p(x) = x + 2: x \in \square$

$$\text{Domain of } q(x) = \sqrt{x+3},$$

$$x+3 \geq 0$$

$$x \geq -3; x \in [-3, \infty)$$

$$\text{Domain of } r(x) = \frac{x+2}{\sqrt{x+3}},$$

$$x+3 > 0$$

$$x > -3; x \in (-3, \infty)$$

b. $r(x) = \frac{p}{q}(x) = \frac{x+2}{\sqrt{x+3}}$

c. $r(6) = \frac{6+2}{\sqrt{6+3}} = \frac{8}{\sqrt{9}} = \frac{8}{3}$

$$r(-6) = \frac{-6+2}{\sqrt{-6+3}} = \frac{-4}{\sqrt{-3}}$$

$$\sqrt{-3} \text{ is not a real number;}$$

$$-6 \text{ is not in the domain of } r(x).$$

31. a. Domain of $p(x) = x^2 - 36: x \in \square$

$$\text{Domain of } q(x) = \sqrt{2x+13},$$

$$2x+13 \geq 0$$

$$2x \geq -13$$

$$x \geq -\frac{13}{2}; x \in \left[-\frac{13}{2}, \infty\right)$$

$$\text{Domain of } r(x) = \frac{x^2-36}{\sqrt{2x+13}},$$

$$2x+13 > 0$$

$$2x > -13$$

$$x > -\frac{13}{2}; x \in \left(-\frac{13}{2}, \infty\right)$$

b. $r(x) = \frac{p}{q}(x) = \frac{x^2-36}{\sqrt{2x+13}}$

c. $r(6) = \frac{6^2-36}{\sqrt{2(6)+13}} = \frac{0}{\sqrt{25}} = 0$

$$r(-6) = \frac{(-6)^2-36}{\sqrt{2(-6)+13}} = \frac{0}{\sqrt{1}} = 0$$

32. a. Domain of $p(x) = x^2 - 6x: x \in \square$

$$\text{Domain of } q(x) = \sqrt{7+3x},$$

$$7+3x \geq 0$$

$$3x \geq -7$$

$$x \geq -\frac{7}{3}; x \in \left[-\frac{7}{3}, \infty\right)$$

$$\text{Domain of } r(x) = \frac{x^2-6x}{\sqrt{7+3x}},$$

$$7+3x > 0$$

$$3x > -7$$

$$x > -\frac{7}{3}; x \in \left(-\frac{7}{3}, \infty\right)$$

b. $r(x) = \frac{p}{q}(x) = \frac{x^2-6x}{\sqrt{7+3x}}$

c. $r(6) = \frac{(6)^2-6(6)}{\sqrt{7+3(6)}} = \frac{0}{\sqrt{25}} = 0$

$$r(-6) = \frac{(-6)^2-6(-6)}{\sqrt{7+3(-6)}} = \frac{72}{\sqrt{-11}}$$

$$\sqrt{-11} \text{ is not a real number;}$$

$$-6 \text{ is not in the domain of } r(x).$$

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33. a. $f(x) = \frac{6x}{x-3}, g(x) = \frac{3x}{x+2}$

$$h(x) = \frac{f(x)}{g(x)} = \frac{\frac{6x}{x-3}}{\frac{3x}{x+2}}$$

$$= \frac{6x}{x-3} \div \frac{3x}{x+2} = \frac{6x}{x-3} \cdot \frac{x+2}{3x}$$

$$= \frac{2(x+2)}{x-3} = \frac{2x+4}{x-3}$$

b. Domain of $h(x) = \frac{2x+4}{x-3}, x \neq 3$

$$x \in (-\infty, 3) \cup (3, \infty)$$

c. $x+2 \neq 0$

$$x \neq -2;$$

$$\frac{3x}{x+2} \neq 0$$

$$x \neq 0$$

34. a. $f(x) = \frac{4x}{x+1}, g(x) = \frac{2x}{x-2}$

$$h(x) = \frac{f(x)}{g(x)} = \frac{\frac{4x}{x+1}}{\frac{2x}{x-2}}$$

$$= \frac{4x}{x+1} \div \frac{2x}{x-2} = \frac{4x}{x+1} \cdot \frac{x-2}{2x}$$

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

b. Domain of $h(x) = \frac{2x-4}{x+1}, x \neq -1$

$$x \in (-\infty, -1) \cup (-1, \infty);$$

c. $x-2 \neq 0$

$$x \neq 2;$$

$$\frac{2x}{x-2} \neq 0$$

$$x \neq 0$$

35. $f(x) = 2x+3$ and $g(x) = x-2$

Sum:

$$f(x) + g(x) = 2x+3 + x-2 = 3x+1$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Difference:

$$f(x) - g(x) = 2x+3 - (x-2)$$

$$= 2x+3 - x+2 = x+5$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (2x+3)(x-2)$$

$$= 2x^2 - 4x + 3x - 6$$

$$= 2x^2 - x - 6$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{2x+3}{x-2}$$

$$x-2 \neq 0$$

$$x \neq 2$$

$$D: x \in (-\infty, 2) \cup (2, \infty)$$

36. $f(x) = x-5$ and $g(x) = 2x-3$

Sum:

$$f(x) + g(x) = x-5 + 2x-3 = 3x-8$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Difference:

$$f(x) - g(x) = x-5 - (2x-3)$$

$$= x-5 - 2x+3$$

$$= -x-2$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (x-5)(2x-3)$$

$$= 2x^2 - 3x - 10x + 15$$

$$= 2x^2 - 13x + 15$$

Domain contains all values of x .

$$D: x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x-5}{2x-3}$$

$$2x-3 \neq 0$$

$$2x \neq 3$$

$$x \neq \frac{3}{2}$$

$$D: x \in \left(-\infty, \frac{3}{2}\right) \cup \left(\frac{3}{2}, \infty\right)$$

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37. $f(x) = x^2 + 7$ and $g(x) = 3x - 2$

Sum:

$$f(x) + g(x) = x^2 + 7 + 3x - 2 = x^2 + 3x + 5$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Difference:

$$f(x) - g(x) = x^2 + 7 - (3x - 2)$$

$$= x^2 + 7 - 3x + 2$$

$$= x^2 - 3x + 9$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (x^2 + 7)(3x - 2)$$

$$= 3x^3 - 2x^2 + 21x - 14$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x^2 + 7}{3x - 2}$$

$$3x - 2 \neq 0$$

$$3x \neq 2$$

$$x \neq \frac{2}{3}$$

$$D : x \in \left(-\infty, \frac{2}{3}\right) \cup \left(\frac{2}{3}, \infty\right)$$

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

Sum:

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

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Difference:

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

$$= x^2 - 3x - x - 4$$

$$= x^2 - 4x - 4$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (x^2 - 3x)(x + 4)$$

$$= x^3 + 4x^2 - 3x^2 - 12x$$

$$= x^3 + x^2 - 12x$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x^2 - 3x}{x + 4}$$

$$x + 4 \neq 0$$

$$x \neq -4$$

$$D : x \in (-\infty, -4) \cup (-4, \infty)$$

39. $f(x) = x^2 + 2x - 3$ and $g(x) = x - 1$

Sum:

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

$$= x^2 + 3x - 4$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Difference:

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

$$= x^2 + 2x - 3 - x + 1$$

$$= x^2 + x - 2$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (x^2 + 2x - 3)(x - 1)$$

$$= x^3 - x^2 + 2x^2 - 2x - 3x + 3$$

$$= x^3 + x^2 - 5x + 3$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x^2 + 2x - 3}{x - 1}$$

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

$$x - 1 \neq 0$$

$$x \neq 1$$

$$D : x \in (-\infty, 1) \cup (1, \infty)$$

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40. $f(x) = x^2 - 2x - 15$ and $g(x) = x + 3$

Sum:

$$f(x) + g(x) = x^2 - 2x - 15 + x + 3$$

$$= x^2 - x - 12$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Difference:

$$f(x) - g(x) = x^2 - 2x - 15 - (x + 3)$$

$$= x^2 - 2x - 15 - x - 3$$

$$= x^2 - 3x - 18$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Product:

$$f(x) \cdot g(x) = (x^2 - 2x - 15)(x + 3)$$

$$= x^3 + 3x^2 - 2x^2 - 6x - 15x - 45$$

$$= x^3 + x^2 - 21x - 45$$

Domain contains all values of x .

$$D : x \in (-\infty, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x^2 - 2x - 15}{x + 3}$$

$$= \frac{(x+3)(x-5)}{x+3} = x - 5$$

$$x + 3 \neq 0$$

$$x \neq -3$$

$$D : x \in (-\infty, -3) \cup (-3, \infty)$$

41. $f(x) = 3x + 1$ and $g(x) = \sqrt{x - 3}$

Sum:

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

$$x - 3 \geq 0$$

$$x \geq 3$$

$$D : x \in [3, \infty)$$

Difference:

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

$$x - 3 \geq 0$$

$$x \geq 3$$

$$D : x \in [3, \infty)$$

Product:

$$f(x) \cdot g(x) = (3x + 1)\sqrt{x - 3}$$

$$x - 3 \geq 0$$

$$x \geq 3$$

$$D : x \in [3, \infty)$$

Quotient:

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

$$x - 3 > 0$$

$$x > 3$$

$$D : x \in (3, \infty)$$

42. $f(x) = x + 2$ and $g(x) = \sqrt{x + 6}$

Sum:

$$f(x) + g(x) = x + 2 + \sqrt{x + 6}$$

$$x + 6 \geq 0$$

$$x \geq -6$$

$$D : x \in [-6, \infty)$$

Difference:

$$f(x) - g(x) = x + 2 - \sqrt{x + 6}$$

$$x + 6 \geq 0$$

$$x \geq -6$$

$$D : x \in [-6, \infty)$$

Product:

$$f(x) \cdot g(x) = (x + 2)\sqrt{x + 6}$$

$$x + 6 \geq 0$$

$$x \geq -6$$

$$D : x \in [-6, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x + 2}{\sqrt{x + 6}}$$

$$x + 6 > 0$$

$$x > -6$$

$$D : x \in (-6, \infty)$$

2.8 Exercises

43. $f(x) = 2x^2$ and $g(x) = \sqrt{x+1}$

Sum:

$$f(x) + g(x) = 2x^2 + \sqrt{x+1}$$

$$x+1 \geq 0$$

$$x \geq -1$$

$$D: x \in [-1, \infty)$$

Difference:

$$f(x) - g(x) = 2x^2 - \sqrt{x+1}$$

$$x+1 \geq 0$$

$$x \geq -1$$

$$D: x \in [-1, \infty)$$

Product:

$$f(x) \cdot g(x) = 2x^2 \sqrt{x+1}$$

$$x+1 \geq 0$$

$$x \geq -1$$

$$D: x \in [-1, \infty)$$

Quotient:

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

$$x+1 > 0$$

$$x > -1$$

$$D: x \in (-1, \infty)$$

44. $f(x) = x^2 + 2$ and $g(x) = \sqrt{x-5}$

Sum:

$$f(x) + g(x) = x^2 + 2 + \sqrt{x-5}$$

$$x-5 \geq 0$$

$$x \geq 5$$

$$D: x \in [5, \infty)$$

Difference:

$$f(x) - g(x) = x^2 + 2 - \sqrt{x-5}$$

$$x-5 \geq 0$$

$$x \geq 5$$

$$D: x \in [5, \infty)$$

Product:

$$f(x) \cdot g(x) = (x^2 + 2)\sqrt{x-5}$$

$$x-5 \geq 0$$

$$x \geq 5$$

$$D: x \in [5, \infty)$$

Quotient:

$$\frac{f(x)}{g(x)} = \frac{x^2 + 1}{\sqrt{x-5}}$$

$$x-5 > 0$$

$$x > 5$$

$$D: x \in (5, \infty)$$

45. $f(x) = \frac{2}{x-3}$ and $g(x) = \frac{5}{x+2}$

Sum:

$$f(x) + g(x) = \frac{2}{x-3} + \frac{5}{x+2}$$

$$= \frac{2(x+2) + 5(x-3)}{(x-3)(x+2)}$$

$$= \frac{2x+4+5x-15}{(x-3)(x+2)}$$

$$= \frac{7x-11}{(x-3)(x+2)}$$

$$x-3 \neq 0 \quad x+2 \neq 0$$

$$x \neq 3 \quad x \neq -2$$

$$D: x \in (-\infty, -2) \cup (-2, 3) \cup (3, \infty)$$

Difference:

$$f(x) - g(x) = \frac{2}{x-3} - \frac{5}{x+2}$$

$$= \frac{2(x+2) - 5(x-3)}{(x-3)(x+2)}$$

$$= \frac{2x+4-5x+15}{(x-3)(x+2)}$$

$$= \frac{-3x+19}{(x-3)(x+2)}$$

$$x-3 \neq 0 \quad x+2 \neq 0$$

$$x \neq 3 \quad x \neq -2$$

$$D: x \in (-\infty, -2) \cup (-2, 3) \cup (3, \infty)$$

Product:

$$f(x) \cdot g(x) = \left(\frac{2}{x-3} \right) \left(\frac{5}{x+2} \right)$$

$$= \frac{10}{(x-3)(x+2)}$$

$$= \frac{10}{x^2 - x - 6}$$

$$x-3 \neq 0 \quad x+2 \neq 0$$

$$x \neq 3 \quad x \neq -2$$

$$D: x \in (-\infty, -2) \cup (-2, 3) \cup (3, \infty)$$

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Quotient:

$$\begin{aligned}\frac{f(x)}{g(x)} &= \frac{\frac{2}{x-3}}{\frac{5}{x+2}} = \left(\frac{2}{x-3}\right)\left(\frac{x+2}{5}\right) \\ &= \frac{2(x+2)}{5(x-3)} = \frac{2x+4}{5x-15} \\ x-3 \neq 0 \quad x+2 \neq 0 \\ x \neq 3 \quad x \neq -2 \\ D: x \in (-\infty, -2) \cup (-2, 3) \cup (3, \infty)\end{aligned}$$

46. $f(x) = \frac{4}{x-3}$ and $g(x) = \frac{1}{x+5}$

Sum:

$$\begin{aligned}f(x) + g(x) &= \frac{4}{x-3} + \frac{1}{x+5} \\ &= \frac{4(x+5) + 1(x-3)}{(x-3)(x+5)} \\ &= \frac{4x+20+x-3}{(x-3)(x+5)} \\ &= \frac{5x+17}{(x-3)(x+5)} \\ x-3 \neq 0 \quad x+5 \neq 0 \\ x \neq 3 \quad x \neq -5 \\ D: x \in (-\infty, -5) \cup (-5, 3) \cup (3, \infty)\end{aligned}$$

Difference:

$$\begin{aligned}f(x) - g(x) &= \frac{4}{x-3} - \frac{1}{x+5} \\ &= \frac{4(x+5) - 1(x-3)}{(x-3)(x+5)} \\ &= \frac{4x+20-x+3}{(x-3)(x+5)} \\ &= \frac{3x+23}{(x-3)(x+5)} \\ x-3 \neq 0 \quad x+5 \neq 0 \\ x \neq 3 \quad x \neq -5 \\ D: x \in (-\infty, -5) \cup (-5, 3) \cup (3, \infty)\end{aligned}$$

Product:

$$\begin{aligned}f(x) \cdot g(x) &= \left(\frac{4}{x-3}\right)\left(\frac{1}{x+5}\right) \\ &= \frac{4}{(x-3)(x+5)} \\ &= \frac{4}{x^2 + 2x - 15} \\ x-3 \neq 0 \quad x+5 \neq 0 \\ x \neq 3 \quad x \neq -5 \\ D: x \in (-\infty, -5) \cup (-5, 3) \cup (3, \infty)\end{aligned}$$

Quotient:

$$\begin{aligned}\frac{f(x)}{g(x)} &= \frac{\frac{4}{x-3}}{\frac{1}{x+5}} = \left(\frac{4}{x-3}\right)\left(\frac{x+5}{1}\right) \\ &= \frac{4(x+5)}{x-3} = \frac{4x+20}{x-3} \\ x-3 \neq 0 \quad x+5 \neq 0 \\ x \neq 3 \quad x \neq -5 \\ D: x \in (-\infty, -5) \cup (-5, 3) \cup (3, \infty)\end{aligned}$$

47. $f(x) = x^2 - 5x - 14$

$$\begin{aligned}f(-2) &= (-2)^2 - 5(-2) - 14 = 4 + 10 - 14 = 0; \\ f(7) &= (7)^2 - 5(7) - 14 = 49 - 35 - 14 = 0; \\ f(2) &= (2)^2 - 5(2) - 14 = 4 - 10 - 14 = -20; \\ f(a-2) &= (a-2)^2 - 5(a-2) - 14 \\ &= a^2 - 4a + 4 - 5a + 10 - 14 \\ &= a^2 - 9a\end{aligned}$$

48. $g(x) = x^3 - 9x$

$$\begin{aligned}g(-3) &= (-3)^3 - 9(-3) = -27 + 27 = 0; \\ g(2) &= (2)^3 - 9(2) = 8 - 18 = -10; \\ g(3) &= (3)^3 - 9(3) = 27 - 27 = 0; \\ g(t+1) &= (t+1)^3 - 9(t+1) \\ &= t^3 + 3t^2 + 3t + 1 - 9t - 9 \\ &= t^3 + 3t^2 - 6t - 8\end{aligned}$$

2.8 Exercises

49. $f(x) = \sqrt{x+3}$ and $g(x) = 2x-5$

(a) $h(x) = (f \circ g)(x) = f[g(x)]$
 $= \sqrt{g(x)+3}$
 $= \sqrt{(2x-5)+3}$
 $= \sqrt{2x-2}$

(b) $H(x) = (g \circ f)(x) = g[f(x)]$
 $= 2(f(x)) - 5$
 $= 2\sqrt{x+3} - 5$

(c) $2x - 2 \geq 0$
 $2x \geq 2$

$x \geq 1$

Domain of $h: x \in [1, \infty)$

$x+3 \geq 0$

$x \geq -3$

Domain of $H: x \in [-3, \infty)$

50. $f(x) = x+3$ and $g(x) = \sqrt{9-x^2}$

(a) $h(x) = (f \circ g)(x) = f[g(x)]$
 $= g(x) + 3$
 $= \sqrt{9-x^2} + 3$

(b) $H(x) = (g \circ f)(x) = g[f(x)]$
 $= \sqrt{9 - (f(x))^2}$
 $= \sqrt{9 - (x+3)^2}$
 $= \sqrt{9 - (x^2 + 6x + 9)}$
 $= \sqrt{-x^2 - 6x}$

(c) $9 - x^2 \geq 0$

$-x^2 \geq -9$

$x^2 \leq 9$

$x \leq 3$ and $x \geq -3$

Domain of $h: x \in [-3, 3]$

$-x^2 - 6x \geq 0$

$-x(x+6) \geq 0$

$x \leq 0$ and $x \geq -6$

Domain of $H: x \in [-6, 0]$

51. $f(x) = \sqrt{x-3}$ and $g(x) = 3x+4$

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$

$h(x) = \sqrt{g(x)-3}$
 $= \sqrt{3x+4-3}$

$= \sqrt{3x+1}$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = 3(f(x)) + 4$
 $= 3\sqrt{x-3} + 4$

(c) $3x+1 \geq 0$
 $3x \geq -1$

$x \geq -\frac{1}{3}$

Domain of $h: \left\{x \mid x \geq -\frac{1}{3}\right\}$

or $\left[-\frac{1}{3}, \infty\right)$;

$x-3 \geq 0$

$x \geq 3$

Domain of $H: \{x \mid x \geq 3\}$

or $[3, \infty)$

52. $f(x) = \sqrt{x+5}$ and $g(x) = 4x-1$

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = \sqrt{g(x)+5}$
 $= \sqrt{4x-1+5}$
 $= \sqrt{4x+4}$
 $= \sqrt{4(x+1)}$

$= 2\sqrt{x+1}$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = 4(f(x)) - 1$
 $= 4\sqrt{x+5} - 1$

(c) $4x+4 \geq 0$

$4x \geq -4$

$x \geq -1$

Domain of $h: \{x \mid x \geq -1\}$

or $[-1, \infty)$;

$x+5 \geq 0$

$x \geq -5$

Domain of $H: \{x \mid x \geq -5\}$

or $[-5, \infty)$

Chapter 2: Relations, Functions and Graphs

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

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = (g(x))^2 - 3(g(x))$
 $= (x+2)^2 - 3(x+2)$
 $= x^2 + 4x + 4 - 3x - 6$
 $= x^2 + x - 2$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = (f(x)) + 2$
 $= x^2 - 3x + 2$

(c) Domain of h : $(-\infty, \infty)$
 Domain of H : $(-\infty, \infty)$

54. $f(x) = 2x^2 - 1$ and $g(x) = 3x + 2$

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = 2(g(x))^2 - 1$
 $= 2(3x+2)^2 - 1$
 $= 2(9x^2 + 12x + 4) - 1$
 $= 18x^2 + 24x + 8 - 1$
 $= 18x^2 + 24x + 7$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = 3(f(x)) + 2$
 $= 3(2x^2 - 1) + 2$
 $= 6x^2 - 3 + 2$
 $= 6x^2 - 1$

(c) Domain of h : $(-\infty, \infty)$
 Domain of H : $(-\infty, \infty)$

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

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = (g(x))^2 + g(x) - 4$
 $= (x+3)^2 + x + 3 - 4$
 $= x^2 + 6x + 9 + x - 1$
 $= x^2 + 7x + 8$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = f(x) + 3$
 $= x^2 + x - 4 + 3$
 $= x^2 + x - 1$

(c) Domain of h : $(-\infty, \infty)$
 Domain of H : $(-\infty, \infty)$

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

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = (g(x))^2 - 4(g(x)) + 2$
 $= (x-2)^2 - 4(x-2) + 2$
 $= x^2 - 4x + 4 - 4x + 8 + 2$
 $= x^2 - 8x + 14$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = f(x) - 2$
 $= x^2 - 4x + 2 - 2$
 $= x^2 - 4x$

(c) Domain of h : $(-\infty, \infty)$
 Domain of H : $(-\infty, \infty)$

57. $f(x) = |x| - 5$ and $g(x) = -3x + 1$

(a) $h(x) = (f \circ g)(x)$
 $h(x) = f[g(x)]$
 $h(x) = |g(x)| - 5$
 $= |-3x+1| - 5$

(b) $H(x) = (g \circ f)(x)$
 $H(x) = g[f(x)]$
 $H(x) = -3(f(x)) + 1$
 $= -3(|x| - 5) + 1$
 $= -3|x| + 15 + 1$
 $= -3|x| + 16$

(c) Domain of h : $(-\infty, \infty)$
 Domain of H : $(-\infty, \infty)$

2.8 Exercises

58. $f(x) = |x - 2|$ and $g(x) = 3x - 5$

(a) $h(x) = (f \circ g)(x)$

$$h(x) = f[g(x)]$$

$$h(x) = |g(x) - 2|$$

$$= |3x - 5 - 2|$$

$$= |3x - 7|$$

(b) $H(x) = (g \circ f)(x)$

$$H(x) = g[f(x)]$$

$$H(x) = 3(f(x)) - 5$$

$$= 3|x - 2| - 5$$

(c) Domain of h : $(-\infty, \infty)$

Domain of H : $(-\infty, \infty)$

59. $f(x) = \frac{2x}{x+3}$ and $g(x) = \frac{5}{x}$

(a)

$(f \circ g)(x)$: For $g(x)$ to be defined, $x \neq 0$.

$$\text{For } f[g(x)] = \frac{2g(x)}{g(x)+3},$$

$$g(x) \neq -3 \text{ so } x \neq -\frac{5}{3}.$$

$$\text{Domain: } \left\{ x \mid x \neq 0, x \neq -\frac{5}{3} \right\}$$

(b)

$(g \circ f)(x)$: For $f(x)$ to be defined, $x \neq -3$.

$$\text{For } g[f(x)] = \frac{5}{f(x)},$$

$$f(x) \neq 0 \text{ so } x \neq 0.$$

$$\text{Domain: } \{x \mid x \neq 0, x \neq -3\}$$

(c) $(f \circ g)(x) = f[g(x)]$

$$= \frac{2(g(x))}{g(x)+3} = \frac{2\left(\frac{5}{x}\right)}{\frac{5}{x}+3} = \frac{\frac{10}{x}}{\frac{5+3x}{x}}$$

$$= \frac{10x}{x(5+3x)} = \frac{10}{5+3x}$$

$$(g \circ f)(x) = g[f(x)]$$

$$= \frac{5}{f(x)} = \frac{5}{\frac{2x}{x+3}} = \frac{5(x+3)}{2x} = \frac{5x+15}{2x}$$

60. $f(x) = \frac{-3}{x}$ and $g(x) = \frac{x}{x-2}$

(a)

$(f \circ g)(x)$: For $g(x)$ to be defined, $x \neq 2$.

$$\text{For } f[g(x)] = \frac{-3}{g(x)},$$

$$g(x) \neq 0 \text{ so } x \neq 0.$$

$$\text{Domain: } \{x \mid x \neq 0, x \neq 2\}$$

(b)

$(g \circ f)(x)$: For $f(x)$ to be defined, $x \neq 0$.

$$\text{For } g[f(x)] = \frac{f(x)}{f(x)-2},$$

$$f(x) \neq 2 \text{ so } x \neq -\frac{3}{2}.$$

$$\text{Domain: } \left\{ x \mid x \neq -\frac{3}{2}, x \neq 0 \right\}$$

(c) $(f \circ g)(x) = f[g(x)]$

$$= \frac{-3}{g(x)} = \frac{-3}{\frac{x}{x-2}} = \frac{-3(x-2)}{x} = \frac{-3x+6}{x}$$

$$(g \circ f)(x) = g[f(x)]$$

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

61. $f(x) = \frac{4}{x}$ and $g(x) = \frac{1}{x-5}$

(a)

$(f \circ g)(x)$: For $g(x)$ to be defined, $x \neq 5$.

$$\text{For } f[g(x)] = \frac{4}{g(x)},$$

$$g(x) \neq 0 \text{ and } g(x) \text{ is never zero.}$$

$$\text{Domain: } \{x \mid x \neq 5\}$$

(b)

$(g \circ f)(x)$: For $f(x)$ to be defined, $x \neq 0$.

$$\text{For } g[f(x)] = \frac{1}{f(x)-5},$$

$$f(x) \neq 5 \text{ so } x \neq \frac{4}{5}.$$

$$\text{Domain: } \left\{ x \mid x \neq 0, x \neq \frac{4}{5} \right\}$$

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$$(c) \quad h(x) = (f \circ g)(x)$$

$$h(x) = f[g(x)]$$

$$h(x) = \frac{4}{g(x)}$$

$$= \frac{4}{\frac{1}{x-5}}$$

$$= 4(x-5)$$

$$= 4x - 20$$

$$H(x) = (g \circ f)(x)$$

$$H(x) = g[f(x)]$$

$$H(x) = \frac{1}{f(x)-5}$$

$$= \frac{1}{\frac{4}{x}-5}$$

$$= \frac{1}{\frac{4-5x}{x}}$$

$$= \frac{x}{4-5x}$$

$$(c) \quad h(x) = (f \circ g)(x)$$

$$h(x) = f[g(x)]$$

$$h(x) = \frac{3}{g(x)}$$

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

$$= 3(x-2)$$

$$= 3x - 6$$

$$H(x) = (g \circ f)(x)$$

$$H(x) = g[f(x)]$$

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

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

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

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

$$62. \quad f(x) = \frac{3}{x} \text{ and } g(x) = \frac{1}{x-2}$$

(a)

$(f \circ g)(x)$: For $g(x)$ to be defined, $x \neq 2$.

$$\text{For } f[g(x)] = \frac{3}{g(x)},$$

$g(x) \neq 0$ and $g(x)$ is never zero.

Domain: $\{x | x \neq 2\}$

(b)

$(g \circ f)(x)$: For $f(x)$ to be defined, $x \neq 0$.

$$\text{For } g[f(x)] = \frac{1}{f(x)-2},$$

$$f(x) \neq 2 \text{ so } x \neq \frac{3}{2}.$$

Domain: $\left\{x \mid x \neq 0, x \neq \frac{3}{2}\right\}$

$$63. \quad f(x) = x^2 - 8 \text{ and } g(x) = x + 2$$

$$h(x) = (f \circ g)(x)$$

$$a. \quad (f \circ g)(x) = f[g(x)]$$

$$= (g(x))^2 - 8$$

$$= (x+2)^2 - 8$$

$$= x^2 + 4x + 4 - 8$$

$$= x^2 + 4x - 4;$$

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

$$h(5) = (5)^2 + 4(5) - 4 = 25 + 20 - 4 = 41$$

$$b. \quad g(5) = 5 + 2 = 7$$

$$f[g(5)] = f(7)$$

$$= (7)^2 - 8 = 49 - 8 = 41$$

2.8 Exercises

64. $p(x) = x^2 - 8$ and $q(x) = x + 2$

$$H(x) = (p \circ q)(x)$$

a. $(p \circ q)(x) = p[q(x)]$

$$= (q(x)^2) - 8$$

$$= (x+2)^2 - 8$$

$$= x^2 + 4x + 4 - 8$$

$$= x^2 + 4x - 4;$$

$$H(x) = x^2 + 4x - 4;$$

$$H(-2) = (-2)^2 + 4(-2) - 4$$

$$= 4 - 8 - 4 = -8$$

b. $q(-2) = -2 + 2 = 0$

$$p[q(-2)] = p(0)$$

$$= (0)^2 - 8 = 0 - 8 = -8$$

65. $h(x) = (\sqrt{x-2} + 1)^3 - 5$

Answers may vary.

$$g(x) = \sqrt{x-2} + 1, f(x) = x^3 - 5$$

66. $h(x) = \sqrt[3]{x^2 - 5} + 2$

Answers may vary.

$$p(x) = \sqrt[3]{x} + 2, q(x) = x^2 - 5$$

67. $f(x) = 2x - 1, g(x) = x^2 - 1,$

$$h(x) = x + 4$$

a. $p(x) = f[g(h(x))]$

$$p(x) = f[(x+4)^2 - 1]$$

$$= 2[(x+4)^2 - 1] - 1$$

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

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

b. $q(x) = g[f(h(x))]$

$$q(x) = g[2(x+4) - 1]$$

$$= g[2x + 8 - 1] = g[2x + 7]$$

$$= (2x+7)^2 - 1$$

68. $f(x) = 2x + 3, g(x) = \frac{x-3}{2}$

a. $(f \circ f)(x) = f(f(x))$

$$= 2(2x+3) + 3 = 4x + 9$$

b. $(g \circ g)(x) = g(g(x))$

$$= \frac{\frac{x-3}{2} - 3}{2} = \frac{x-3-6}{4} = \frac{x-9}{4}$$

c. $(f \circ g)(x) = f(g(x))$

$$= 2\left(\frac{x-3}{2}\right) + 3 = x - 3 + 3 = x$$

d. $(g \circ f)(x) = g(f(x))$

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

69. a. $C(5) = 6000$

b. $T(8) = 3000$

c. $C(9) + T(9) = 6000 + 2000 = 8000$

d. $C(9) - T(9) = 6000 - 2000 = 4000$

70. a. $M(2) = \$12$ million

b. $P(5) = \$12$ million

c. $M(9) + P(9) = 12 + 8 = \$20$ million

d. $P(10) - M(10) = 14 - 4 = \10 million

71. a. $R(2) = \$1$ billion

b. $C(8) = \$5$ billion

c. $R(t) = C(t)$

Broke even 2003, 2007, 2010

$$C(t) > R(t):$$

d. $t \in (2000, 2003) \cup (2007, 2010)$

e. $R(t) > C(t), t \in (2003, 2007)$

f. $R(5) - C(5) = 5 - 1 = \$4$ billion

72. a. $D(2) = \$6$ billion

b. $R(6) = \$5$ billion

c. $R(t) = D(t)$

2001, 2004, 2007

d. $R(t) > D(t), t \in (2000, 2001) \cup (2004, 2007)$

e. $R(t) < D(t), t \in (2001, 2004) \cup (2007, 2010)$

f. $D(t) + R(t)$

$$D(10) + R(10) = 6 + 3 = \$9$$
 billion

Chapter 2: Relations, Functions and Graphs

73. a. $(f + g)(-4) = f(-4) + g(-4)$
 $= 5 + (-1) = 4$
- b. $(f \cdot g)(1) = f(1) \cdot g(1)$
 $= 0(3) = 0$
- c. $(f - g)(4) = f(4) - g(4)$
 $= 5 - 3 = 2$
- d. $(f + g)(0) = f(0) + g(0)$
 $= 1 + 2 = 3$
- e. $\left(\frac{f}{g}\right)(2) = \frac{f(2)}{g(2)} = \frac{-1}{3}$
- f. $(f \cdot g)(-2) = f(-2) \cdot g(-2)$
 $= 3(2) = 6$
- g. $(g \cdot f)(2) = g(2) \cdot f(2)$
 $= 3(-1) = -3$
- h. $(f - g)(-1) = f(-1) - g(-1)$
 $= 2 - 1 = 1$
- i. $(f + g)(8) = f(8) + g(8)$
 $= -1 + 2 = 1$
- j. $\left(\frac{f}{g}\right)(7) = \frac{f(7)}{g(7)} = \frac{1}{0}$ undefined
- k. $(g \circ f)(4) = g(f(4))$
 $= g(5) = \frac{1}{2} = 0.5$
- l. $(f \circ g)(4) = f(g(4))$
 $= f(3) = 2$
74. a. $(p + q)(-4) = p(-4) + q(-4)$
 $= 4 + (-4) = 0$
- b. $(p \cdot q)(1) = p(1) \cdot q(1)$
 $= 4(-3) = -12$
- c. $(p - q)(4) = p(4) - q(4)$
 $= 2 - 0 = 2$
- d. $(p + q)(0) = p(0) + q(0)$
 $= 1 + 1 = 2$
- e. $\left(\frac{p}{q}\right)(5) = \frac{p(5)}{q(5)} = \frac{1}{6}$
- f. $(p \cdot q)(-2) = p(-2) \cdot q(-2)$
 $= -3(2) = -6$
- g. $(q \cdot p)(2) = q(2) \cdot p(2)$
 $= -4(5) = -20$
- h. $(p - q)(-1) = p(-1) - q(-1)$
 $= -2 - 3 = -5$
- i. $(p + q)(7) = p(7) + q(7)$
 $= 6 + (-3) = 3$
- j. $\left(\frac{p}{q}\right)(6) = \frac{p(6)}{q(6)} = \frac{2}{0}$ undefined
- k. $(q \circ p)(4) = q(p(4))$
 $= q(2) = -4$
- l. $(p \circ q)(-1) = p(q(-1))$
 $= p(3) = 4 = \frac{-1}{3}$
75. $h(x) = f(x) - g(x)$
 $= 5 - \left(\frac{2}{3}x + 1\right) = 5 - \frac{2}{3}x - 1$
 $= -\frac{2}{3}x + 4$
76. $h(x) = f(x) - g(x)$
 $= (2\sqrt{x} + 1) - 3 = 2\sqrt{x} - 2$
77. $h(x) = f(x) - g(x)$
 $= (5x - x^2) - x = 4x - x^2$
78. $h(x) = f(x) - g(x)$
 $= \left[-(x - 3)^2 + 13\right] - (x - 2)^2$
 $= -(x^2 - 6x + 9) + 13 - (x^2 - 4x + 4)$
 $= -x^2 + 6x - 9 + 13 - x^2 + 4x - 4$
 $= -2x^2 + 10x$
79. $A = 40\pi r + 2\pi r^2$
 $A = 2\pi(20 + r)$
 $A(r) = (f \cdot g)(r)$
 $f(r) = 2\pi r, g(r) = 20 + r$
 $A(5) = 2\pi(5)(20 + 5) = 10\pi(25) = 250\pi \text{ units}^2$
80. $A(r) = P(1 + r)^t$
 $g(r) = 1 + r, f(r) = 1000r^5$ Answers will vary.

2.8 Exercises

81. Revenue: $R(x) = 40,000x$
 Cost: $C(x) = 108,000 + 28,000x$
- $P(x) = R(x) - C(x)$
 $= 40,000x - 108,000 - 28,000x$
 $= 12,000x - 108,000$
 - Break even when $P(x) = 0$
 $12,000x - 108,000 = 0$
 $12,000x = 108,000$
 $x = 9$
 9 boats must be sold to break even.
82. Revenue: $R(x) = 1.50x$
 Cost: $C(x) = 900 + 0.25x$
- $P(x) = R(x) - C(x)$
 $= 1.50x - (900 + 0.25x)$
 $= 1.50x - 900 - 0.25x$
 $= 1.25x - 900$
 - Break even when $P(x) = 0$
 $1.25x - 900 = 0$
 $1.25x = 900$
 $x = 720$
 720 newsletters must be sold to break even.
 - Let $x = 1000$
 $P(1000) = 1.25(1000) - 900 = 350$
 \$350 will be returned.
83. a. $P(n) = R(n) - C(n)$
 $P(n) = 11.45n - 0.1n^2$
- $P(12) = 11.45(12) - 0.1(12)^2$
 $= 137.4 - 14.4 = \$123$
 - $P(60) = 11.45(60) - 0.1(60)^2$
 $= 687 - 360 = \$327$
 - At $n = 115$, costs exceed revenue,
 $C(115) > R(115)$.
84. a. $T(t) = M(t) + C(t)$
 $T(t) = 2t + 1 + 0.1t^2 + 2$
 $T(t) = 0.1t^2 + 2t + 3$
- $D(t) = C(t) - M(t)$
 $D(t) = 0.1t^2 + 2 - (2t + 1)$
 $D(t) = 0.1t^2 + 2 - 2t - 1$
 $D(t) = 0.1t^2 - 2t + 1$
- c. $C(t) = 0.1t^2 + 2$
 $C(10) = 0.1(10)^2 + 2 = 10 + 2 = 12$
 \$12,000
- d. $D(10) = 0.1(10)^2 - 2(10) + 1$
 $D(10) = 10 - 20 + 1 = -9$
 \$9,000
- e. $P(t) = R(t) - T(t)$
 $P(t) = 10\sqrt{t} - (0.1t^2 + 2t + 3)$
 $P(t) = 10\sqrt{t} - 0.1t^2 - 2t - 3$
- f. $P(t) = 10\sqrt{t} - 0.1t^2 - 2t - 3$
 $P(5) = 10\sqrt{5} - 0.1(5)^2 - 2(5) - 3$
 $P(5) = 10\sqrt{5} - 2.5 - 10 - 3$
 $P(5) = 10\sqrt{5} - 15.5$
 $P(5) = 6.861$
 \$6,861;
 $P(10) = 10\sqrt{10} - 0.1(10)^2 - 2(10) - 3$
 $P(10) = 10\sqrt{10} - 10 - 20 - 3$
 $P(10) = 10\sqrt{10} - 33$
 $P(10) = -1.377$
 -\$1,377
 No profit was made in the 10th month.
 There was a loss.
85. $f(x) = 0.5x - 14$; $g(x) = 2x + 23$
 $h(x) = (f \circ g)(x) = f[g(x)]$
 $h(x) = 0.5(g(x)) - 14$
 $= 0.5(2x + 23) - 14$
 $= x + 11.5 - 14$
 $= x - 2.5$
 $h(13) = 13 - 2.5 = 10.5$
86. $E(x) = 1.12x$; $Y(x) = 1061x$
- $E(100) = 1.12(100) = 112$ euros
 - $Y(112) = 1061(112) = 118832$ yen
 - $M(x) = (Y \circ E)(x) = Y[E(x)]$
 $M(x) = 1061(E(x))$
 $= 1061(1.12x)$
 $= 1188.32x$
 $M(100) = 1188.32(100) = 118832$ yen
 Parts b and c agree.

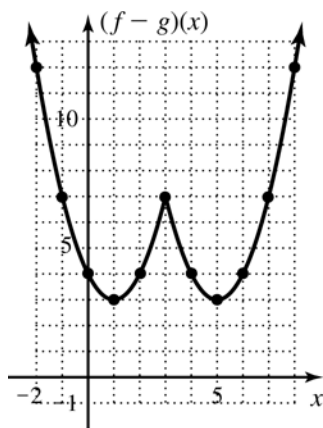
Chapter 2: Relations, Functions and Graphs

87. $T(x) = 41.6x$; $R(x) = 10.9x$
- (a) $T(100) = 41.6(100) = 4160$ baht
- (b) $R(4160) = 10.9(4160) = 45,344$ rRinggit
- (c) $M(x) = (R \circ T)(x) = R[T(x)]$
 $M(x) = 10.9(T(x))$
 $= 10.9(41.6x)$
 $= 453.44x$;
 $M(100) = 453.44(100) = 45344$ ringgit
 Parts B and C agree.
88. $r(t) = 2t$; $A = \pi r^2$
- (a) $A(t) = (A \circ r)(t) = A[r(t)]$
 $= \pi(r(t))^2$
 $= \pi(2t)^2$
 $= 4\pi t^2$
- (b) $A(60) = 4\pi(60)^2 = 14400\pi \text{ m}^2$
89. $r(t) = 3t$; $A = \pi r^2$
- (a) $r(2) = 3(2) = 6$ ft
- (b) $A(6) = \pi(6)^2 = 36\pi \text{ ft}^2$
- (c) $A(t) = (A \circ r)(t) = A[r(t)]$
 $A(t) = \pi(r(t))^2$
 $= \pi(3t)^2$
 $= 9\pi t^2$;
 $A(2) = 9\pi(2)^2 = 36\pi \text{ ft}^2$
 The answers do agree.
90. $r(t) = 1.05t$; $SA = 4\pi r^2$
- (A) $r(2) = 1.05(2) = 2.1$ Gm
- (B) $SA = 4\pi(2.1)^2$
 $SA = 17.64\pi \text{ Gm}^2$
- (C) $h(t) = (S \circ r)(t) = S[r(t)]$
 $h(t) = 4\pi(1.05t)^2$
 $h(t) = 4.41\pi t^2$
 The answers do agree.
91. $C(x) = 0.0345x^4 - 0.8996x^3 + 7.5383x^2 - 21.7215x + 40$
 $L(x) = -0.0345x^4 + 0.8996x^3 - 7.5383x^2 + 21.7215x + 10$
- (a) Using the grapher, 1995 to 1996; 1999 to 2004
- (b) Using the grapher, 30 seats; 1995
- (c) Using the grapher, 20 seats; 1997
- (d) Using the grapher, the total number in the senate (50); the number of additional seats held by the majority.
92. $f(x) = x^3 + 2$ and $g(x) = \sqrt[3]{x-2}$
 $h(x) = (f \circ g)(x) = f[g(x)]$
 $h(x) = (g(x))^3 + 2$
 $= (\sqrt[3]{x-2})^3 + 2$
 $= x - 2 + 2 = x$
 $H(x) = (g \circ f)(x) = g[f(x)]$
 $= \sqrt[3]{x^3 + 2 - 2} = x$
 Answers will vary.
93. $f(x) = \sqrt{1-x}$ and $g(x) = \sqrt{x-2}$
 Using the grapher,
 $(f+g)(x)$ cannot be found because their domains do not overlap.
94. a. $(f \circ g)(x) = f(g(x))$
 $f(\sqrt{x+1}) = \frac{1}{(\sqrt{x+1})^2 - 4} = \frac{1}{|x+1| - 4}$
 $h(x) = \frac{1}{|x+1| - 4}$
- b. Domain of $h(x)$
 $\frac{1}{x+1-4} = \frac{1}{x-3}$; $x \neq 3$;
 $\frac{1}{-(x+1)-4} = \frac{1}{-x-5}$; $x \neq -5$;
 Yes, Domain includes $x = 2$, $x = -2$, $x = -3$.
- c. Domain of f : $x \neq 2$, $x \neq -2$;
 Domain of g : $x+1 \geq 0$
 $x \geq -1$
 Domain of h : $[-1, 2) \cup (2, 3) \cup (3, \infty)$
 For $x \geq -1$, 2 is not in the domain of f and 3 is not in the domain of h . Thus, 2 and 3 are not in the domain of h .

2.8 Exercises

95. $f(x) = (x-3)^2 + 2$, $g(x) = 4|x-3| - 5$

x	$f(x)$	$g(x)$	$(f-g)(x)$
-2	27	15	12
-1	18	11	7
0	11	7	4
1	6	3	3
2	3	-1	4
3	2	-5	7
4	3	-1	4
5	6	3	3
6	11	7	4
7	18	11	7
8	27	15	12



96. $2 + 3i$ and $2 - 3i$

Sum:

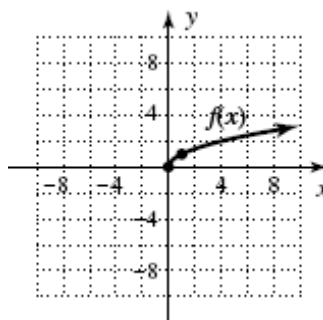
$$(2 + 3i) + (2 - 3i) = 4$$

Product:

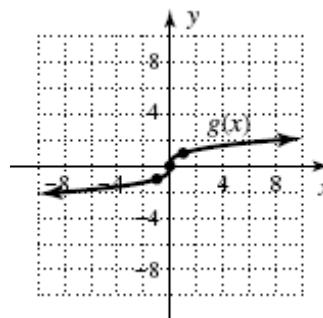
$$(2 + 3i)(2 - 3i) = 4 - 9i^2 = 4 + 9 = 13$$

97. $f(x) = \sqrt{x}$; $g(x) = \sqrt[3]{x}$; $h(x) = |x|$

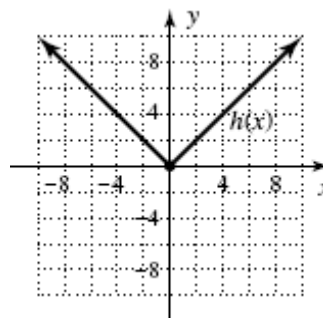
(a)



(b)



(c)



98. $2x^2 - 3x + 4 = 0$

$$x = \frac{3 \pm \sqrt{(-3)^2 - 4(2)(4)}}{2(2)}$$

$$x = \frac{3 \pm \sqrt{9 - 32}}{4}$$

$$x = \frac{3 \pm \sqrt{-23}}{4}$$

$$x = \frac{3}{4} \pm \frac{\sqrt{23}}{4}i$$

99. $-2x + 3y = 9$

$$3y = 2x + 9$$

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

$$m = \frac{2}{3};$$

Slope of a line perpendicular is $-\frac{3}{2}$.

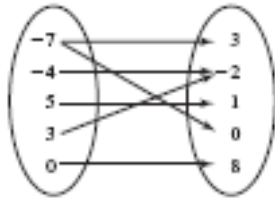
y-intercept (0,0);

$$\text{Equation: } y = -\frac{3}{2}x$$

Chapter 2: Relations, Functions and Graphs

Chapter 2 Summary and Review

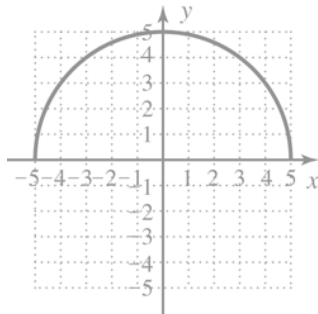
1.



$$x \in \{-7, -4, 0, 3, 5\}$$

$$y \in \{-2, 0, 1, 3, 8\}$$

2.



x	y
-5	$y = \sqrt{25 - (-5)^2} = 0$
-4	$y = \sqrt{25 - (-4)^2} = 3$
-2	$y = \sqrt{25 - (-2)^2} \approx 4.58$
0	$y = \sqrt{25 - 0^2} = 5$
2	$y = \sqrt{25 - (2)^2} \approx 4.58$
4	$y = \sqrt{25 - (4)^2} = 3$
5	$y = \sqrt{25 - (5)^2} = 0$

Domain: $x \in [-5, 5]$

Range: $y \in [0, 5]$

3. (19,25), (-14,-31)

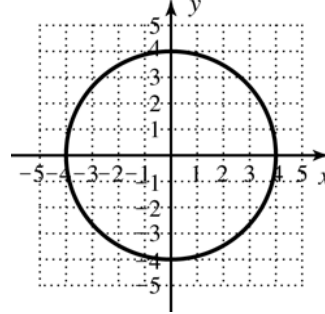
$$\begin{aligned} d &= \sqrt{(-14-19)^2 + (-31-25)^2} \\ &= \sqrt{1089 + 3136} = \sqrt{4225} = 65 \\ &65 \text{ miles} \end{aligned}$$

4. (19,25), (-14,-31)

$$\begin{aligned} \text{Midpoint: } &\left(\frac{19+(-14)}{2}, \frac{25+(-31)}{2} \right) \\ &= \left(\frac{5}{2}, \frac{-6}{2} \right) = \left(\frac{5}{2}, -3 \right) \end{aligned}$$

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

Center (0,0), Radius 4

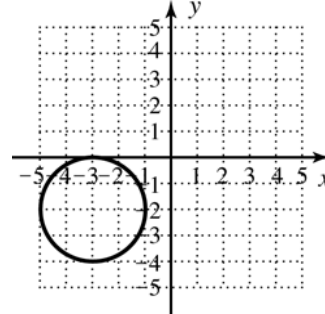


6. $x^2 + y^2 + 6x + 4y + 9 = 0$

$$x^2 + 6x + 9 + y^2 + 4y + 4 = -9 + 9 + 4$$

$$(x+3)^2 + (y+2)^2 = 4$$

Center (-3,-2), Radius 2



7. (-3,0) and (0,4)

To find the center, find the midpoint.

$$\left(\frac{-3+0}{2}, \frac{0+4}{2} \right) = \left(-\frac{3}{2}, 2 \right)$$

To find the radius, find the distance between

$$\left(-\frac{3}{2}, 2 \right) \text{ and } (0, 4)$$

$$\begin{aligned} d &= \sqrt{\left(0 - \left(-\frac{3}{2} \right) \right)^2 + (4-2)^2} \\ &= \sqrt{\frac{9}{4} + 4} = \sqrt{\frac{25}{4}} = \frac{5}{2} = 2.5 \end{aligned}$$

Radius: 2.5

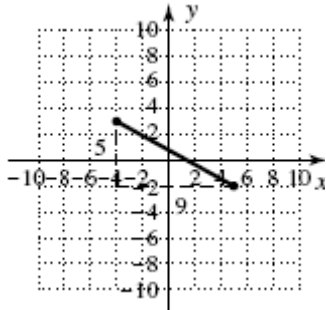
$$\text{Equation: } \left(x + \frac{3}{2} \right)^2 + (y-2)^2 = 6.25$$

Summary and Review

8. a. $(-4, 3)$ and $(5, -2)$

Slope triangle: $-\frac{5}{9}$

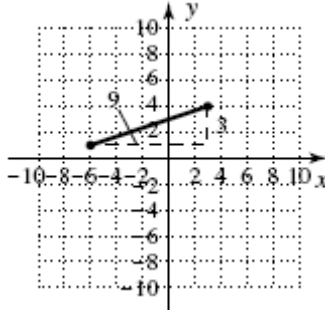
$(14, -7)$



- b. $(3, 4)$ and $(-6, 1)$

Slope triangle: $\frac{1}{3}$

$(0, 3)$



9. a. $L_1: (-2, 0)$ and $(0, 6)$

$$m = \frac{6-0}{0-(-2)} = \frac{6}{2} = 3$$

- $L_2: (1, 8)$ and $(0, 5)$

$$m = \frac{5-8}{0-1} = \frac{-3}{-1} = 3$$

Parallel

- b. $L_1: (1, 10)$ and $(-1, 7)$

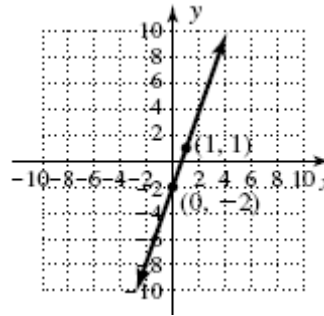
$$m = \frac{7-10}{-1-1} = \frac{-3}{-2} = \frac{3}{2}$$

- $L_2: (-2, -1)$ and $(1, -3)$

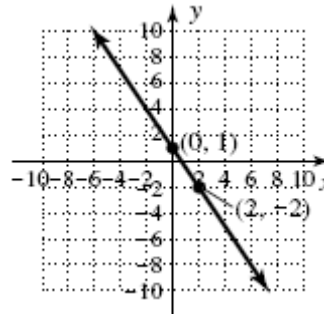
$$m = \frac{-3-(-1)}{1-(-2)} = \frac{-2}{3}$$

Perpendicular

10. a. $y = 3x - 2$



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



11. a. $2x + 3y = 6$

x -intercept: $(3, 0)$ y -intercept: $(0, 2)$

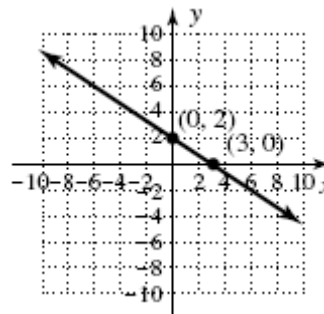
$$2x + 3(0) = 6 \quad 2(0) + 3y = 6$$

$$2x = 6$$

$$3y = 6$$

$$x = 3$$

$$y = 2$$



Chapter 2: Relations, Functions and Graphs

b. $y = \frac{4}{3}x - 2$

x-intercept: $\left(\frac{3}{2}, 0\right)$ y-intercept: $(0, -2)$

$$0 = \frac{4}{3}x - 2$$

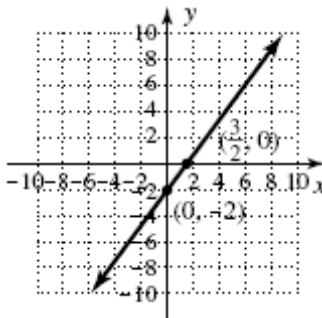
$$y = \frac{4}{3}(0) - 2$$

$$2 = \frac{4}{3}x$$

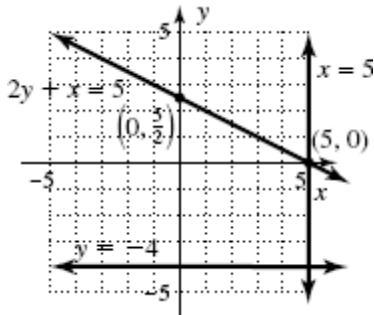
$$y = -2$$

$$\frac{6}{4} = x$$

$$\frac{3}{2} = x$$



12. a. $x = 5$; vertical
b. $y = -4$; horizontal
c. $2y + x = 5$; neither



13. $(-5, -4)$ $(7, 2)$ $(0, 16)$
 $m = \frac{16 - 2}{0 - 7} = \frac{14}{-7} = -2$;
 $m = \frac{2 - (-4)}{7 - (-5)} = \frac{6}{12} = \frac{1}{2}$

Yes

14. $m = \frac{4}{6} = \frac{2}{3}$; y-intercept $(0, 2)$

When the rodent population increases by 3000, the hawk population increases by 200.

15. a. $4x + 3y - 12 = 0$
 $3y = -4x + 12$

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

$$m = -\frac{4}{3}$$
; y-intercept $(0, 4)$

b. $5x - 3y = 15$

$$-3y = -5x + 15$$

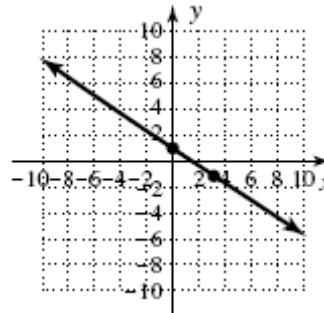
$$y = \frac{5}{3}x - 5$$

$$m = \frac{5}{3}$$
; y-intercept $(0, -5)$

16. a. $f(x) = -\frac{2}{3}x + 1$

$$m = -\frac{2}{3}$$
; y-intercept $(0, 1)$

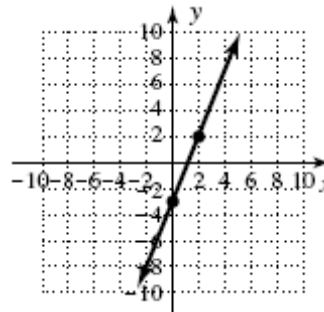
Slope falls



b. $h(x) = \frac{5}{2}x - 3$

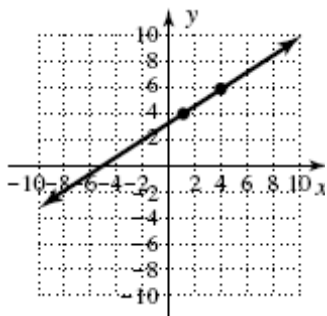
$$m = \frac{5}{2}$$
; y-intercept $(0, -3)$

Slope rises

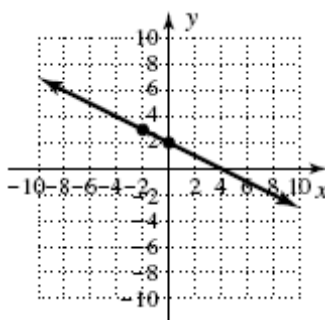


Summary and Review

17. a. $m = \frac{2}{3}; (1, 4)$



b. $m = -\frac{1}{2}; (-2, 3)$



18. $(-2, 5)$
 $x = -2; y = 5$
 Point is on $y = 5$.

19. $(1, 2)$ and $(-3, 5)$

$$m = \frac{5-2}{-3-1} = -\frac{3}{4}$$

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

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

$$y = -\frac{3}{4}x + \frac{11}{4}$$

20. $4x - 3y = 12; (3, 4)$

$$-3y = -4x + 12$$

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

$$y - 4 = \frac{4}{3}(x - 3)$$

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

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

$$f(x) = \frac{4}{3}x$$

21. $m = \frac{2}{5}; y\text{-intercept } (0, 2)$

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

When the rabbit population increases by 500, the wolf population increases by 200.

22. a. $m = -\frac{15}{2}; (6, 60)$

$$y - 60 = -\frac{15}{2}(x - 6)$$

$$y - 60 = -\frac{15}{2}x + 45$$

$$y = -\frac{15}{2}x + 105$$

b. $x\text{-intercept: } (14, 0); y\text{-intercept: } (0, 105)$

$$0 = -\frac{15}{2}x + 105$$

$$-105 = -\frac{15}{2}x$$

$$-210 = -15x$$

$$14 = x$$

$$y = -\frac{15}{2}(0) + 105$$

$$y = 105$$

c. $f(x) = -\frac{15}{2}x + 105$

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- d. $f(20) = -\frac{15}{2}(20) + 105$
 $= -150 + 105$
 $= -45;$
 $15 = -\frac{15}{2}x + 105$
 $-90 = -\frac{15}{2}x$
 $-180 = -15x$
 $12 = x$
23. a. $f(x) = \sqrt{4x+5}$
 $4x+5 \geq 0$
 $4x \geq -5$
 $x \geq -\frac{5}{4}$
 $x \in \left[-\frac{5}{4}, \infty\right)$
- b. $g(x) = \frac{x-4}{x^2-x-6}$
 $x^2-x-6 = 0$
 $(x-3)(x+2) = 0$
 $x-3 = 0$ or $x+2 = 0$
 $x = 3$ or $x = -2$
 These values must be excluded because they cause division by zero.
 $x \in (-\infty, -2) \cup (-2, 3) \cup (3, \infty)$
24. $h(x) = 2x^2 - 3x$
 $h(-2) = 2(-2)^2 - 3(-2) = 14;$
 $h\left(-\frac{2}{3}\right) = 2\left(-\frac{2}{3}\right)^2 - 3\left(-\frac{2}{3}\right) = \frac{8}{9} + \frac{6}{3} = \frac{26}{9};$
 $h(3a) = 2(3a)^2 - 3(3a) = 18a^2 - 9a$
25. It is a function.
26. I. a. $D = \{-1, 0, 1, 2, 3, 4, 5\}$
 $R = \{-2, -1, 0, 1, 2, 3, 4\}$
 b. $f(2) = 1$
 c. When $f(x) = 1$, $x = 2$
- II. a. $x \in (-\infty, \infty)$
 $y \in (-\infty, \infty)$
 b. $f(2) = -1$
 c. When $f(x) = 1$, $x = 3$
- III. a. $x \in [-3, \infty)$
 $y \in [-4, \infty)$
 b. $f(2) = -1.5$
 c. When $f(x) = 1$, $x = -3$ or 3
27. $D: x \in (-\infty, \infty)$
 $R: y \in [-5, \infty)$
 $f(x) \uparrow: x \in (2, \infty)$
 $f(x) \downarrow: x \in (-\infty, 2)$
 $f(x) > 0: x \in (-\infty, -1) \cup (5, \infty)$
 $f(x) < 0: x \in (-1, 5)$
28. $D: x \in [-3, \infty)$
 $R: y \in (-\infty, 0)$
 $f(x) \uparrow: \text{None}$
 $f(x) \downarrow: x \in (-3, \infty)$
 $f(x) > 0: \text{None}$
 $f(x) < 0: x \in (-3, \infty)$
29. $D: x \in (-\infty, \infty)$
 $R: y \in (-\infty, \infty)$
 $f(x) \uparrow: x \in (-\infty, -3) \cup (1, \infty)$
 $f(x) \downarrow: x \in (-3, 1)$
 $f(x) > 0: x \in (-5, -1) \cup (4, \infty)$
 $f(x) < 0: x \in (-\infty, -5) \cup (-1, 4)$
30. a. $f(-x) = 2(-x)^5 - \sqrt[3]{-x}$
 $= -2x^5 + \sqrt[3]{x}$, odd
- b. $g(-x) = (-x)^4 - \frac{\sqrt[3]{-x}}{-x}$
 $= x^4 - \frac{\sqrt[3]{x}}{x}$, even
- c. $p(-x) = |3(-x)| - (-x)^3$
 $p(-x) = |3x| + (x)^3$, neither
- d. $q(-x) = \frac{(-x)^2 - |-x|}{-x}$
 $= \frac{(x)^2 - |x|}{-x}$, odd

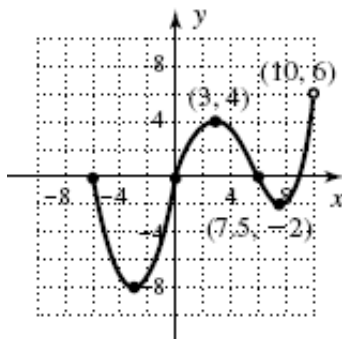
Summary and Review

31. a.
$$\frac{f(x_2) - f(x_1)}{x_2 - x_1} = \frac{\sqrt{5+4} - \sqrt{-3+4}}{5 - (-3)}$$
$$= \frac{3-1}{8} = \frac{1}{4}$$

Graph is rising to the right.

b.
$$\frac{j(x+h) - j(x)}{h}$$
$$= \frac{(x+h)^2 - (x+h) - (x^2 - x)}{h}$$
$$= \frac{x^2 + 2xh + h^2 - x - h - x^2 + x}{h}$$
$$= \frac{2xh + h^2 - h}{h} = 2x - 1 + h$$
$$x = 2, h = 0.01$$
$$2(2) - 1 + 0.01 = 3.01$$

32. Zeroes: $(-6, 0), (0, 0), (6, 0), (9, 0)$
Minimum: $(-3, -8), (7.5, -2)$
Maximum: $(-6, 0), (3, 4)$



33. Squaring function
a. up on left/up on the right
b. x -intercepts: $(-4, 0), (0, 0)$
y-intercept: $(0, 0)$
c. Vertex: $(-2, -4)$
d. $x \in (-\infty, \infty), y \in [-4, \infty)$

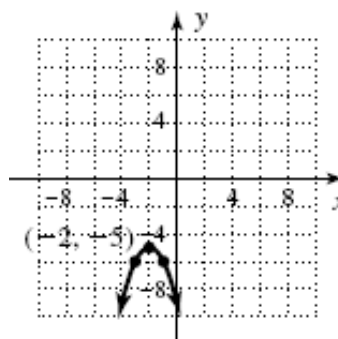
34. Square root function
a. down on the right
b. x -intercept: $(0, 0)$
y-intercept: $(0, 0)$
c. Initial point: $(-1, 2)$
d. $x \in [-1, \infty), y \in (-\infty, 2]$

35. Cubing function
a. down on left/up on right
b. x -intercepts: $(-2, 0), (-1, 0), (4, 0)$
y-intercept: $(0, 2)$
c. Inflection point: $(1, 0)$
d. $x \in (-\infty, \infty), y \in (-\infty, \infty)$

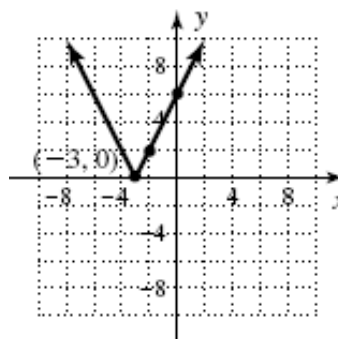
36. Absolute value function
a. down on left/ down on right
b. x -intercepts: $(-1, 0), (3, 0)$
y-intercept: $(0, 1)$
c. Vertex: $(1, 2)$
d. $x \in (-\infty, \infty), y \in (-\infty, 2]$

37. Cube root
a. up on left/ down on right
b. x -intercept: $(1, 0)$
y-intercept: $(0, 1)$
c. Inflection: $(1, 0)$
d. $x \in (-\infty, \infty), y \in (-\infty, \infty)$

38. $f(x) = -(x+2)^2 - 5$; Quadratic

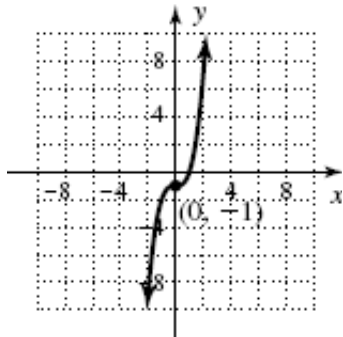


39. $f(x) = 2|x+3|$; Absolute Value

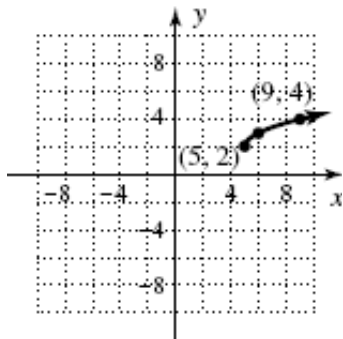


Chapter 2: Relations, Functions and Graphs

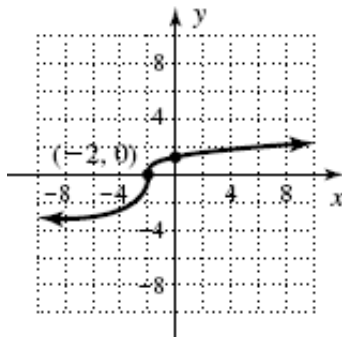
40. $f(x) = x^3 - 1$; Cubic



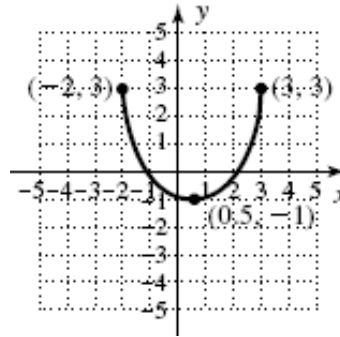
41. $f(x) = \sqrt{x-5} + 2$; Square Root



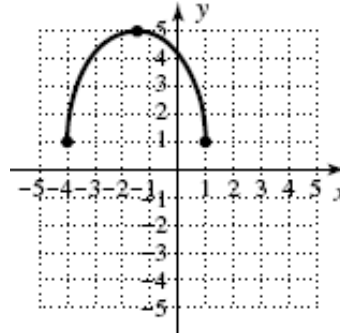
42. $f(x) = \sqrt[3]{x+2}$; Cube Root



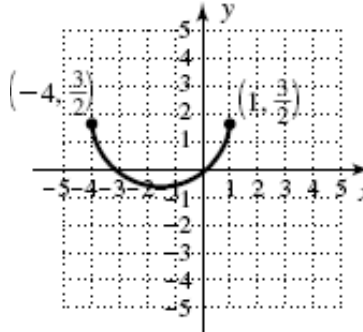
43. a. $f(x-2)$
Right 2



b. $-f(x) + 4$
Reflect, up 4



c. $\frac{1}{2}f(x)$
Compressed down



44. a.
$$f(x) = \begin{cases} 5 & x \leq -3 \\ -x+1 & -3 < x \leq 3 \\ 3\sqrt{x-3}-1 & x > 3 \end{cases}$$

$Y_1 = 5$; $Y_2 = -x+1$; $Y_3 = 3\sqrt{x-3}-1$

b. $R: y \in [-2, \infty)$

Summary and Review

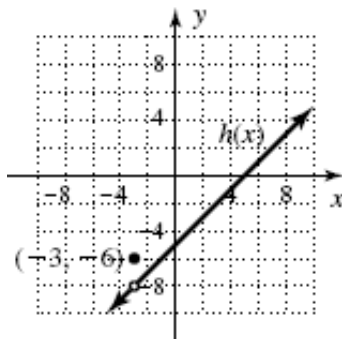
$$45. h(x) = \begin{cases} \frac{x^2 - 2x - 15}{x + 3} & x \neq -3 \\ -6 & x = -3 \end{cases}$$

$$x \in (-\infty, \infty)$$

$$y \in (-\infty, -8) \cup (-8, \infty)$$

Discontinuity at $x = -3$

Define $h(x) = -8$ at $x = -3$



$$46. p(x) = \begin{cases} -4 & x < -2 \\ -|x| - 2 & -2 \leq x < 3 \\ 3\sqrt{x} - 9 & x \geq 3 \end{cases}$$

$$p(-4) = -4;$$

$$p(-2) = -|-2| - 2 = -2 - 2 = -4;$$

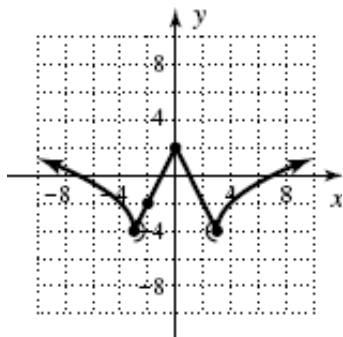
$$p(2.5) = -|2.5| - 2 = -2.5 - 2 = -4.5;$$

$$p(2.99) = -|2.99| - 2 = -2.99 - 2 = -4.99;$$

$$p(3) = 3\sqrt{3} - 9;$$

$$p(3.5) = 3\sqrt{3.5} - 9$$

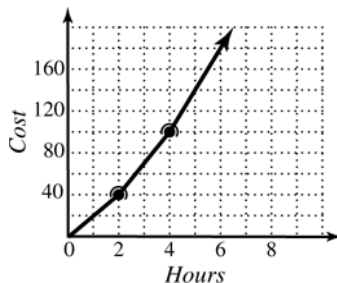
$$47. q(x) = \begin{cases} 2\sqrt{-x-3} - 4 & x \leq -3 \\ -2|x| + 2 & -3 < x < 3 \\ 2\sqrt{x-3} - 4 & x \geq 3 \end{cases}$$



$$D: x \in (-\infty, \infty)$$

$$R: y \in [-4, \infty)$$

48.



$$f(x) = \begin{cases} 20x & x \leq 2 \\ 30x - 20 & 2 < x \leq 4 \\ 40x - 60 & x > 4 \end{cases}$$

$$49. f(x) = x^2 + 4x \text{ and } g(x) = 3x - 2$$

$$(f + g)(a) = f(a) + g(a)$$

$$= a^2 + 4a + 3a - 2$$

$$= a^2 + 7a - 2$$

$$50. f(x) = x^2 + 4x \text{ and } g(x) = 3x - 2$$

$$(f \cdot g)(3) = f(3) \cdot g(3)$$

$$= ((3)^2 + 4(3))(3(3) - 2)$$

$$= (9 + 12)(9 - 2)$$

$$= (21)(7)$$

$$= 147$$

$$51. f(x) = x^2 + 4x \text{ and } g(x) = 3x - 2$$

$$\left(\frac{f}{g}\right)(x) = \frac{x^2 + 4x}{3x - 2}$$

$$D: x \in \left(-\infty, \frac{2}{3}\right) \cup \left(\frac{2}{3}, \infty\right)$$

$$52. p(x) = 4x - 3; q(x) = x^2 + 2x;$$

$$(p \circ q)(x) = p[q(x)]$$

$$= 4(q(x)) - 3$$

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

$$= 4x^2 + 8x - 3$$

$$53. p(x) = 4x - 3; q(x) = x^2 + 2x;$$

$$(q \circ p)(3) = q[p(3)]$$

$$p(3) = 4(3) - 3 = 12 - 3 = 9$$

$$q(9) = (9)^2 + 2(9) = 81 + 18 = 99$$

Chapter 2: Relations, Functions and Graphs

54. $p(x) = 4x - 3$; $q(x) = x^2 + 2x$; and

$$r(x) = \frac{x+3}{4};$$

$$(p \circ r)(x) = p[r(x)]$$

$$= 4(r(x)) - 3$$

$$= 4\left(\frac{x+3}{4}\right) - 3$$

$$= x + 3 - 3$$

$$= x;$$

$$(r \circ p)(x) = r[p(x)]$$

$$= \frac{p(x)+3}{4}$$

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

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

$$= x$$

55. $h(x) = \sqrt{3x-2} + 1$;

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

$$g(x) = 3x - 2$$

56. $h(x) = x^{\frac{2}{3}} - 3x^{\frac{1}{3}} - 10$

$$f(x) = x^2 - 3x - 10$$

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

57. $r(t) = 2t + 3$

$$A(t) = \pi(2t + 3)^2$$

58. a. $(f + g)(-2) = f(-2) + g(-2)$
 $= -1 + 5 = 4$

b. $(g \circ f)(5) = g(f(5))$
 $g(0) = 7$

c. $(g - f)(7) = g(7) - f(7)$
 $= 5 - (-1) = 6$

d. $\frac{g}{f}(10) = \frac{g(10)}{f(10)} = -\frac{1}{5}$

e. $(f \square g)(3) = f(3) \square g(3) = 7(2) = 14$

Chapter 2 Mixed Review

1. $4x + 3y = 12$

$$3y = -4x + 12$$

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

2. $x - 2y = 8$

$$-2y = -x + 8$$

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

Slope: $\frac{1}{2}$; Slope of perpendicular line: -2

$$y - 3 = -2(x - 1)$$

$$y - 3 = -2x + 2$$

$$y = -2x + 5$$

3. a. $f(x) = \frac{x+1}{x^2-5x+4}$

$$x^2 - 5x + 4 = 0$$

$$(x-4)(x-1) = 0$$

$$x-4=0 \text{ or } x-1=0$$

$$x=4 \text{ or } x=1$$

These values are restricted because they cause division by zero.

$$\text{Domain: } (-\infty, 1) \cup (1, 4) \cup (4, \infty)$$

b. $g(x) = \frac{1}{\sqrt{2x-3}}$

Set the radicand greater than zero. (Zero must be excluded because the radical is in the denominator.)

$$2x - 3 > 0$$

$$2x > 3$$

$$x > \frac{3}{2}$$

$$\text{Domain: } \left(\frac{3}{2}, \infty\right)$$

Chapter 2 Mixed Review

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

a.
$$p\left(-\frac{1}{3}\right) = -\left(-\frac{1}{3}\right)^2 + 3\left(-\frac{1}{3}\right) - 1$$
$$= -\frac{1}{9} - 1 - 1 = -\frac{19}{9}$$

b.
$$p(3a) = -(3a)^2 + 3(3a) - 1$$
$$= -9a^2 + 9a - 1$$

c.
$$p(a-1) = -(a-1)^2 + 3(a-1) - 1$$
$$= -(a^2 - 2a + 1) + 3a - 3 - 1$$
$$= -a^2 + 5a - 5$$

5. $m = -\frac{3}{2}$; y -intercept $(0, -2)$
$$y = -\frac{3}{2}x - 2$$

6. a. Domain: $[-4, 3]$
b. $g(2) = 3$;
c. $g(k) = -3$; $k = -4$

7. $L_1 : (-3, 7), (2, 2)$

Slope: $\frac{2-7}{2-(-3)} = -1$;

$L_2 : (2, 2), (5, 5)$

Slope: $\frac{5-2}{5-2} = 1$;

Lines are perpendicular. Vertex of right angle is $(2, 2)$.

Radius: distance between $(-3, 7)$ and $(2, 2)$.

$$d = \sqrt{(2-(-3))^2 + (2-7)^2} = \sqrt{50};$$

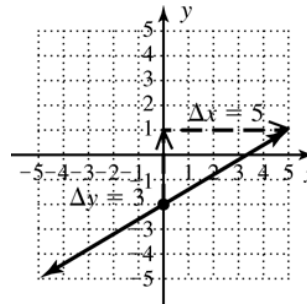
Center $(2, 2)$, radius $\sqrt{50}$

Equation: $(x-2)^2 + (y-2)^2 = 50$

8. End behavior: up, up; Vertex: $(1, -4)$
 $x = 1; (-1, 0), (3, 0), (0, -3)$

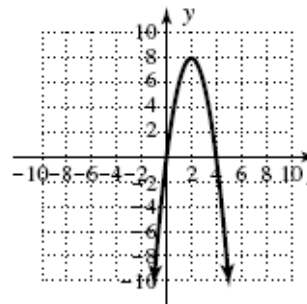
9. $y = \frac{3}{5}x - 2$

y -intercept $(0, -2)$



10. $f(x) = 4x - \frac{4}{3}x^2$, $f(x) < 0$
 $(-\infty, 0) \cup (3, \infty)$

11. a. $p(x) = -2x^2 + 8x$



Rate of change is positive in $[-2, -1]$ since p is increasing in $(-\infty, 2)$.

The rate of change in $[1, 2]$ will be less than the rate of change in $[-2, -1]$.

$$\frac{\Delta p}{\Delta x} = \frac{p(2) - p(1)}{2 - 1} = \frac{8 - 6}{1} = 2;$$

$$\frac{\Delta p}{\Delta x} = \frac{p(-1) - p(-2)}{-1 - (-2)} = \frac{-10 - (-24)}{1} = 14$$

b. $A(t) = 1000e^{0.07t}$

For $[10, 10.01]$,

$$\frac{1000e^{0.07(10.01)} - 1000e^{0.07(10)}}{10.01 - 10} \approx 141.0;$$

For $[15, 15.01]$,

$$\frac{1000e^{0.07(15.01)} - 1000e^{0.07(15)}}{15.01 - 15} \approx 200.1;$$

For $[20, 20.01]$,

$$\frac{1000e^{0.07(20.01)} - 1000e^{0.07(20)}}{20.01 - 20} \approx 284.0;$$

In the interval: $[15, 15.01]$

Chapter 2: Relations, Functions and Graphs

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

$$\frac{g\left(\frac{1}{2}\right)}{f\left(\frac{1}{2}\right)} = \frac{3\left(\frac{1}{2}\right) - 2}{\frac{3}{\left(\frac{1}{2}\right)^2 - 1}}$$

$$= \frac{\frac{3}{2} - 2}{\frac{3}{\frac{1}{4} - 1}} = -\frac{1}{2} \div \left(-\frac{3}{4}\right)$$

$$= -\frac{1}{2} \div -4 = -\frac{1}{2} \cdot -\frac{1}{4} = \frac{1}{8}$$

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

$$\begin{aligned} (f \circ g)(x) &= \frac{3}{(3x - 2)^2 - 1} \\ &= \frac{3}{9x^2 - 12x + 4 - 1} = \frac{3}{9x^2 - 12x + 3} \\ &= \frac{3}{3(3x^2 - 4x + 1)} = \frac{1}{3x^2 - 4x + 1} \end{aligned}$$

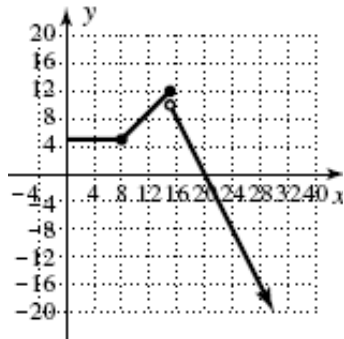
To find domain, $3x^2 - 4x + 1 = 0$

$$(3x - 1)(x - 1) = 0$$

$$x = \frac{1}{3}, x = 1$$

$$\text{Domain: } \left(-\infty, \frac{1}{3}\right) \cup \left(\frac{1}{3}, 1\right) \cup (1, \infty)$$

14. $h(x) = \begin{cases} 5 & 0 \leq x < 8 \\ x - 3 & 8 \leq x \leq 15 \\ -2x + 40 & x > 15 \end{cases}$



15. $f(x) = x^2 + 1, g(x) = 3x - 2$

$$\begin{aligned} \frac{f(x+h) - f(x)}{h} &= \frac{[(x+h)^2 + 1] - [x^2 + 1]}{h} \\ &= \frac{x^2 + 2xh + h^2 + 1 - x^2 - 1}{h} \end{aligned}$$

$$= \frac{2xh + h^2}{h} = \frac{h(2x + h)}{h} = 2x + h;$$

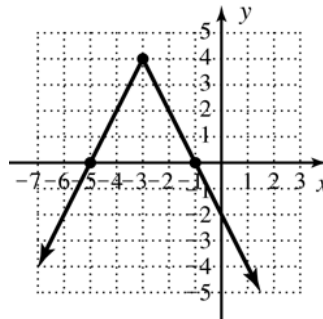
$$\begin{aligned} \frac{g(x+h) - g(x)}{h} &= \frac{[3(x+h) - 2] - [3x - 2]}{h} \\ &= \frac{3x + 3h - 2 - 3x + 2}{h} = \frac{3h}{h} = 3; \end{aligned}$$

For small h , $2x + h = 3$

$$\text{when } x \approx \frac{3}{2}$$

16. $g(x) = -2|x + 3| + 4$

Absolute Value, shift left 3, reflect and stretch up 4



17. a. $D: x \in (-\infty, 6]$

$$R: y \in (-\infty, 3]$$

b. Min: $(3, -3)$

$$\text{Max: } y = 3 \text{ for } x \in (-6, -3); (6, 0)$$

c. $g(x) \uparrow: x \in (-\infty, -6) \cup (3, 6)$

$$g(x) \downarrow: x \in (-3, 3)$$

$$g(x) \text{ constant: } x \in (-6, -3)$$

d. $g(x) > 0: x \in (-7, -1)$

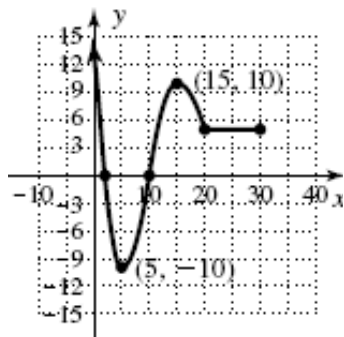
$$g(x) < 0: x \in (-\infty, -7) \cup (-1, 6)$$

Chapter 2 Practice Test

18. Zeroes: (2, 0), (10, 0)

Max: (15, 10)

Min: (5, -10)



19. x-intercepts: (-1, 0), (1.5, 0)

y-intercept: (0, 3)

$$f(x) = a(x+1)(x-1.5)$$

$$f(x) = a\left(x^2 - \frac{1}{2}x - \frac{3}{2}\right)$$

$$3 = a\left(0^2 - \frac{1}{2}(0) - \frac{3}{2}\right)$$

$$3 = -\frac{3}{2}a$$

$$-2 = a;$$

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

20. $m = \frac{431 - 257}{0 - 25} = \frac{174}{-25} = -6.96$

$$y - y_1 = m(x - x_1)$$

$$y - 431 = -6.96(x - 0)$$

$$y = -6.96x + 431$$

$$f(33) = -6.96(33) + 431 = 201.32$$

201,320 deaths from heart disease in 2008.

Chapter 2 Practice Test

1. a. $x = y^2 + 2y$

b. $y = \sqrt{5 - 2x}$

c. $|y| + 1 = x$

d. $y = x^2 + 2x$

a and c are non-functions, do not pass the vertical line test.

2. $L_1: 2x + 5y = -15$

$$5y = -2x - 15$$

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

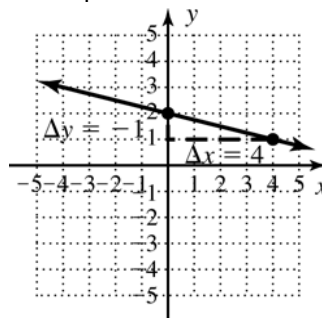
$$L_2: y = \frac{2}{5}x + 7$$

Neither

3. $x + 4y = 8$

$$4y = -x + 8$$

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

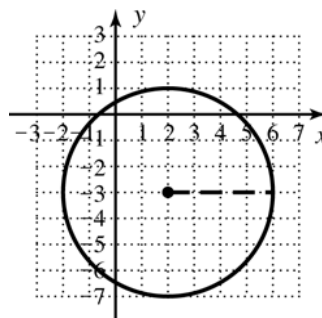


4. $x^2 - 4x + y^2 + 6y = 3$

$$x^2 - 4x + 4 + y^2 + 6y + 9 = 3 + 4 + 9$$

$$(x - 2)^2 + (y + 3)^2 = 16$$

Center: (2, -3); radius: 4



Chapter 2: Relations, Functions and Graphs

5. $6x + 5y = 3$

$$6x + 5y = 3$$

$$5y = -6x + 3$$

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

$$\text{Slope: } -\frac{6}{5}$$

$$\text{Point } (2, -2), \text{ slope } -\frac{6}{5}$$

$$y - (-2) = -\frac{6}{5}(x - 2)$$

$$y + 2 = -\frac{6}{5}x + \frac{12}{5}$$

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

6. $(-20, 15)$ and $(35, -12)$

a. $M = \left(\frac{-20 + 35}{2}, \frac{15 - 12}{2} \right) = (7.5, 1.5)$

b. $d = \sqrt{(-20 - 35)^2 + (15 + 12)^2}$

$$d = \sqrt{(-55)^2 + (27)^2}$$

$$d = \sqrt{3025 + 729}$$

$$d = \sqrt{3754}$$

$$d \approx 61.27 \text{ miles}$$

7. L1: $x = -3$

$$L2: y = 4$$

8. a. $x \in \{-4, -2, 0, 2, 4, 6\}$

$$y \in \{-2, -1, 0, 1, 2, 3\}$$

b. $x \in [-2, 6]$

$$y \in [1, 4]$$

9. a. $W(24) = 300$

b. $h = 30$ when $W(h) = 375$

c. $(20, 250)$ and $(40, 500)$

$$m = \frac{500 - 250}{40 - 20} = \frac{250}{20} = \frac{25}{2}$$

$$W(h) = \frac{25}{2}h$$

d. Wages are \$12.50 per hour.

e. $h \in [0, 40]$

$$w \in [0, 500]$$

10. Graph I

a. Square Root

b. $x \in [-4, \infty)$

$$y \in [-3, \infty)$$

c. x -intercept: $(-2, 0)$

y -intercept: $(0, 1)$

d. Up on right

e. $(-2, \infty)$

f. $[-4, -2)$

Graph II

a. Cubic

b. $x \in (-\infty, \infty)$

$$y \in (-\infty, \infty)$$

c. x -intercept: $(2, 0)$

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

d. Down on left, up on right

e. $(2, \infty)$

f. $(-\infty, 2)$

Graph III

a. Absolute value

b. $x \in (-\infty, \infty)$

$$y \in (-\infty, 4]$$

c. x -intercepts: $(-1, 0)$ and $(3, 0)$

y -intercept: $(0, 2)$

d. Down/down

e. $(-1, 3)$

f. $(-\infty, -1) \cup (3, \infty)$

Graph IV

a. Quadratic

b. $x \in (-\infty, \infty)$

$$y \in [-5.5, \infty]$$

c. x -intercepts: $(0, 0)$ and $(5, 0)$

y -intercept: $(0, 0)$

d. Up/up

e. $(-\infty, 0) \cup (5, \infty)$

f. $(0, 5)$

11. $f(x) = \frac{2 - x^2}{x^2}$

a. $f\left(\frac{2}{3}\right) = \frac{2 - \left(\frac{2}{3}\right)^2}{\left(\frac{2}{3}\right)^2} = \frac{2 - \left(\frac{4}{9}\right)}{\frac{4}{9}}$

$$= \frac{\frac{14}{9}}{\frac{4}{9}} = \frac{14}{9} \div \frac{4}{9} = \frac{7}{2}$$

Chapter 2 Practice Test

$$\begin{aligned} \text{b. } f(a+3) &= \frac{2-(a+3)^2}{(a+3)^2} \\ &= \frac{2-(a^2+6a+9)}{a^2+6a+9} = \frac{2-a^2-6a-9}{a^2+6a+9} \\ &= \frac{-a^2-6a-7}{a^2+6a+9} \end{aligned}$$

$$\begin{aligned} \text{c. } f(1+2i) &= \frac{2-(1+2i)^2}{(1+2i)^2} \\ &= \frac{2-(1+4i+4i^2)}{1+4i+4i^2} = \frac{2-1-4i-4i^2}{1+4i-4} \\ &= \frac{1-4i+4}{-3+4i} = \frac{5-4i}{-3+4i} \\ &= \frac{5-4i}{-3+4i} \cdot \frac{-3-4i}{-3-4i} = \frac{-15-20i+12i+16i^2}{9-16i^2} \\ &= \frac{-15-8i-16}{9+16} = \frac{-31-8i}{25} \\ &= -\frac{31}{25} - \frac{8}{25}i \end{aligned}$$

$$\begin{aligned} 12. \quad f(x) &= x^2 + 2, g(x) = \sqrt{3x-1} \\ (f \circ g)(x) &= (\sqrt{3x-1})^2 + 2 = 3x-1+2 \\ &= 3x+1; \\ \text{To find domain: } 3x-1 &\geq 0 \\ 3x &\geq 1 \\ x &\geq \frac{1}{3} \end{aligned}$$

$$\text{Domain: } x \in \left[\frac{1}{3}, \infty \right)$$

$$13. \quad S(t) = 2t^2 - 3t$$

a. No, new company and sales should be growing.

$$\text{b. For } [5, 6], S(5) = 2(5)^2 - 3(5) = 35$$

$$S(6) = 2(6)^2 - 3(6) = 54$$

$$\text{Rate of Change: } \frac{54-35}{6-5} = 19$$

$$\text{For } [6, 7], S(7) = 2(7)^2 - 3(7) = 77$$

$$\text{Rate of Change: } \frac{77-54}{7-6} = 23$$

$$\begin{aligned} \text{c. } &\frac{2(t+h)^2 - 3(t+h) - (2t^2 - 3t)}{h} \\ &= \frac{2(t^2 + 2th + h^2) - 3t - 3h - 2t^2 + 3t}{h} \\ &= \frac{2t^2 + 4th + 2h^2 - 3h - 2t^2}{h} \\ &= \frac{4th + 2h^2 - 3h}{h} = 4t - 3 + 2h \end{aligned}$$

For small h :

$$4(10) - 3 = 37, 4(18) - 3 = 69,$$

$$4(24) - 3 = 93$$

For small h , sales volume is approximately

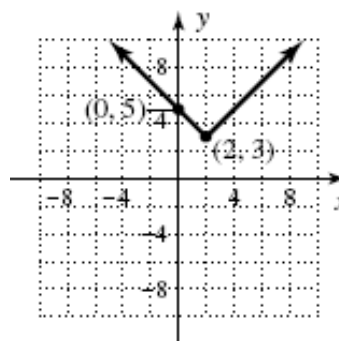
$$\frac{37,000 \text{ units}}{1 \text{ mo}} \text{ in month 10,}$$

$$\frac{69,000 \text{ units}}{1 \text{ mo}} \text{ in month 18,}$$

$$\frac{93,000 \text{ units}}{1 \text{ mo}} \text{ in month 24}$$

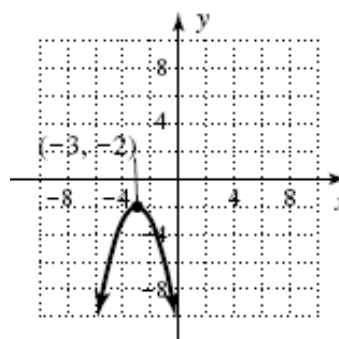
$$14. \quad f(x) = |x-2| + 3$$

Right 2, up 3



$$15. \quad g(x) = -(x+3)^2 - 2$$

Left 3, reflected across x -axis, down 2



Chapter 2: Relations, Functions and Graphs

16. $r(t) = \sqrt{t}$; $V(r) = \frac{4}{3}\pi r^3$

a. $(V \circ r)(t) = V[r(t)]$

$$V(t) = \frac{4}{3}\pi(\sqrt{t})^3$$

b. $V(9) = \frac{4}{3}\pi(\sqrt{9})^3$

$$V(9) = \frac{4}{3}\pi(27)$$

$$V(9) = 36\pi \text{ in}^3$$

17. a. $D: x \in [-4, \infty)$

$$R: y \in [-3, \infty)$$

b. $f(-1) \approx 2.2$

c. $f(x) < 0: x \in (-4, -3)$

$$f(x) > 0: x \in (-3, \infty)$$

d. $f(x) \uparrow: (-4, \infty)$

$$f(x) \downarrow: \text{none}$$

e. Parent graph: $y = \sqrt{x}$

Graph shifts left 4, down 3

$$y = a\sqrt{x+4} - 3$$

$$3 = a\sqrt{0+4} - 3$$

$$3 = a\sqrt{4} - 3$$

$$3 = 2a - 3$$

$$6 = 2a$$

$$3 = a$$

$$y = 3\sqrt{x+4} - 3$$

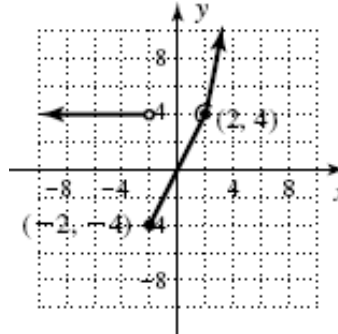
18. $h(x) = \begin{cases} 4 & x < -2 \\ 2x & -2 \leq x \leq 2 \\ x^2 & x > 2 \end{cases}$

$$h(-3) = 4,$$

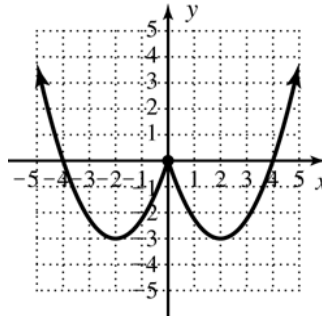
$$h(-2) = 2(-2) = -4,$$

$$h\left(\frac{5}{2}\right) = \left(\frac{5}{2}\right)^2 = 6.25$$

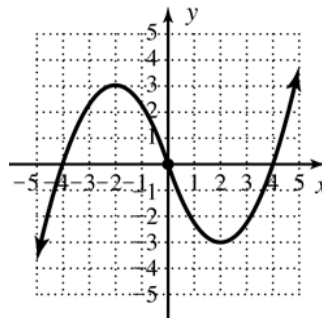
b.



19.



20.



Ch 2 Calculator Exploration

Exercise 1: $y = -5(x+4)^2 + 6; (-4, 6)$

Exercise 2: (2, 3), est: (0, 8),
computed: (0, 8.0396842), very close

Ch. 2 Strengthening Core Skills

Exercise 1: $f(x) = x^2 - 8x - 12$

$$\frac{b}{2a} = \frac{-8}{2(1)} = -4$$

Cumulative Review Chapters 1–2

$$\begin{aligned}
 g(x) &= x + 4 \\
 h(x) &= f[g(x)] = f(x + 4) \\
 &= (x + 4)^2 - 8(x + 4) - 12 \\
 &= x^2 + 8x + 16 - 8x - 32 - 12 \\
 &= x^2 - 28 \\
 x^2 - 28 &= 0 \\
 x^2 &= 28 \\
 x &= \pm 2\sqrt{7} ; \\
 4 \pm 2\sqrt{7}
 \end{aligned}$$

Exercise 2: $f(x) = x^2 + 4x + 5$

$$\begin{aligned}
 \frac{b}{2a} &= \frac{4}{2(1)} = 2 \\
 g(x) &= x - 2 \\
 h(x) &= f[g(x)] = f(x - 2) \\
 &= (x - 2)^2 + 4(x - 2) + 5 \\
 &= x^2 - 4x + 4 + 4x - 8 + 5 \\
 &= x^2 + 1 \\
 x^2 + 1 &= 0 \\
 x^2 &= -1 \\
 x &= \pm i \\
 -2 \pm i
 \end{aligned}$$

Exercise 3: $f(x) = 2x^2 - 10x + 11$

$$\begin{aligned}
 \frac{b}{2a} &= \frac{-10}{2(2)} = -\frac{5}{2} \\
 g(x) &= x + \frac{5}{2} \\
 h(x) &= f[g(x)] = f\left(x + \frac{5}{2}\right) \\
 &= 2\left(x + \frac{5}{2}\right)^2 - 10\left(x + \frac{5}{2}\right) + 11 \\
 &= 2\left(x^2 + 5x + \frac{25}{4}\right) - 10x - \frac{50}{2} + 11 \\
 &= 2x^2 + 10x + \frac{50}{4} - 10x - \frac{50}{2} + 11 \\
 &= 2x^2 - \frac{3}{2} \\
 2x^2 - \frac{3}{2} &= 0 \\
 2x^2 &= \frac{3}{2} \\
 x^2 &= \frac{3}{4} \\
 x &= \pm \frac{\sqrt{3}}{2} \\
 \frac{5}{2} \pm \frac{\sqrt{3}}{2}
 \end{aligned}$$

Cumulative Review Chapters 1–2

$$\begin{aligned}
 1. \quad & (x^3 - 5x^2 + 2x - 10) \div (x - 5) \\
 &= \frac{x^2(x - 5) + 2(x - 5)}{x - 5} \\
 &= \frac{(x - 5)(x^2 + 2)}{x - 5} \\
 &= x^2 + 2
 \end{aligned}$$

$$\begin{aligned}
 2. \quad & 2 - x < 5 \quad \text{and} \quad 3x + 2 < 8 \\
 & -x < 3 \quad \quad \quad 3x < 6 \\
 & x > -3 \quad \quad \quad x < 2 \\
 \text{Solution set: } & -3 < x < 2
 \end{aligned}$$

Chapter 2: Relations, Functions and Graphs

$$\begin{aligned} 3. \quad A &= \pi r^2 \\ 69 &= \pi r^2 \\ \frac{69}{\pi} &= r^2 \end{aligned}$$

$$21.96 \approx r^2$$

$$4.686 \approx r;$$

$$C = 2\pi r$$

$$C = 2\pi(4.686)$$

$$C \approx 29.45 \text{ cm}$$

$$\begin{aligned} 4. \quad A &= 2\pi r^2 + 2\pi rh \\ 2\pi r^2 + 2\pi rh - A &= 0 \\ r &= \frac{-2\pi h \pm \sqrt{(2\pi h)^2 - 4(2\pi)(-A)}}{2(2\pi)} \\ r &= \frac{-2\pi h \pm \sqrt{4\pi^2 h^2 + 4(2\pi A)}}{4\pi} \\ r &= \frac{-2\pi h \pm \sqrt{4(\pi^2 h^2 + 2\pi A)}}{4\pi} \\ r &= \frac{-2\pi h \pm 2\sqrt{\pi^2 h^2 + 2\pi A}}{4\pi} \\ r &= \frac{-\pi h \pm \sqrt{\pi^2 h^2 + 2\pi A}}{2\pi} \end{aligned}$$

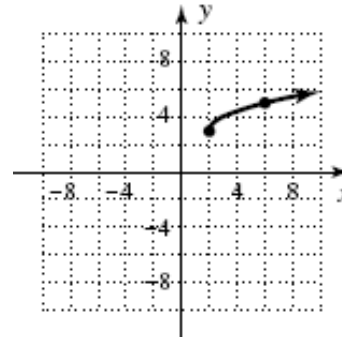
$$\begin{aligned} 5. \quad -2(3-x) + 5x &= 4(x+1) - 7 \\ -6 + 2x + 5x &= 4x + 4 - 7 \\ 7x - 6 &= 4x - 3 \\ 3x &= 3 \\ x &= 1 \end{aligned}$$

$$6. \quad \left(\frac{27}{8}\right)^{-\frac{2}{3}} = \left(\frac{8}{27}\right)^{\frac{2}{3}} = \left(\sqrt[3]{\frac{8}{27}}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

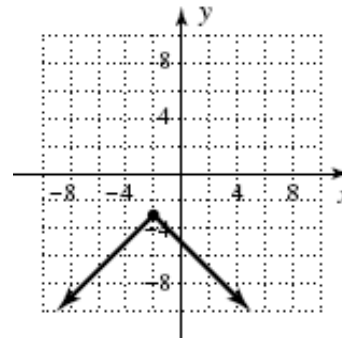
$$\begin{aligned} 7. \quad \text{a.} \quad (-4, 7) \text{ and } (2, 5) \\ m &= \frac{7-5}{-4-2} = \frac{2}{-6} = -\frac{1}{3} \end{aligned}$$

$$\begin{aligned} \text{b.} \quad 3x - 5y &= 20 \\ -5y &= -3x + 20 \\ y &= \frac{3}{5}x - 4 \\ m &= \frac{3}{5} \end{aligned}$$

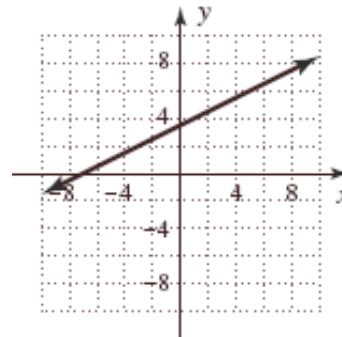
$$\begin{aligned} 8. \quad \text{a.} \quad f(x) &= \sqrt{x-2} + 3 \\ \text{Right 2, up 3} \end{aligned}$$



$$\begin{aligned} \text{b.} \quad f(x) &= -|x+2| - 3 \\ \text{Left 2, reflected across x-axis, down 3} \end{aligned}$$



$$9. \quad (-3, 2); m = \frac{1}{2}$$



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

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

$$y = \frac{1}{2}x + \frac{7}{2}$$

Cumulative Review Chapters 1–2

10. $x^2 - 2x + 26 = 0$

$$(1+5i)^2 - 2(1+5i) + 26 = 0$$

$$1+10i+25i^2 - 2-10i+26=0$$

$$1+10i-25-2-10i+26=0$$

$$0=0$$

11. $f(x) = 3x^2 - 6x$ and $g(x) = x - 2$

$$(f \cdot g)(x) = f(x) \cdot g(x)$$

$$= (3x^2 - 6x)(x - 2)$$

$$= 3x^3 - 6x^2 - 6x^2 + 12x$$

$$= 3x^3 - 12x^2 + 12x$$

$$(f \div g)(x) = \frac{f(x)}{g(x)}$$

$$= \frac{3x^2 - 6x}{x - 2}$$

$$= \frac{3x(x-2)}{x-2}$$

$$= 3x; \quad x \neq 2;$$

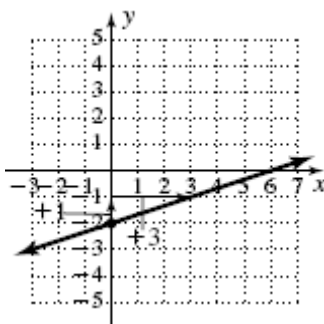
$$(g \circ f)(-2) = g[f(-2)]$$

$$f(-2) = 3(-2)^2 - 6(-2) = 24;$$

$$g(24) = 24 - 2 = 22$$

12. $y = \frac{1}{3}x - 2$; y -intercept: $(0, -2)$;

$$m = \frac{1}{3}$$



13. $f(x) = \begin{cases} x^2 - 4 & x < 2 \\ x - 1 & 2 \leq x \leq 8 \end{cases}$

a. $D: x \in (-\infty, 8]$

$$R: y \in [-4, \infty)$$

b. $f(-3) = (-3)^2 - 4 = 9 - 4 = 5;$

$$f(-1) = (-1)^2 - 4 = 1 - 4 = -3;$$

$$f(1) = (1)^2 - 4 = 1 - 4 = -3;$$

$$f(2) = 2 - 1 = 1;$$

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

c. $(-2, 0)$

d. $f(x) < 0: x \in (-2, 2)$

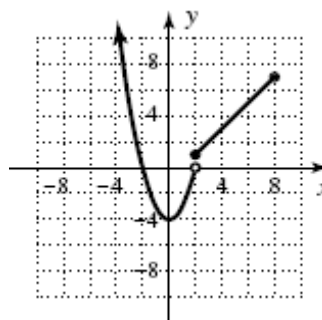
$$f(x) > 0: x \in (-\infty, -2) \cup [2, 8]$$

e. Max: $(8, 7)$

$$\text{Min: } (0, -4)$$

f. $f(x) \uparrow: x \in (0, 8)$

$$f(x) \downarrow: x \in (-\infty, 0)$$



14. $f(x) = x^2$ and $g(x) = x^3$

a. $\frac{\Delta f}{\Delta x} = \frac{f(0.6) - f(0.5)}{0.6 - 0.5} = 1.1;$

$$\frac{\Delta g}{\Delta x} = \frac{g(0.6) - g(0.5)}{0.6 - 0.5} = 0.91;$$

$$f(x) \text{ increases faster.}$$

b. $\frac{\Delta f}{\Delta x} = \frac{f(1.6) - f(1.5)}{1.6 - 1.5} = 3.1;$

$$\frac{\Delta g}{\Delta x} = \frac{g(1.6) - g(1.5)}{1.6 - 1.5} = 7.21;$$

$$g(x) \text{ increases faster}$$

Chapter 2: Relations, Functions and Graphs

$$\begin{aligned}
 15. \text{ a. } & \frac{-2}{x^2 - 3x - 10} + \frac{1}{x+2} \\
 &= \frac{-2}{(x-5)(x+2)} + \frac{1}{x+2} \\
 &= \frac{-2}{(x-5)(x+2)} + \frac{1(x-5)}{(x-5)(x+2)} \\
 &= \frac{-2+x-5}{(x-5)(x+2)} \\
 &= \frac{x-7}{(x-5)(x+2)}
 \end{aligned}$$

$$\text{ b. } \frac{b^2}{4a^2} - \frac{c}{a} = \frac{b^2}{4a^2} - \frac{4ac}{4a^2} = \frac{b^2 - 4ac}{4a^2}$$

$$16. \text{ a. } \frac{-10 + \sqrt{72}}{4} = \frac{-10 + 6\sqrt{2}}{4} = -\frac{5}{2} + \frac{3\sqrt{2}}{2}$$

$$\text{ b. } \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{2}} \cdot \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$$17. \text{ a. } N \subset Z \subset W \subset Q \subset R$$

False

$$\text{ b. } W \subset N \subset Z \subset Q \subset R$$

False

$$\text{ c. } N \subset W \subset Z \subset Q \subset R$$

True

$$\text{ d. } N \subset R \subset Z \subset Q \subset W$$

False

18. No; Raphael is grouped with The School of Athens and Parnassus. Michelangelo corresponds to no element of the second set.

$$19. \quad 2x^2 + 49 = -20x$$

$$2x^2 + 20x + 49 = 0$$

$$2x^2 + 20x = -49$$

$$x^2 + 10x = \frac{-49}{2}$$

$$x^2 + 10x + 25 = -\frac{49}{2} + 25$$

$$(x+5)^2 = \frac{1}{2}$$

$$x+5 = \pm \sqrt{\frac{1}{2}}$$

$$x+5 = \pm \frac{\sqrt{2}}{2}$$

$$x = -5 \pm \frac{\sqrt{2}}{2};$$

$$x \approx -4.293$$

$$x \approx -5.707$$

$$20. \quad 2x^2 + 20x = -51$$

$$2x^2 + 20x + 51 = 0$$

$$x = \frac{-20 \pm \sqrt{(20)^2 - 4(2)(51)}}{2(2)}$$

$$x = \frac{-20 \pm \sqrt{400 - 408}}{4}$$

$$x = \frac{-20 \pm \sqrt{-8}}{4}$$

$$x = \frac{-20 \pm 2i\sqrt{2}}{4}$$

$$x = -5 \pm \frac{i\sqrt{2}}{2}$$

21. Let w represent the width.

Let l represent the length.

$$A = lw$$

$$1457 = (w+16)w$$

$$0 = w^2 + 16w - 1457$$

$$0 = (w-31)(w+47)$$

$$w = 31 \text{ cm}; l = 47 \text{ cm}$$

Cumulative Review Chapters 1–2

$$22. \text{ a. } (2+5i)^2 = 4 + 20i + 25i^2 \\ = 4 + 20i - 25 = -21 + 20i$$

$$\text{ b. } \frac{1-2i}{1+2i} = \frac{1-2i}{1+2i} \cdot \frac{1-2i}{1-2i} \\ = \frac{1-4i+4i^2}{1-4i^2} = \frac{1-4i-4}{1+4} \\ = \frac{-3-4i}{5} = -\frac{3}{5} - \frac{4}{5}i$$

$$23. \text{ a. } 6x^2 - 7x = 20 \\ 6x^2 - 7x - 20 = 0$$

$$(3x+4)(2x-5) = 0$$

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

$$\text{ b. } x^3 + 5x^2 - 15 = 3x$$

$$x^3 + 5x^2 - 3x - 15 = 0$$

$$(x^3 + 5x^2) - (3x + 15) = 0$$

$$x^2(x+5) - 3(x+5) = 0$$

$$(x+5)(x^2 - 3) = 0$$

$$x = -5; \quad x = \sqrt{3}; \quad x = -\sqrt{3}$$

$$24. \quad m_1 = \frac{1}{2}; \quad m_2 = -2; \quad (1, 2)$$

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

$$y - 2 = -2x + 2$$

$$y = -2x + 4$$

$$25. \quad (-4, 5), (4, -1), (0, 8)$$

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

$$d = \sqrt{(-8)^2 + (6)^2}$$

$$d = \sqrt{100}$$

$$d = 10;$$

$$d = \sqrt{(4-0)^2 + (-1-8)^2}$$

$$d = \sqrt{(4)^2 + (-9)^2}$$

$$d = \sqrt{97}$$

$$d \approx 9.85;$$

$$d = \sqrt{(-4-0)^2 + (5-8)^2}$$

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

$$d = \sqrt{25}$$

$$d = 5;$$

$$P = 10 + \sqrt{97} + 5 = 15 + \sqrt{97}$$

$$\approx 15 + 9.85 \approx 24.85 \text{ units}$$

No it is not a right triangle.

$$5^2 + (\sqrt{97})^2 \neq 10^2$$

Chapter 2: Relations, Functions and Graphs

Connections to Calculus Chapter 2

$$\begin{aligned}
 1. \quad a. \quad & f(x) = -3x + 5 \\
 & \frac{f(x+h) - f(x)}{h} \\
 &= \frac{(-3(x+h) + 5) - (-3x + 5)}{h} \\
 &= \frac{-3x - 3h + 5 + 3x - 5}{h} = \frac{-3h}{h} = -3
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, -3 \text{ remains constant}$$

$$\begin{aligned}
 2. \quad a. \quad & g(x) = \frac{2}{3}x - 7 \\
 & \frac{g(x+h) - g(x)}{h} \\
 &= \frac{\left(\frac{2}{3}(x+h) - 7\right) - \left(\frac{2}{3}x - 7\right)}{h} \\
 &= \frac{\left(\frac{2}{3}x + \frac{2}{3}h - 7\right) - \frac{2}{3}x + 7}{h} \\
 &= \frac{\frac{2}{3}h}{h} = \frac{2}{3}
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, \frac{2}{3} \text{ remains constant}$$

$$\begin{aligned}
 3. \quad a. \quad & h(x) = x^2 - 3x \\
 & \frac{h(x+h) - h(x)}{h} \\
 &= \frac{((x+h)^2 - 3(x+h)) - (x^2 - 3x)}{h} \\
 &= \frac{x^2 + 2xh + h^2 - 3x - 3h - x^2 + 3x}{h} \\
 &= \frac{2xh + h^2 - 3h}{h} = \frac{h(2x + h - 3)}{h} \\
 &= 2x - 3 + h, \quad h \neq 0
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, 2(2) - 3 + h \rightarrow 1$$

$$\begin{aligned}
 4. \quad a. \quad & r(x) = -2x^2 + 3x + 7 \\
 & \frac{r(x+h) - r(x)}{h} \\
 &= \frac{(-2(x+h)^2 + 3(x+h) + 7) - (-2x^2 + 3x + 7)}{h} \\
 &= \frac{-2(x^2 + 2xh + h^2) + 3x + 3h + 7 + 2x^2 - 3x - 7}{h} \\
 &= \frac{-2x^2 - 4xh - 2h^2 + 3x + 3h + 7 + 2x^2 - 3x - 7}{h} \\
 &= \frac{-4xh - 2h^2 + 3h}{h} = \frac{h(-4x - 2h + 3)}{h} \\
 &= -4x + 3 - 2h, \quad h \neq 0
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, -4(2) + 3 - 2h \rightarrow -5$$

$$\begin{aligned}
 5. \quad a. \quad & f(x) = \frac{1}{x} \\
 & \frac{f(x+h) - f(x)}{h} \\
 &= \frac{\frac{1}{x+h} - \frac{1}{x}}{h} \\
 &= \frac{\frac{x}{x} \cdot \frac{1}{x+h} - \frac{1}{x} \cdot \frac{x+h}{x+h}}{h} \\
 &= \frac{\frac{x - (x+h)}{x(x+h)} \cdot \frac{1}{h}}{1} \\
 &= \frac{x - x - h}{x(x+h)} \cdot \frac{1}{h} \\
 &= \frac{-h}{hx(x+h)} = \frac{-1}{x(x+h)}
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, \frac{-1}{2(2+h)} \rightarrow -\frac{1}{4}$$

Connections to Calculus

$$\begin{aligned}
 6. \quad a. \quad g(x) &= \frac{3}{x+1} \\
 \frac{g(x+h) - g(x)}{h} &= \frac{\frac{3}{(x+h)+1} - \frac{3}{x+1}}{h} \\
 &= \frac{\frac{3}{(x+h)+1} - \frac{3}{x+1}}{h} \\
 &= \left(\frac{x+1}{x+1} \cdot \frac{3}{x+h+1} - \frac{3}{x+1} \cdot \frac{x+h+1}{x+h+1} \right) \div \frac{h}{1} \\
 &= \left(\frac{3x+3}{(x+1)(x+h+1)} - \frac{(3x+3h+3)}{(x+1)(x+h+1)} \right) \cdot \frac{1}{h} \\
 &= \frac{3x+3-3x-3h-3}{(x+1)h(x+h+1)} \\
 &= \frac{-3h}{(x+1)h(x+h+1)} \\
 &= \frac{-3}{(x+1)(x+h+1)}
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, \frac{-3}{(2+1)(2+h+1)} \rightarrow -\frac{1}{3}$$

$$\begin{aligned}
 7. \quad a. \quad h(x) &= \frac{1}{2x^2} \\
 \frac{h(x+h) - h(x)}{h} &= \frac{\frac{1}{2(x+h)^2} - \frac{1}{2x^2}}{h} \\
 &= \left(\frac{x^2}{x^2} \cdot \frac{1}{2(x+h)^2} - \frac{1}{2x^2} \cdot \frac{(x+h)^2}{(x+h)^2} \right) \div \frac{h}{1} \\
 &= \left(\frac{x^2 - (x^2 + 2xh + h^2)}{2x^2(x+h)^2} \right) \cdot \frac{1}{h} \\
 &= \frac{x^2 - x^2 - 2xh - h^2}{2x^2(x+h)^2 h} \\
 &= \frac{-2xh - h^2}{2x^2(x+h)^2 h} \\
 &= \frac{h(-2x - h)}{2x^2(x+h)^2 h} \\
 &= \frac{-2x - h}{2x^2(x+h)^2}
 \end{aligned}$$

$$b. \quad x = 2 : \text{as } h \rightarrow 0, \frac{-2(2) - h}{2(2)^2(2+h)^2} \rightarrow -\frac{1}{8}$$

$$\begin{aligned}
 8. \quad a. \quad r(x) &= x^3 - 2x - 2 \\
 \frac{r(x+h) - r(x)}{h} &= \frac{(x+h)^3 - 2(x+h) - 2 - (x^3 - 2x - 2)}{h} \\
 &= \frac{x^3 + 3x^2h + 3xh^2 + h^3 - 2x - 2h - 2 - x^3 + 2x + 2}{h} \\
 &= \frac{3x^2h + 3xh^2 + h^3 - 2h}{h} \\
 &= \frac{h(3x^2 + 3xh + h^2 - 2)}{h}
 \end{aligned}$$

$$= 3x^2 + 3xh + h^2 - 2, h \neq 0$$

$$b. \quad x = 2 :$$

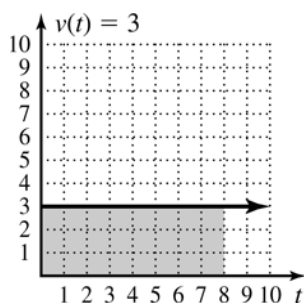
$$\text{as } h \rightarrow 0, 3(2)^2 + 3(2)h + h^2 - 2 \rightarrow 10$$

Chapter 2: Relations, Functions and Graphs

9. $v(t) = 3, t = 0 \text{ to } t = 8$

$$A = LW = 3 \cdot 8 = 24$$

Distance 24 ft

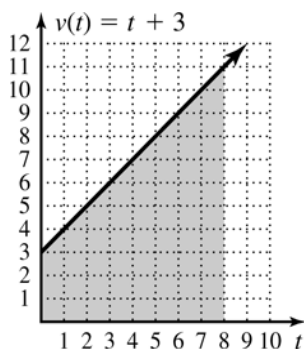


10. $v(t) = t + 3, t = 0 \text{ to } t = 8$

$$A = \frac{1}{2}(b_1 + b_2)h$$

$$A = \frac{1}{2}(3 + 11)8 = 56$$

Distance 56 ft

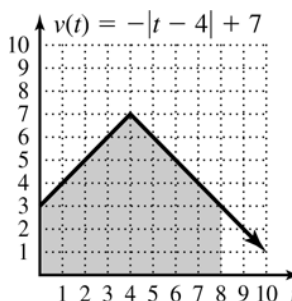


11. $v(t) = -|t - 4| + 7$

$$A = \frac{1}{2}bh + lw$$

$$A = \frac{1}{2}(8)4 + 8 \cdot 3 = 40$$

Distance 40 ft



12. $v(t) = -\frac{1}{2}(t - 4)^2 + 11$

$$A = \frac{4}{3}ab + lw$$

$$A = \frac{4}{3}(4)8 + 8 \cdot 3 = \frac{200}{3} = 66\frac{2}{3}$$

Distance $66\frac{2}{3}$ ft