Student Study and Solutions Manual

TRIGONOMETRY

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Ron Larson

Student Study and Solutions Manual

Trigonometry

NINTH EDITION

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C H A P T E R P
Prerequisites

Section P.1 Review of Real Numbers and Their Properties

1. irrational

3. absolute value

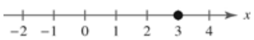
5. terms

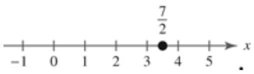
7. $-9, -\frac{7}{2}, 5, \frac{2}{3}, \sqrt{2}, 0, 1, -4, 2, -11$

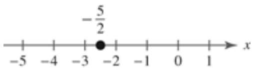
(a) Natural numbers: 5, 1, 2
(b) Whole numbers: 0, 5, 1, 2
(c) Integers: $-9, 5, 0, 1, -4, 2, -11$
(d) Rational numbers: $-9, -\frac{7}{2}, 5, \frac{2}{3}, 0, 1, -4, 2, -11$
(e) Irrational numbers: $\sqrt{2}$

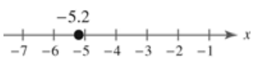
9. $2.01, 0.666\ldots, -13, 0.010110111\ldots, 1, -6$

(a) Natural numbers: 1
(b) Whole numbers: 1
(c) Integers: $-13, 1, -6$
(d) Rational numbers: $2.01, 0.666\ldots, -13, 1, -6$
(e) Irrational numbers: $0.010110111\ldots$

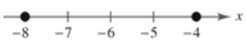
11. (a) 

(b) 

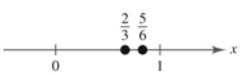
(c) 

(d) 

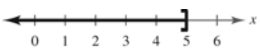
13. $-4 > -8$



15. $\frac{5}{6} > \frac{2}{3}$

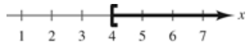


17. (a) The inequality $x \le 5$ denotes the set of all real numbers less than or equal to 5.

(b) 

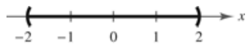
(c) The interval is unbounded.

19. (a) The interval $[4, \infty)$ denotes the set of all real numbers greater than or equal to 4.

(b) 

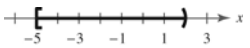
(c) The interval is unbounded.

21. (a) The inequality $-2 < x < 2$ denotes the set of all real numbers greater than -2 and less than 2.

(b) 

(c) The interval is bounded.

23. (a) The interval $[-5, 2)$ denotes the set of all real numbers greater than or equal to -5 and less than 2.

(b) 

(c) The interval is bounded.

25. $y \ge 0; [0, \infty)$

27. $10 \le t \le 22; [10, 22]$

29. $W > 65; (65, \infty)$

31. $|-10| = -(-10) = 10$

33. $|3 - 8| = |-5| = -(-5) = 5$

35. $|-1| - |-2| = 1 - 2 = -1$

37. $\dfrac{-5}{|-5|} = \dfrac{-5}{-(-5)} = \dfrac{-5}{5} = -1$

39. If $x < -2$, then $x + 2$ is negative.

So, $\dfrac{|x + 2|}{x + 2} = \dfrac{-(x + 2)}{x + 2} = -1.$

41. $|-4| = |4|$ because $|-4| = 4$ and $|4| = 4$.

43. $-|-6| < |-6|$ because $|-6| = 6$ and $-|-6| = -(6) = -6$.

45. $d(126, 75) = |75 - 126| = 51$

47. $d\left(-\frac{5}{2}, 0\right) = \left|0 - \left(-\frac{5}{2}\right)\right| = \frac{5}{2}$

49. $d\left(\frac{16}{5}, \frac{112}{75}\right) = \left|\frac{112}{75} - \frac{16}{5}\right| = \frac{128}{75}$

51. $d(x, 5) = |x - 5|$ and $d(x, 5) \le 3$, so $|x - 5| \le 3$.

53. $d(y, a) = |y - a|$ and $d(y, a) \le 2$, so $|y - a| \le 2$.

	Receipts, R	Expenditures, E	$\lvert R - E \rvert$
55.	\$1880.1	\$2292.8	$\lvert 1880.1 - 2292.8 \rvert = \$412.7$ billion
57.	\$2524.0	\$2982.5	$\lvert 2524.0 - 2982.5 \rvert = \$458.5$ billion

59. $7x + 4$

Terms: $7x, 4$

Coefficient: 7

61. $4x^3 + \frac{x}{2} - 5$

Terms: $4x^3, \frac{x}{2}, -5$

Coefficients: $4, \frac{1}{2}$

63. $4x - 6$

(a) $4(-1) - 6 = -4 - 6 = -10$

(b) $4(0) - 6 = 0 - 6 = -6$

65. $-x^2 + 5x - 4$

(a) $-(-1)^2 + 5(-1) - 4 = -1 - 5 - 4 = -10$

(b) $-(1)^2 + 5(1) - 4 = -1 + 5 - 4 = 0$

67. $\frac{1}{(h + 6)}(h + 6) = 1, h \ne -6$

Multiplicative Inverse Property

69. $2(x + 3) = 2 \cdot x + 2 \cdot 3$

Distributive Property

71. $x(3y) = (x \cdot 3)y$ Associative Property of Multiplication

$= (3x)y$ Commutative Property of Multiplication

73. $\frac{5}{8} - \frac{5}{12} + \frac{1}{6} = \frac{15}{24} - \frac{10}{24} + \frac{4}{24} = \frac{9}{24} = \frac{3}{8}$

75. $\frac{2x}{3} - \frac{x}{4} = \frac{8x}{12} - \frac{3x}{12} = \frac{5x}{12}$

77. (a) Because $A > 0, -A < 0$.
The expression is negative.

(b) Because $B < A, B - A < 0$.
The expression is negative.

(c) Because $C < 0, -C > 0$.
The expression is positive.

(d) Because $A > C, A - C > 0$.
The expression is positive.

79. False. Because 0 is nonnegative but not positive, not every nonnegative number is positive.

81. (a)

n	0.0001	0.01	1	100	10,000
$5/n$	50,000	500	5	0.05	0.0005

(b) (i) As n approaches 0, the value of $5/n$ increases without bound (approaches infinity).

(ii) As n increases without bound (approaches infinity), the value of $5/n$ approaches 0.

Section P.2 Solving Equations

1. equation

3. extraneous

5.
$$\begin{aligned} x + 11 &= 15 \\ x + 11 - 11 &= 15 - 11 \\ x &= 4 \end{aligned}$$

7.
$$\begin{aligned} 7 - 2x &= 25 \\ 7 - 7 - 2x &= 25 - 7 \\ -2x &= 18 \\ \frac{-2x}{-2} &= \frac{18}{-2} \\ x &= -9 \end{aligned}$$

9.
$$\begin{aligned} 4y + 2 - 5y &= 7 - 6y \\ 4y - 5y + 2 &= 7 - 6y \\ -y + 2 &= 7 - 6y \\ -y + 6y + 2 &= 7 - 6y + 6y \\ 5y + 2 &= 7 \\ 5y + 2 - 2 &= 7 - 2 \\ 5y &= 5 \\ \frac{5y}{5} &= \frac{5}{5} \\ y &= 1 \end{aligned}$$

11.
$$\begin{aligned} x - 3(2x + 3) &= 8 - 5x \\ x - 6x - 9 &= 8 - 5x \\ -5x - 9 &= 8 - 5x \\ -5x + 5x - 9 &= 8 - 5x + 5x \\ -9 &\neq 8 \end{aligned}$$

No solution

13.
$$\begin{aligned} \frac{3x}{8} - \frac{4x}{3} &= 4 \\ \frac{9x}{24} - \frac{32x}{24} &= 4 \\ -\frac{23x}{24} &= 4 \\ -\frac{23x}{24}\left(-\frac{24}{23}\right) &= 4\left(-\frac{24}{23}\right) \\ x &= -\frac{96}{23} \end{aligned}$$

or

$$\begin{aligned} \frac{3x}{8} - \frac{4x}{3} &= 4 \\ 24\left(\frac{3x}{8} - \frac{4x}{3}\right) &= 24(4) \\ 9x - 32x &= 96 \\ -23x &= 96 \\ x &= -\frac{96}{23} \end{aligned}$$

The second method is easier. The fractions are eliminated in the first step.

15.
$$\begin{aligned} \frac{5x - 4}{5x + 4} &= \frac{2}{3} \\ 3(5x - 4) &= 2(5x + 4) \\ 15x - 12 &= 10x + 8 \\ 5x &= 20 \\ x &= 4 \end{aligned}$$

17.
$$\begin{aligned} 10 - \frac{13}{x} &= 4 + \frac{5}{x} \\ \frac{10x - 13}{x} &= \frac{4x + 5}{x} \\ 10x - 13 &= 4x + 5 \\ 6x &= 18 \\ x &= 3 \end{aligned}$$

19.
$$\begin{aligned} \frac{x}{x + 4} + \frac{4}{x + 4} + 2 &= 0 \\ \frac{x + 4}{x + 4} + 2 &= 0 \\ 1 + 2 &= 0 \\ 3 &\neq 0 \end{aligned}$$

Contradiction; no solution

21.
$$\frac{2}{(x - 4)(x - 2)} = \frac{1}{x - 4} + \frac{2}{x - 2}$$ Multiply both sides by $(x - 4)(x - 2)$.
$$\begin{aligned} 2 &= 1(x - 2) + 2(x - 4) \\ 2 &= x - 2 + 2x - 8 \\ 2 &= 3x - 10 \\ 12 &= 3x \\ 4 &= x \end{aligned}$$

A check reveals that $x = 4$ is an extraneous solution—it makes the denominator zero. There is no real solution.

23.
$$\frac{1}{x - 3} + \frac{1}{x + 3} = \frac{10}{x^2 - 9}$$
$$\frac{1}{x - 3} + \frac{1}{x + 3} = \frac{10}{(x + 3)(x - 3)}$$ Multiply both sides by $(x + 3)(x - 3)$.
$$\begin{aligned} 1(x + 3) + 1(x - 3) &= 10 \\ 2x &= 10 \\ x &= 5 \end{aligned}$$

25. $6x^2 + 3x = 0$

$3x(2x + 1) = 0$

$3x = 0$ or $2x + 1 = 0$

$x = 0$ or $x = -\frac{1}{2}$

27. $x^2 - 2x - 8 = 0$

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

$x - 4 = 0$ or $x + 2 = 0$

$x = 4$ or $x = -2$

29. $x^2 + 10x + 25 = 0$

$(x + 5)(x + 5) = 0$

$x + 5 = 0$

$x = -5$

31. $x^2 + 4x = 12$

$x^2 + 4x - 12 = 0$

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

$x + 6 = 0$ or $x - 2 = 0$

$x = -6$ or $x = 2$

33. $\frac{3}{4}x^2 + 8x + 20 = 0$

$4\left(\frac{3}{4}x^2 + 8x + 20\right) = 4(0)$

$3x^2 + 32x + 80 = 0$

$(3x + 20)(x + 4) = 0$

$3x + 20 = 0$ or $x + 4 = 0$

$x = -\frac{20}{3}$ or $x = -4$

35. $x^2 = 49$

$x = \pm 7$

37. $3x^2 = 81$

$x^2 = 27$

$x = \pm 3\sqrt{3}$

39. $(x - 12)^2 = 16$

$x - 12 = \pm 4$

$x = 12 \pm 4$

$x = 16$ or $x = 8$

41. $(2x - 1)^2 = 18$

$2x - 1 = \pm\sqrt{18}$

$2x = 1 \pm 3\sqrt{2}$

$x = \dfrac{1 \pm 3\sqrt{2}}{2}$

43. $x^2 + 4x - 32 = 0$

$x^2 + 4x = 32$

$x^2 + 4x + 2^2 = 32 + 2^2$

$(x + 2)^2 = 36$

$x + 2 = \pm 6$

$x = -2 \pm 6$

$x = 4$ or $x = -8$

45. $x^2 + 6x + 2 = 0$

$x^2 + 6x = -2$

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

$(x + 3)^2 = 7$

$x + 3 = \pm\sqrt{7}$

$x = -3 \pm \sqrt{7}$

47. $9x^2 - 18x = -3$

$x^2 - 2x = -\dfrac{1}{3}$

$x^2 - 2x + 1^2 = -\dfrac{1}{3} + 1^2$

$(x - 1)^2 = \dfrac{2}{3}$

$x - 1 = \pm\sqrt{\dfrac{2}{3}}$

$x = 1 \pm \sqrt{\dfrac{2}{3}}$

$x = 1 \pm \dfrac{\sqrt{6}}{3}$

49. $2x^2 + 5x - 8 = 0$

$2x^2 + 5x = 8$

$x^2 + \dfrac{5}{2}x = 4$

$x^2 + \dfrac{5}{2}x + \left(\dfrac{5}{4}\right)^2 = 4 + \left(\dfrac{5}{4}\right)^2$

$\left(x + \dfrac{5}{4}\right)^2 = \dfrac{89}{16}$

$x + \dfrac{5}{4} = \pm\dfrac{\sqrt{89}}{4}$

$x = -\dfrac{5}{4} \pm \dfrac{\sqrt{89}}{4}$

$x = \dfrac{-5 \pm \sqrt{89}}{4}$

51. $2x^2 + x - 1 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-1 \pm \sqrt{1^2 - 4(2)(-1)}}{2(2)} = \frac{-1 \pm 3}{4} = \frac{1}{2}, -1$$

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

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

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-2 \pm \sqrt{2^2 - 4(-1)(2)}}{2(-1)} = \frac{-2 \pm 2\sqrt{3}}{-2} = 1 \pm \sqrt{3}$$

55. $2x^2 - 3x - 4 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{3 \pm \sqrt{(-3)^2 - 4(2)(-4)}}{2(2)} = \frac{3 \pm \sqrt{41}}{4} = \frac{3}{4} \pm \frac{\sqrt{41}}{4}$$

57. $12x - 9x^2 = -3$

$-9x^2 + 12x + 3 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-12 \pm \sqrt{12^2 - 4(-9)(3)}}{2(-9)} = \frac{-12 \pm 6\sqrt{7}}{-18} = \frac{2}{3} \pm \frac{\sqrt{7}}{3}$$

59. $9x^2 + 30x + 25 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-30 \pm \sqrt{30^2 - 4(9)(25)}}{2(9)} = \frac{-30 \pm 0}{18} = -\frac{5}{3}$$

61. $8t = 5 + 2t^2$

$-2t^2 + 8t - 5 = 0$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-8 \pm \sqrt{8^2 - 4(-2)(-5)}}{2(-2)} = \frac{-8 \pm 2\sqrt{6}}{-4} = 2 \pm \frac{\sqrt{6}}{2}$$

63. $(y - 5)^2 = 2y$

$y^2 - 12y + 25 = 0$

$$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-12) \pm \sqrt{(-12)^2 - 4(1)(25)}}{2(1)} = \frac{12 \pm 2\sqrt{11}}{2} = 6 \pm \sqrt{11}$$

65. $5.1x^2 - 1.7x - 3.2 = 0$

$$x = \frac{1.7 \pm \sqrt{(-1.7)^2 - 4(5.1)(-3.2)}}{2(5.1)} \approx 0.976, -0.643$$

67. $422x^2 - 506x - 347 = 0$

$$x = \frac{506 \pm \sqrt{(-506)^2 - 4(422)(-347)}}{2(422)} \approx 1.687, -0.488$$

69. $x^2 - 2x - 1 = 0$ Complete the square.

$x^2 - 2x = 1$

$x^2 - 2x + 1^2 = 1 + 1^2$

$(x - 1)^2 = 2$

$x - 1 = \pm\sqrt{2}$

$x = 1 \pm \sqrt{2}$

71. $(x + 3)^2 = 81$ Extract square roots.

$x + 3 = \pm 9$

$x + 3 = 9$ or $x + 3 = -9$

$x = 6$ or $x = -12$

73. $x^2 - x - \frac{11}{4} = 0$ Complete the square.

$$x^2 - x = \frac{11}{4}$$
$$x^2 - x + \left(\frac{1}{2}\right)^2 = \frac{11}{4} + \left(\frac{1}{2}\right)^2$$
$$\left(x - \frac{1}{2}\right)^2 = \frac{12}{4}$$
$$x - \frac{1}{2} = \pm\sqrt{\frac{12}{4}}$$
$$x = \frac{1}{2} \pm \sqrt{3}$$

75. $(x+1)^2 = x^2$ Extract square roots.

$$x^2 = (x+1)^2$$
$$x = \pm(x+1)$$

For $x = +(x+1)$:

$0 \neq 1$ No solution

For $x = -(x+1)$:

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

77. $6x^4 - 14x^2 = 0$

$$2x^2(3x^2 - 7) = 0$$
$$2x^2 = 0 \Rightarrow x = 0$$
$$3x^2 - 7 = 0 \Rightarrow x = \pm\frac{\sqrt{21}}{3}$$

79. $5x^3 + 3 - x^2 + 45x = 0$

$$5x(x^2 + 6x + 9) = 0$$
$$5x(x+3)^2 = 0$$
$$5x = 0 \Rightarrow x = 0$$
$$x + 3 = 0 \Rightarrow x = -3$$

81. $\sqrt{3x} - 12 = 0$

$$\sqrt{3x} = 12$$
$$3x = 144$$
$$x = 48$$

83. $\sqrt[3]{2x+5} + 3 = 0$

$$\sqrt[3]{2x+5} = -3$$
$$2x + 5 = -27$$
$$2x = -32$$
$$x = -16$$

85. $-\sqrt{26 - 11x} + 4 = x$

$$4 - x = \sqrt{26 - 11x}$$
$$16 - 8x + x^2 = 26 - 11x$$
$$x^2 + 3x - 10 = 0$$
$$(x+5)(x-2) = 0$$
$$x + 5 = 0 \Rightarrow x = -5$$
$$x - 2 = 0 \Rightarrow x = 2$$

87. $\sqrt{x} - \sqrt{x-5} = 1$

$$\sqrt{x} = 1 + \sqrt{x-5}$$
$$\left(\sqrt{x}\right)^2 = \left(1 + \sqrt{x-5}\right)^2$$
$$x = 1 + 2\sqrt{x-5} + x - 5$$
$$4 = 2\sqrt{x-5}$$
$$2 = \sqrt{x-5}$$
$$4 = x - 5$$
$$9 = x$$

89. $(x-5)^{3/2} = 8$

$$(x-5)^3 = 8^2$$
$$x - 5 = \sqrt[3]{64}$$
$$x = 5 + 4 = 9$$

91. $(x^2 - 5)^{3/2} = 27$

$$(x^2 - 5)^3 = 27^2$$
$$x^2 - 5 = \sqrt[3]{27^2}$$
$$x^2 = 5 + 9$$
$$x^2 = 14$$
$$x = \pm\sqrt{14}$$

93. $|2x - 5| = 11$

$$2x - 5 = 11 \Rightarrow x = 8$$
$$-(2x - 5) = 11 \Rightarrow x = -3$$

95. $\left|x^2 + 6x\right| = 3x + 18$

First equation:

$$x^2 + 6x = 3x + 18$$
$$x^2 + 3x - 18 = 0$$
$$(x - 3)(x + 6) = 0$$
$$x - 3 = 0 \Rightarrow x = 3$$
$$x + 6 = 0 \Rightarrow x = -6$$

Second equation:

$$-\left(x^2 + 6x\right) = 3x + 18$$
$$0 = x^2 + 9x + 18$$
$$0 = (x + 3)(x + 6)$$
$$0 = x + 3 \Rightarrow x = -3$$
$$x = x + 6 \Rightarrow x = -6$$

The solutions of the original equation are $x = \pm 3$ and $x = -6$.

97. Let $y = 18$:

$$y = 0.432x - 10.44$$
$$18 = 0.432x - 10.44$$
$$28.44 = 0.432x$$
$$\frac{28.44}{0.432} = x$$
$$65.8 \approx x$$

So, the height of the female is about 65.8 inches or 5 feet 6 inches.

99. False—See Example 14 on page 123.

101. True. There is no value to satisfy this equation.

$$\sqrt{x + 10} - \sqrt{x - 10} = 0$$
$$\sqrt{x + 10} = \sqrt{x - 10}$$
$$x + 10 = x - 10$$
$$10 \neq -10$$

103. Equivalent equations are derived from the substitution principle and simplification techniques. They have the same solution(s).

$2x + 3 = 8$ and $2x = 5$ are equivalent equations.

Section P.3 The Cartesian Plane and Graphs of Equations

1. Cartesian

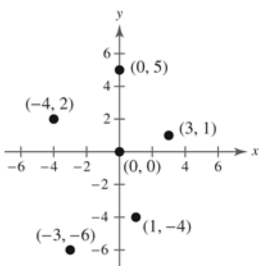
3. Midpoint Formula

5. graph

7. y-axis

9. $A: (2, 6), B: (-6, -2), C: (4, -4), D: (-3, 2)$

11.



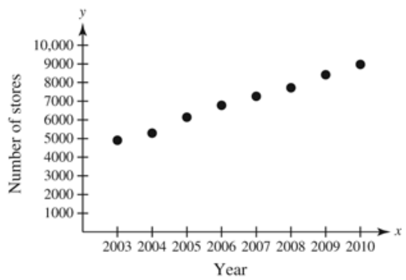
13. $(-3, 4)$

15. $x > 0$ and $y < 0$ in Quadrant IV.

17. $(x, -y)$ is in the second Quadrant means that (x, y) is in Quadrant III.

19.

Year, x	Number of Stores, y
2003	4906
2004	5289
2005	6141
2006	6779
2007	7262
2008	7720
2009	8416
2010	8970



Year $(t = 3 \leftrightarrow 2003)$

21. $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
$= \sqrt{(3 - (-2))^2 + (-6 - 6)^2}$
$= \sqrt{(5)^2 + (-12)^2}$
$= \sqrt{25 + 144}$
$= 13$ units

23. $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
$= \sqrt{(-5 - 1)^2 + (-1 - 4)^2}$
$= \sqrt{(-6)^2 + (-5)^2}$
$= \sqrt{36 + 25}$
$= \sqrt{61}$ units

25. (a) $(1, 0), (13, 5)$

Distance $= \sqrt{(13 - 1)^2 + (5 - 0)^2}$
$= \sqrt{12^2 + 5^2} = \sqrt{169} = 13$

$(13, 5), (13, 0)$

Distance $= |5 - 0| = |5| = 5$

$(1, 0), (13, 0)$

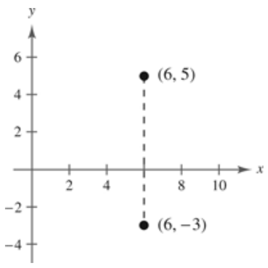
Distance $= |1 - 13| = |-12| = 12$

(b) $5^2 + 12^2 = 25 + 144 = 169 = 13^2$

27. $d_1 = \sqrt{(4 - 2)^2 + (0 - 1)^2} = \sqrt{4 + 1} = \sqrt{5}$
$d_2 = \sqrt{(4 + 1)^2 + (0 + 5)^2} = \sqrt{25 + 25} = \sqrt{50}$
$d_3 = \sqrt{(2 + 1)^2 + (1 + 5)^2} = \sqrt{9 + 36} = \sqrt{45}$
$(\sqrt{5})^2 + (\sqrt{45})^2 = (\sqrt{50})^2$

29. $d_1 = \sqrt{(1 - 3)^2 + (-3 - 2)^2} = \sqrt{4 + 25} = \sqrt{29}$
$d_2 = \sqrt{(3 + 2)^2 + (2 - 4)^2} = \sqrt{25 + 4} = \sqrt{29}$
$d_3 = \sqrt{(1 + 2)^2 + (-3 - 4)^2} = \sqrt{9 + 49} = \sqrt{58}$
$d_1 = d_2$

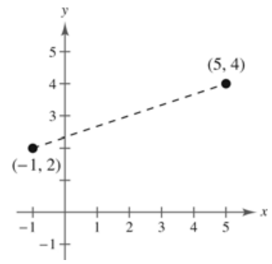
31. (a)



(b) $d = \sqrt{(5 - (-3))^2 + (6 - 6)^2} = \sqrt{64} = 8$

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

33. (a)



(b) $d = \sqrt{(5 + 1)^2 + (4 - 2)^2}$
$= \sqrt{36 + 4} = 2\sqrt{10}$

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

35. $d = \sqrt{120^2 + 150^2}$
$= \sqrt{36{,}900}$
$= 30\sqrt{41}$
≈ 192.09

The plane flies about 192 kilometers.

37. midpoint $= \left(\frac{2002 + 2010}{2}, \frac{19{,}564 + 35{,}123}{2}\right)$
$= (2006, 27{,}343.5)$

In 2006, the sales for the Coca-Cola Company were about \$27,343.5 million.

39. (a) $(0, 2)$: $2 \stackrel{?}{=} \sqrt{0 + 4}$
$2 = 2$

Yes, the point *is* on the graph.

(b) $(5, 3)$: $3 \stackrel{?}{=} \sqrt{5 + 4}$
$3 \stackrel{?}{=} \sqrt{9}$
$3 = 3$

Yes, the point *is* on the graph.

41. (a) $(2, 0)$: $(2)^2 - 3(2) + 2 \stackrel{?}{=} 0$

$$4 - 6 + 2 \stackrel{?}{=} 0$$
$$0 = 0$$

Yes, the point *is* on the graph.

(b) $(-2, 8)$: $(-2)^2 - 3(-2) + 2 \stackrel{?}{=} 8$

$$4 + 6 + 2 \stackrel{?}{=} 8$$
$$12 \neq 8$$

No, the point *is not* on the graph.

43. (a) $(3, -2)$: $(3)^2 + (-2)^2 \stackrel{?}{=} 20$

$$9 + 4 \stackrel{?}{=} 20$$
$$13 \neq 20$$

No, the point *is not* on the graph.

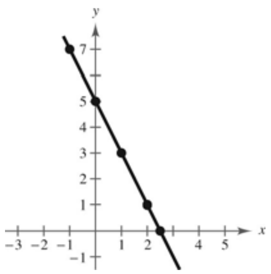
(b) $(-4, 2)$: $(-4)^2 + (2)^2 \stackrel{?}{=} 20$

$$16 + 4 \stackrel{?}{=} 20$$
$$20 = 20$$

Yes, the point *is* on the graph.

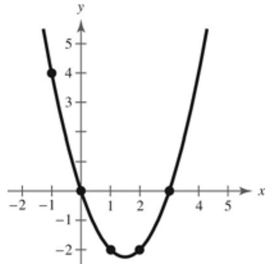
45. $y = -2x + 5$

x	-1	0	1	2	$\frac{5}{2}$
y	7	5	3	1	0
(x, y)	$(-1, 7)$	$(0, 5)$	$(1, 3)$	$(2, 1)$	$\left(\frac{5}{2}, 0\right)$



47. $y = x^2 - 3x$

x	-1	0	1	2	3
y	4	0	-2	-2	0
(x, y)	$(-1, 4)$	$(0, 0)$	$(1, -2)$	$(2, -2)$	$(3, 0)$



49. $y = 16 - 4x^2$

x-intercepts: $0 = 16 - 4x^2$

$$4x^2 = 16$$
$$x^2 = 4$$
$$x = \pm 2$$
$$(-2, 0), (2, 0)$$

y-intercept: $y = 16 - 4(0)^2 = 16$

$$(0, 16)$$

51. $y = 5x - 6$

x-intercept: $0 = 5x - 6$

$$6 = 5x$$
$$\frac{6}{5} = x$$
$$\left(\frac{6}{5}, 0\right)$$

y-intercept: $y = 5(0) - 6 = -6$

$$(0, -6)$$

53. $y = \sqrt{x + 4}$

x-intercept: $0 = \sqrt{x + 4}$

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

y-intercept: $y = \sqrt{0 + 4} = 2$

$$(0, 2)$$

55. $y = |3x - 7|$

x-intercept: $0 = |3x - 7|$

$0 = 3x - 7$

$\frac{7}{3} = 0$

$\left(\frac{7}{3}, 0\right)$

y-intercept: $y = |3(0) - 7| = 7$

$(0, 7)$

57. $y = 2x^3 - 4x^2$

x-intercept: $0 = 2x^3 - 4x^2$

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

$x = 0$ or $x = 2$

$(0, 0), (2, 0)$

y-intercept: $y = 2(0)^3 - 4(0)^2$

$y = 0$

$(0, 0)$

59. $y^2 = 6 - x$

x-intercept: $0 = 6 - x$

$x = 6$

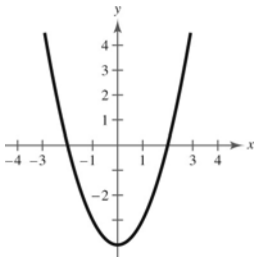
$(6, 0)$

y-intercepts: $y^2 = 6 - 0$

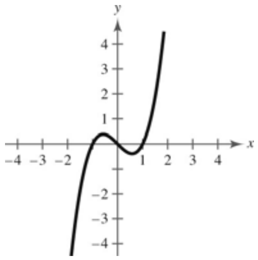
$y = \pm\sqrt{6}$

$\left(0, \sqrt{6}\right), \left(0, -\sqrt{6}\right)$

61.



63.



65. $x^2 - y = 0$

$(-x)^2 - y = 0 \Rightarrow x^2 - y = 0 \Rightarrow$ y-axis symmetry

$x^2 - (-y) = 0 \Rightarrow x^2 + y = 0 \Rightarrow$ No x-axis symmetry

$(-x)^2 - (-y) = 0 \Rightarrow x^2 + y = 0 \Rightarrow$ No origin symmetry

67. $y = x^3$

$y = (-x)^3 \Rightarrow y = -x^3 \Rightarrow$ No y-axis symmetry

$-y = x^3 \Rightarrow y = -x^3 \Rightarrow$ No x-axis symmetry

$-y = (-x)^3 \Rightarrow -y = -x^3 \Rightarrow y = x^3 \Rightarrow$ Origin symmetry

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

$y = \dfrac{-x}{(-x)^2 + 1} \Rightarrow y = \dfrac{-x}{x^2 + 1} \Rightarrow$ No y-axis symmetry

$-y = \dfrac{x}{x^2 + 1} \Rightarrow y = \dfrac{-x}{x^2 + 1} \Rightarrow$ No x-axis symmetry

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

71. $xy^2 + 10 = 0$

$(-x)y^2 + 10 = 0 \Rightarrow -xy^2 + 10 = 0 \Rightarrow$ No y-axis symmetry

$x(-y)^2 + 10 = 0 \Rightarrow xy^2 + 10 = 0 \Rightarrow$ x-axis symmetry

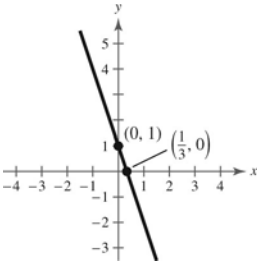
$(-x)(-y)^2 + 10 = 0 \Rightarrow -xy^2 + 10 = 0 \Rightarrow$ No origin symmetry

73. $y = -3x + 1$

x-intercept: $\left(\frac{1}{3}, 0\right)$

y-intercept: $(0, 1)$

No symmetry



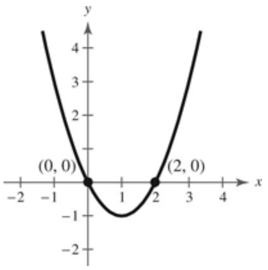
75. $y = x^2 - 2x$

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

y-intercept: $(0, 0)$

No symmetry

x	-1	0	1	2	3
y	3	0	-1	0	3



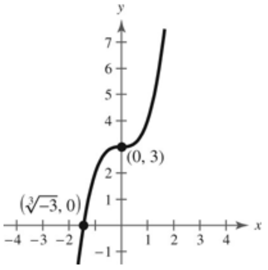
77. $y = x^3 + 3$

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

y-intercept: $(0, 3)$

No symmetry

x	-2	-1	0	1	2
y	-5	2	3	4	11



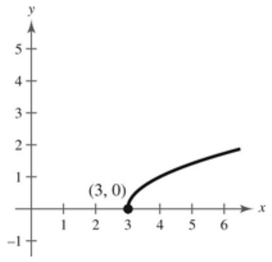
79. $y = \sqrt{x - 3}$

x-intercept: $(3, 0)$

y-intercept: none

No symmetry

x	3	4	7	12
y	0	1	2	3



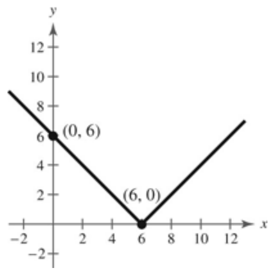
81. $y = |x - 6|$

x-intercept: $(6, 0)$

y-intercept: $(0, 6)$

No symmetry

x	–2	0	2	4	6	8	10
y	8	6	4	2	0	2	4



83. Center: $(0, 0)$; Radius: 4

$$(x - 0)^2 + (y - 0)^2 = 4^2$$
$$x^2 + y^2 = 16$$

85. Center: $(-1, 2)$; Solution point: $(0, 0)$

$$(x - (-1))^2 + (y - 2)^2 = r^2$$
$$(0 + 1)^2 + (0 - 2)^2 = r^2 \Rightarrow 5 = r^2$$
$$(x + 1)^2 + (y - 2)^2 = 5$$

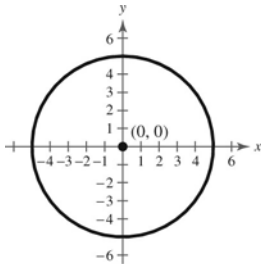
87. Endpoints of a diameter: $(0, 0), (6, 8)$

Center: $\left(\dfrac{0 + 6}{2}, \dfrac{0 + 8}{2}\right) = (3, 4)$

$$(x - 3)^2 + (y - 4)^2 = r^2$$
$$(0 - 3)^2 + (0 - 4)^2 = r^2 \Rightarrow 25 = r^2$$
$$(x - 3)^2 + (y - 4)^2 = 25$$

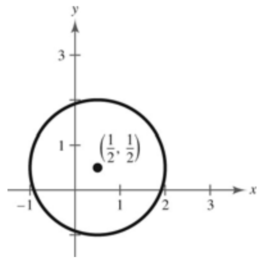
89. $x^2 + y^2 = 25$

Center: $(0, 0)$, Radius: 5

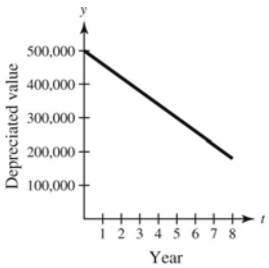


91. $\left(x - \frac{1}{2}\right)^2 + \left(y - \frac{1}{2}\right)^2 = \frac{9}{4}$

Center: $\left(\frac{1}{2}, \frac{1}{2}\right)$, Radius: $\frac{3}{2}$



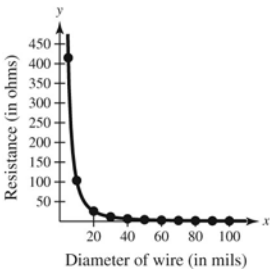
93. $y = 500{,}000 - 40{,}000t, 0 \le t \le 8$



95. (a)

x	5	10	20	30	40	50	60	70	80	90	100
y	414.8	103.7	25.9	11.5	6.5	4.1	2.9	2.1	1.6	1.3	1.0

(b)



When $x = 85.5$, the resistance is about 1.4 ohms.

(c) When $x = 85.5$,

$$y = \frac{10,370}{(85.5)^2} = 1.4 \text{ ohms.}$$

(d) As the diameter of the copper wire increases, the resistance decreases.

97. False, you would have to use the Midpoint Formula 15 times.

99. False. A graph is symmetric with respect to the x-axis if, whenever (x, y) is on the graph, $(x, -y)$ is also on the graph.

101. The y-coordinate of a point on the x-axis is 0. The x-coordinates of a point on the y-axis is 0.

103. Use the Midpoint Formula to prove the diagonals of the parallelogram bisect each other.

$$\left(\frac{b + a}{2}, \frac{c + 0}{2}\right) = \left(\frac{a + b}{2}, \frac{c}{2}\right)$$

$$\left(\frac{a + b + 0}{2}, \frac{c + 0}{2}\right) = \left(\frac{a + b}{2}, \frac{c}{2}\right)$$

105. Because $x_m = \dfrac{x_1 + x_2}{2}$ and $y_m = \dfrac{y_1 + y_2}{2}$ we have:

$$2x_m = x_1 + x_2 \qquad 2y_m = y_1 + y_2$$

$$2x_m - x_1 = x_2 \qquad 2y_m - y_1 = y_2$$

So, $(x_2, y_2) = (2x_m - x_1, 2y_m - y_1)$.

(a) $(x_2, y_2) = (2x_m - x_1, 2y_m - y_1) = (2 \cdot 4 - 1, 2(-1) - (-2)) = (7, 0)$

(b) $(x_2, y_2) = (2x_m - x_1, 2y_m - y_1) = (2 \cdot 2 - (-5), 2 \cdot 4 - 11) = (9, -3)$

Section P.4 Linear Equations in Two Variables

1. linear

3. point-slope

5. perpendicular

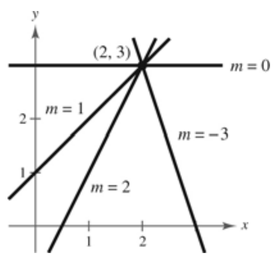
7. linear extrapolation

9. (a) $m = \frac{2}{3}$. Because the slope is positive, the line rises. Matches L_2.

(b) m is undefined. The line is vertical. Matches L_3.

(c) $m = -2$. The line falls. Matches L_1.

11.



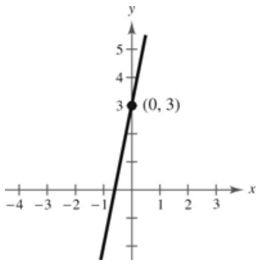
13. Two points on the line: $(0, 0)$ and $(4, 6)$

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{6}{4} = \frac{3}{2}$$

15. $y = 5x + 3$

Slope: $m = 5$

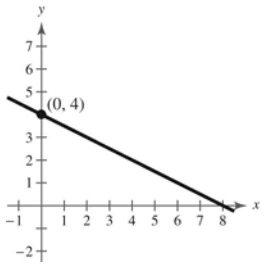
y-intercept: $(0, 3)$



17. $y = -\frac{1}{2}x + 4$

Slope: $m = -\frac{1}{2}$

y-intercept: $(0, 4)$

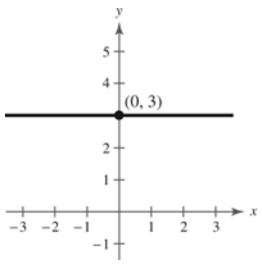


19. $y - 3 = 0$

$y = 3$, horizontal line

Slope: $m = 0$

y-intercept: $(0, 3)$

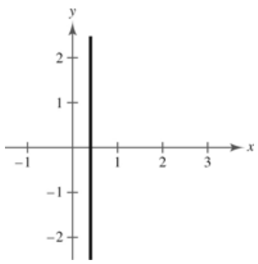


21. $5x - 2 = 0$

$x = \frac{2}{5}$, vertical line

Slope: undefined

No y-intercept



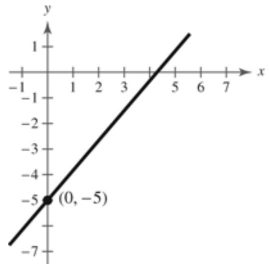
23. $7x - 6y = 30$

$-6y = -7x + 30$

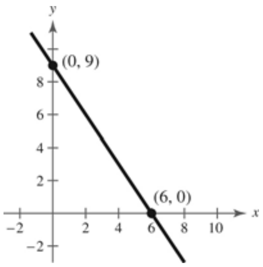
$y = \frac{7}{6}x - 5$

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

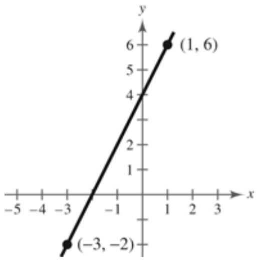
y-intercept: $(0, -5)$



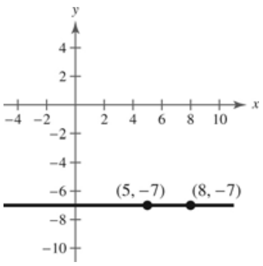
25. $m = \dfrac{0 - 9}{6 - 0} = \dfrac{-9}{6} = -\dfrac{3}{2}$



27. $m = \dfrac{6 - (-2)}{1 - (-3)} = \dfrac{8}{4} = 2$

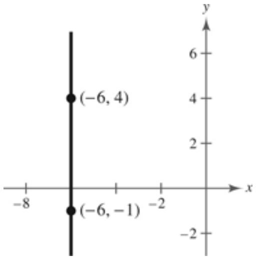


29. $m = \dfrac{-7 - (-7)}{8 - 5} = \dfrac{0}{3} = 0$

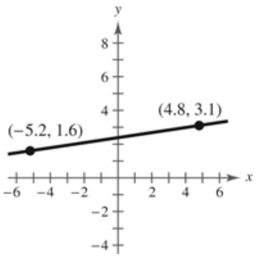


31. $m = \dfrac{4 - (-1)}{-6 - (-6)} = \dfrac{5}{0}$

m is undefined.



33. $m = \dfrac{1.6 - 3.1}{-5.2 - 4.8} = \dfrac{-1.5}{-10} = 0.15$



35. Point: $(2, 1)$, Slope: $m = 0$

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

37. Point: $(-8, 1)$, Slope is undefined.

Because m is undefined, x does not change. Three points are $(-8, 0)$, $(-8, 2)$, and $(-8, 3)$.

39. Point: $(-5, 4)$, Slope: $m = 2$

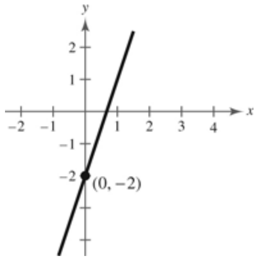
Because $m = 2 = \frac{2}{1}$, y increases by 2 for every one unit increase in x. Three additional points are $(-4, 6)$, $(-3, 8)$, and $(-2, 10)$.

41. Point: $(-1, -6)$, Slope: $m = -\frac{1}{2}$

Because $m = -\frac{1}{2}$, y decreases by 1 unit for every two unit increase in x. Three additional points are $(1, -7)$, $(3, -8)$, and $(-13, 0)$.

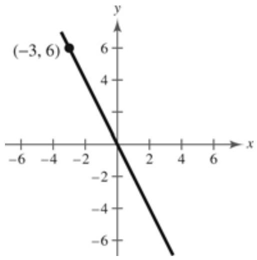
43. Point: $(0, -2)$; $m = 3$

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



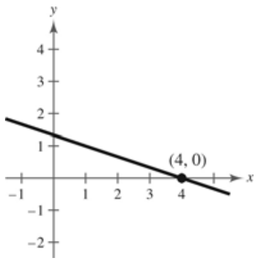
45. Point: $(-3, 6)$; $m = -2$

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



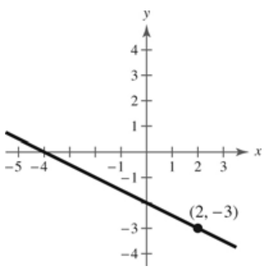
47. Point: $(4, 0)$; $m = -\frac{1}{3}$

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



49. Point: $(2, -3)$; $m = -\dfrac{1}{2}$

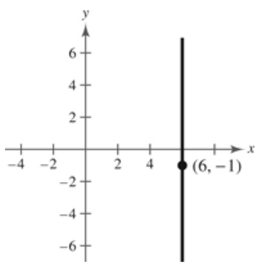
$$y - (-3) = -\frac{1}{2}(x - 2)$$
$$y + 3 = -\frac{1}{2}x + 1$$
$$y = -\frac{1}{2}x - 2$$



51. Point: $(6, -1)$; m is undefined.

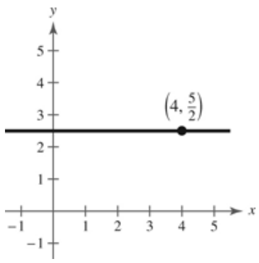
Because the slope is undefined, the line is a vertical line.

$x = 6$



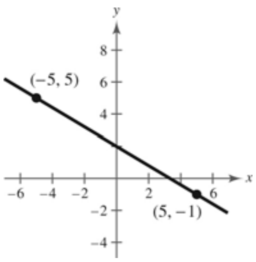
53. Point: $\left(4, \frac{5}{2}\right)$; $m = 0$

$$y - \tfrac{5}{2} = 0(x - 4)$$
$$y - \tfrac{5}{2} = 0$$
$$y = \tfrac{5}{2}$$



55. $(5, -1), (-5, 5)$

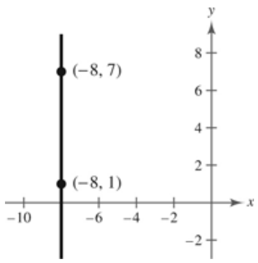
$$y + 1 = \frac{5 + 1}{-5 - 5}(x - 5)$$
$$y = -\frac{3}{5}(x - 5) - 1$$
$$y = -\frac{3}{5}x + 2$$



57. $(-8, 1), (-8, 7)$

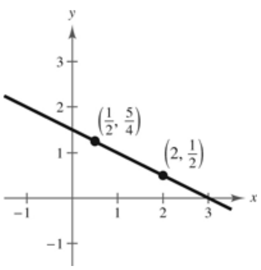
Because both points have $x = -8$, the slope is undefined, and the line is vertical.

$$x = -8$$



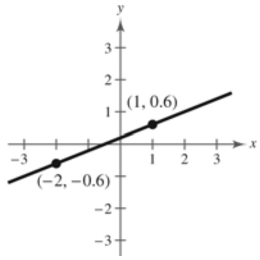
59. $\left(2, \frac{1}{2}\right), \left(\frac{1}{2}, \frac{5}{4}\right)$

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



61. $(1, 0.6), (-2, -0.6)$

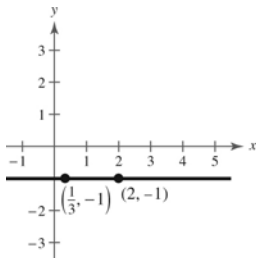
$$y - 0.6 = \frac{-0.6 - 0.6}{-2 - 1}(x - 1)$$
$$y = 0.4(x - 1) + 0.6$$
$$y = 0.4x + 0.2$$



63. $(2, -1), \left(\frac{1}{3}, -1\right)$

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

The line is horizontal.



65. $L_1: y = \frac{1}{3}x - 2$

$$m_1 = \tfrac{1}{3}$$

$L_2: y = \frac{1}{3}x + 3$

$$m_2 = \tfrac{1}{3}$$

The lines are parallel.

67. $L_1: y = \frac{1}{2}x - 3$

$$m_1 = \tfrac{1}{2}$$

$L_2: y = -\frac{1}{2}x + 1$

$$m_2 = -\tfrac{1}{2}$$

The lines are neither parallel nor perpendicular.

69. $L_1: (0, -1), (5, 9)$

$$m_1 = \frac{9 + 1}{5 - 0} = 2$$

$L_2: (0, 3), (4, 1)$

$$m_2 = \frac{1 - 3}{4 - 0} = -\frac{1}{2}$$

The lines are perpendicular.

71. $L_1: (3, 6), (-6, 0)$

$$m_1 = \frac{0 - 6}{-6 - 3} = \frac{2}{3}$$

$L_2: (0, -1), \left(5, \frac{7}{3}\right)$

$$m_2 = \frac{\frac{7}{3} + 1}{5 - 0} = \frac{2}{3}$$

The lines are parallel.

73. $4x - 2y = 3$

$$y = 2x - \tfrac{3}{2}$$

Slope: $m = 2$

(a) $(2, 1), m = 2$

$$y - 1 = 2(x - 2)$$
$$y = 2x - 3$$

(b) $(2, 1), m = -\frac{1}{2}$

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

75. $3x + 4y = 7$

$$y = -\tfrac{3}{4}x + \tfrac{7}{4}$$

Slope: $m = -\frac{3}{4}$

(a) $\left(-\frac{2}{3}, \frac{7}{8}\right), m = -\frac{3}{4}$

$$y - \tfrac{7}{8} = -\tfrac{3}{4}\left(x - \left(-\tfrac{2}{3}\right)\right)$$
$$y = -\tfrac{3}{4}x + \tfrac{3}{8}$$

(b) $\left(-\frac{2}{3}, \frac{7}{8}\right), m = \frac{4}{3}$

$$y - \tfrac{7}{8} = \tfrac{4}{3}\left(x - \left(-\tfrac{2}{3}\right)\right)$$
$$y = \tfrac{4}{3}x + \tfrac{127}{72}$$

77. $y + 3 = 0$

$$y = -3$$

Slope: $m = 0$

(a) $(-1, 0), m = 0$

$$y = 0$$

(b) $(-1, 0)$, m is undefined.

$$x = -1$$

79. $x - y = 4$

$$y = x - 4$$

Slope: $m = 1$

(a) $(2.5, 6.8), m = 1$

$$y - 6.8 = 1(x - 2.5)$$
$$y = x + 4.3$$

(b) $(2.5, 6.8), m = -1$

$$y - 6.8 = (-1)(x - 2.5)$$
$$y = -x + 9.3$$

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

$$3x + 2y - 6 = 0$$

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

$$6x + \frac{3}{2}y = -1$$
$$12x + 3y + 2 = 0$$

85. $\frac{x}{c} + \frac{y}{c} = 1, c \neq 0$

$$x + y = c$$
$$1 + 2 = c$$
$$3 = c$$
$$x + y = 3$$
$$x + y - 3 = 0$$

87. (a) $m = 135$. The sales are increasing 135 units per year.

(b) $m = 0$. There is no change in sales during the year.

(c) $m = -40$. The sales are decreasing 40 units per year.

89. $y = \frac{6}{100}x$

$$y = \tfrac{6}{100}(200) = 12 \text{ feet}$$

91. $(10, 2540), m = -125$

$$V - 2540 = -125(t - 10)$$
$$V - 2540 = -125t + 1250$$
$$V = -125t + 3790, 5 \le t \le 10$$

93. The C-intercept measures the fixed costs of manufacturing when zero bags are produced.

The slope measures the cost to produce one laptop bag.

95. Using the points $(0, 875)$ and $(5, 0)$, where the first coordinate represents the year t and the second coordinate represents the value V, you have

$$m = \frac{0 - 875}{5 - 0} = -175$$
$$V = -175t + 875, 0 \le t \le 5.$$

97. Using the points $(0, 32)$ and $(100, 212)$, where the first coordinate represents a temperature in degrees Celsius and the second coordinate represents a temperature in degrees Fahrenheit, you have

$$m = \frac{212 - 32}{100 - 0} = \frac{180}{100} = \frac{9}{5}.$$

Since the point $(0, 32)$ is the F- intercept, $b = 32$, the equation is $F = \frac{9}{5}C + 32$.

99. (a) Total Cost = cost for fuel and maintainance + cost for operator + purchase cost

$$C = 9.5t + 11.5t + 42{,}000$$
$$C = 21.0t + 42{,}000$$

(b) Revenue = Rate per hour · Hours

$$R = 45t$$

(c) $P = R - C$

$$P = 45t - (21t + 42{,}000)$$
$$P = 24t - 42{,}000$$

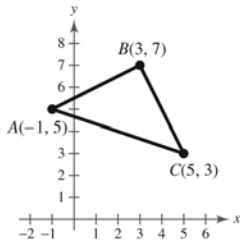
(d) Let $P = 0$, and solve for t.

$$0 = 24t - 42{,}000$$
$$42{,}000 = 24t$$
$$1750 = t$$

The equipment must be used 1750 hours to yield a profit of 0 dollars.

101. False. The slope with the greatest magnitude corresponds to the steepest line.

103. Find the slope of the line segments between the points A and B, and B and C.



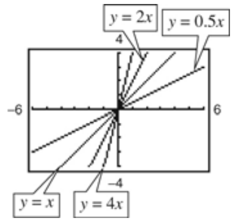
$$m_{AB} = \frac{7 - 5}{3 - (-1)} = \frac{2}{4} = \frac{1}{2}$$
$$m_{BC} = \frac{3 - 7}{5 - 3} = \frac{-4}{2} = -2$$

Since the slopes are negative reciprocals, the line segments are perpendicular and therefore intersect to form a right angle. So, the triangle is a right triangle.

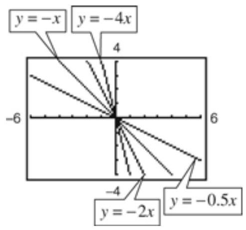
105. No. The slope cannot be determined without knowing the scale on the y-axis. The slopes will be the same if the scale on the y-axis of (a) is $2\frac{1}{2}$ and the scale on the y-axis of (b) is 1. Then the slope of both is $\frac{5}{4}$.

107. No, the slopes of two perpendicular lines have opposite signs. (Assume that neither line is vertical or horizontal.)

109. The line $y = 4x$ rises most quickly.



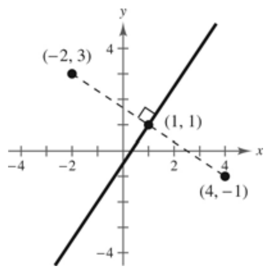
The line $y = -4x$ falls most quickly.



The greater the magnitude of the slope (the absolute value of the slope), the faster the line rises or falls.

111. Set the distance between $(4, -1)$ and (x, y) equal to the distance between $(-2, 3)$ and (x, y).

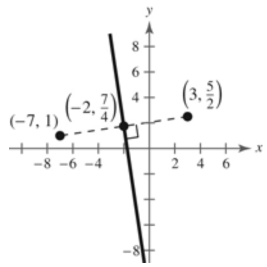
$$\sqrt{(x-4)^2 + [y-(-1)]^2} = \sqrt{[x-(-2)]^2 + (y-3)^2}$$
$$(x-4)^2 + (y+1)^2 = (x+2)^2 + (y-3)^2$$
$$x^2 - 8x + 16 + y^2 + 2y + 1 = x^2 + 4x + 4 + y^2 - 6y + 9$$
$$-8x + 2y + 17 = 4x - 6y + 13$$
$$0 = 12x - 8y - 4$$
$$0 = 4(3x - 2y - 1)$$
$$0 = 3x - 2y - 1$$



This line is the perpendicular bisector of the line segment connecting $(4, -1)$ and $(-2, 3)$.

113. Set the distance between $\left(3, \frac{5}{2}\right)$ and (x, y) equal to the distance between $(-7, 1)$ and (x, y).

$$\sqrt{(x-3)^2 + \left(y - \frac{5}{2}\right)^2} = \sqrt{[x-(-7)]^2 + (y-1)^2}$$
$$(x-3)^2 + \left(y - \frac{5}{2}\right)^2 = (x+7)^2 + (y-1)^2$$
$$x^2 - 6x + 9 + y^2 - 5y + \frac{25}{4} = x^2 + 14x + 49 + y^2 - 2y + 1$$
$$-6x - 5y + \frac{61}{4} = 14x - 2y + 50$$
$$-24x - 20y + 61 = 56x - 8y + 200$$
$$80x + 12y + 139 = 0$$



This line is the perpendicular bisector of the line segment connecting $\left(3, \frac{5}{2}\right)$ and $(-7, 1)$.

Section P.5 Functions

1. domain; range; function

3. implied domain

5. Yes, the relationship is a function. Each domain value is matched with exactly one range value.

7. No, it does not represent a function. The input values of 10 and 7 are each matched with two output values.

9. (a) Each element of A is matched with exactly one element of B, so it does represent a function.

(b) The element 1 in A is matched with two elements, -2 and 1 of B, so it does not represent a function.

(c) Each element of A is matched with exactly one element of B, so it does represent a function.

(d) The element 2 in A is not matched with an element of B, so the relation does not represent a function.

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

No, *y is not* a function of *x*.

13. $2x + 3y = 4 \Rightarrow y = \frac{1}{3}(4 - 2x)$

Yes, *y is* a function of *x*.

15. $y = \sqrt{16 - x^2}$

Yes, *y is* a function of *x*.

17. $y = |4 - x|$

Yes, *y is* a function of *x*.

19. $y = -75$ or $y = -75 + 0x$

Yes, *y is* a function of *x*.

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

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

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

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

23. $g(t) = 4t^2 - 3t + 5$

(a) $g(2) = 4(2)^2 - 3(2) + 5 = 15$

(b) $g(t - 2) = 4(t - 2)^2 - 3(t - 2) + 5 = 4t^2 - 19t + 27$

(c) $g(t) - g(2) = 4t^2 - 3t + 5 - 15 = 4t^2 - 3t - 10$

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

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

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

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

27. $q(x) = \dfrac{1}{x^2 - 9}$

(a) $q(0) = \dfrac{1}{0^2 - 9} = -\dfrac{1}{9}$

(b) $q(3) = \dfrac{1}{3^2 - 9}$ is undefined.

(c) $q(y + 3) = \dfrac{1}{(y + 3)^2 - 9} = \dfrac{1}{y^2 + 6y}$

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

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

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

(c) $f(x - 1) = \dfrac{|x - 1|}{x - 1} = \begin{cases} -1, & \text{if } x < 1 \\ 1, & \text{if } x > 1 \end{cases}$

31. $f(x) = \begin{cases} 2x + 1, & x < 0 \\ 2x + 2, & x \ge 0 \end{cases}$

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

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

(c) $f(2) = 2(2) + 2 = 6$

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

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

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

$f(0) = (0)^2 - 3 = -3$

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

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

x	-2	-1	0	1	2
$f(x)$	1	-2	-3	-2	1

35. $f(x) = \begin{cases} -\frac{1}{2}x + 4, & x \le 0 \\ (x - 2)^2, & x > 0 \end{cases}$

$f(-2) = -\frac{1}{2}(-2) + 4 = 5$

$f(-1) = -\frac{1}{2}(-1) + 4 = 4\frac{1}{2} = \frac{9}{2}$

$f(0) = -\frac{1}{2}(0) + 4 = 4$

$f(1) = (1 - 2)^2 = 1$

$f(2) = (2 - 2)^2 = 0$

x	-2	-1	0	1	2
$f(x)$	5	$\frac{9}{2}$	4	1	0

37. $15 - 3x = 0$

$3x = 15$

$x = 5$

39. $\dfrac{3x - 4}{5} = 0$

$3x - 4 = 0$

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

41. $x^2 - 9 = 0$

$x^2 = 9$

$x = \pm 3$

43. $x^3 - x = 0$

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

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

$x = 0, x = -1$, or $x = 1$

45.
$$f(x) = g(x)$$
$$x^2 = x + 2$$
$$x^2 - x - 2 = 0$$
$$(x - 2)(x + 1) = 0$$
$$x - 2 = 0 \quad x + 1 = 0$$
$$x = 2 \qquad x = -1$$

47.
$$f(x) = g(x)$$
$$x^4 - 2x^2 = 2x^2$$
$$x^4 - 4x^2 = 0$$
$$x^2(x^2 - 4) = 0$$
$$x^2(x + 2)(x - 2) = 0$$
$$x^2 = 0 \Rightarrow x = 0$$
$$x + 2 = 0 \Rightarrow x = -2$$
$$x - 2 = 0 \Rightarrow x = 2$$

49. $f(x) = 5x^2 + 2x - 1$

Because $f(x)$ is a polynomial, the domain is all real numbers x.

51. $h(t) = \dfrac{4}{t}$

The domain is all real numbers t except $t = 0$.

53. $g(y) = \sqrt{y - 10}$

Domain: $y - 10 \geq 0$

$y \geq 10$

The domain is all real numbers y such that $y \geq 10$.

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

The domain is all real numbers x except $x = 0, x = -2$.

57. $f(s) = \dfrac{\sqrt{s - 1}}{s - 4}$

Domain: $s - 1 \geq 0 \Rightarrow s \geq 1$ and $s \neq 4$

The domain consists of all real numbers s, such that $s \geq 1$ and $s \neq 4$.

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

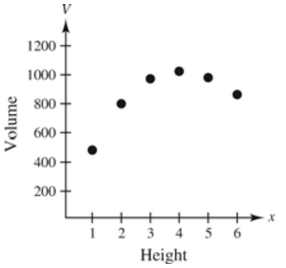
The domain is all real numbers x such that $x > 0$ or $(0, \infty)$.

61. (a)

Height, x	Volume, V
1	484
2	800
3	972
4	1024
5	980
6	864

The volume is maximum when $x = 4$ and $V = 1024$ cubic centimeters.

(b)



V is a function of x.

(c) $V = x(24 - 2x)^2$

Domain: $0 < x < 12$

63. $A = s^2$ and $P = 4s \Rightarrow \dfrac{P}{4} = s$

$$A = \left(\frac{P}{4}\right)^2 = \frac{P^2}{16}$$

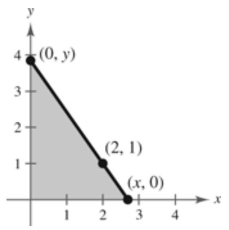
65.
$$y = -\tfrac{1}{10}x^2 + 3x + 6$$
$$y(30) = -\tfrac{1}{10}(30)^2 + 3(30) + 6 = 6 \text{ feet}$$

If the child holds a glove at a height of 5 feet, then the ball *will* be over the child's head because it will be at a height of 6 feet.

67. $A = \frac{1}{2}bh = \frac{1}{2}xy$

Because $(0, y), (2, 1),$ and $(x, 0)$ all lie on the same line, the slopes between any pair are equal.

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



So, $A = \frac{1}{2}x\left(\frac{x}{x-2}\right) = \frac{x^2}{2(x-2)}.$

The domain of A includes x-values such that $x^2/[2(x-2)] > 0.$ By solving this inequality, the domain is $x > 2.$

69. For 2004 through 2007, use

$$p(t) = 4.57t + 27.3.$$

2004: $p(4) = 4.57(4) + 27.3 = 45.58\%$

2005: $p(5) = 4.57(5) + 27.3 = 50.15\%$

2006: $p(6) = 4.57(6) + 27.3 = 54.72\%$

2007: $p(7) = 4.57(7) + 27.3 = 59.29\%$

For 2008 through 2010, use

$$p(t) = 3.35t + 37.6.$$

2008: $p(8) = 3.35(8) + 37.6 = 64.4\%$

2009: $p(9) = 3.35(9) + 37.6 = 67.75\%$

2010: $p(10) = 3.35(10) + 37.6 = 71.1\%$

71. (a) Cost = variable costs + fixed costs

$C = 12.30x + 98{,}000$

(b) Revenue = price per unit × number of units

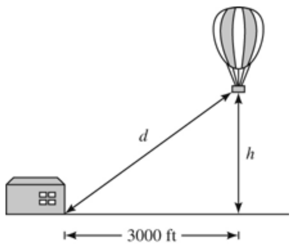
$R = 17.98x$

(c) Profit = Revenue − Cost

$P = 17.98x - (12.30x + 98{,}000)$

$P = 5.68x - 98{,}000$

73. (a)



(b) $(3000)^2 + h^2 = d^2$

$$h = \sqrt{d^2 - (3000)^2}$$

Domain: $d \geq 3000$ (because both $d \geq 0$ and $d^2 - (3000)^2 \geq 0$)

75. (a) $R = n(\text{rate}) = n[8.00 - 0.05(n - 80)], n \geq 80$

$R = 12.00n - 0.05n^2 = 12n - \frac{n^2}{20} = \frac{240n - n^2}{20}, n \geq 80$

(b)

n	90	100	110	120	130	140	150
$R(n)$	\$675	\$700	\$715	\$720	\$715	\$700	\$675

The revenue is maximum when 120 people take the trip.

77.
$$\begin{aligned} f(x) &= x^2 - x + 1 \\ f(2+h) &= (2+h)^2 - (2+h) + 1 \\ &= 4 + 4h + h^2 - 2 - h + 1 \\ &= h^2 + 3h + 3 \\ f(2) &= (2)^2 - 2 + 1 = 3 \\ f(2+h) - f(2) &= h^2 + 3h \\ \frac{f(2+h) - f(2)}{h} &= \frac{h^2 + 3h}{h} = h + 3, h \neq 0 \end{aligned}$$

79.
$$\begin{aligned} f(x) &= x^3 + 3x \\ f(x+h) &= (x+h)^3 + 3(x+h) \\ &= x^3 + 3x^2h + 3xh^2 + h^3 + 3x + 3h \\ \frac{f(x+h) - f(x)}{h} &= \frac{(x^3 + 3x^2h + 3xh^2 + h^3 + 3x + 3h) - (x^3 + 3x)}{h} \\ &= \frac{h(3x^2 + 3xh + h^2 + 3)}{h} \\ &= 3x^2 + 3xh + h^2 + 3, h \neq 0 \end{aligned}$$

81.
$$\begin{aligned} g(x) &= \frac{1}{x^2} \\ \frac{g(x) - g(3)}{x - 3} &= \frac{\frac{1}{x^2} - \frac{1}{9}}{x - 3} \\ &= \frac{9 - x^2}{9x^2(x-3)} \\ &= \frac{-(x+3)(x-3)}{9x^2(x-3)} \\ &= -\frac{x+3}{9x^2}, x \neq 3 \end{aligned}$$

83. $f(x) = \sqrt{5x}$

$$\frac{f(x) - f(5)}{x - 5} = \frac{\sqrt{5x} - 5}{x - 5}, x \neq 5$$

85. By plotting the points, we have a parabola, so $g(x) = cx^2$. Because $(-4, -32)$ is on the graph, you have $-32 = c(-4)^2 \Rightarrow c = -2$. So, $g(x) = -2x^2$.

87. Because the function is undefined at 0, we have $r(x) = c/x$. Because $(-4, -8)$ is on the graph, you have $-8 = c/-4 \Rightarrow c = 32$. So, $r(x) = 32/x$.

89. False. The equation $y^2 = x^2 + 4$ is a relation between x and y. However, $y = \pm\sqrt{x^2 + 4}$ does not represent a function.

91. False. The range is $[-1, \infty)$.

93. $f(x) = \sqrt{x - 1}$ Domain: $x \geq 1$

$g(x) = \dfrac{1}{\sqrt{x - 1}}$ Domain: $x > 1$

The value 1 may be included in the domain of $f(x)$ as it is possible to find the square root of 0. However, 1 cannot be included in the domain of $g(x)$ as it causes a zero to occur in the denominator which results in the function being undefined.

95. No; x is the independent variable, f is the name of the function.

97. (a) Yes. The amount that you pay in sales tax will increase as the price of the item purchased increases.

(b) No. The length of time that you study the night before an exam does not necessarily determine your score on the exam.

Section P.6 Analyzing Graphs of Functions

1. Vertical Line Test

3. decreasing

5. average rate of change; secant

7. Domain: $(-\infty, \infty)$; Range: $[-4, \infty)$

(a) $f(-2) = 0$

(b) $f(-1) = -1$

(c) $f\left(\frac{1}{2}\right) = 0$

(d) $f(1) = -2$

9. Domain: $(-\infty, \infty)$; Range: $(-2, \infty)$

(a) $f(2) = 0$

(b) $f(1) = 1$

(c) $f(3) = 2$

(d) $f(-1) = 3$

11. $y = \frac{1}{4}x^3$

A vertical line intersects the graph at most once, so *y is* a function of *x*.

13. $x^2 + y^2 = 25$

A vertical line intersects the graph more than once, so *y is not* a function of *x*.

15.
$$\begin{aligned} f(x) &= 2x^2 - 7x - 30 \\ 2x^2 - 7x - 30 &= 0 \\ (2x + 5)(x - 6) &= 0 \end{aligned}$$
$$2x + 5 = 0 \quad \text{or} \quad x - 6 = 0$$
$$x = -\tfrac{5}{2} \qquad\qquad x = 6$$

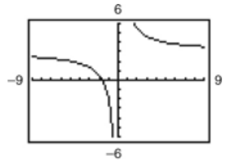
17.
$$\begin{aligned} f(x) &= \frac{x}{9x^2 - 4} \\ \frac{x}{9x^2 - 4} &= 0 \\ x &= 0 \end{aligned}$$

19.
$$\begin{aligned} f(x) &= \tfrac{1}{2}x^3 - x \\ \tfrac{1}{2}x^3 - x &= 0 \\ x^3 - 2x &= 2(0) \\ x(x^2 - 2) &= 0 \end{aligned}$$
$$x = 0 \quad \text{or} \quad x^2 - 2 = 0$$
$$x^2 = 2$$
$$x = \pm\sqrt{2}$$

21.
$$\begin{aligned} f(x) &= 4x^3 - 24x^2 - x + 6 \\ 4x^3 - 24x^2 - x + 6 &= 0 \\ 4x^2(x - 6) - 1(x - 6) &= 0 \\ (x - 6)(4x^2 - 1) &= 0 \\ (x - 6)(2x + 1)(2x - 1) &= 0 \end{aligned}$$
$$x - 6 = 0 \quad \text{or} \quad 2x + 1 = 0 \quad \text{or} \quad 2x - 1 = 0$$
$$x = 6 \qquad\qquad x = -\tfrac{1}{2} \qquad\qquad x = \tfrac{1}{2}$$

23.
$$\begin{aligned} f(x) &= \sqrt{2x} - 1 \\ \sqrt{2x} - 1 &= 0 \\ \sqrt{2x} &= 1 \\ 2x &= 1 \\ x &= \tfrac{1}{2} \end{aligned}$$

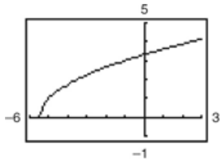
25. (a)



Zero: $x = -\dfrac{5}{3}$

(b)
$$\begin{aligned} f(x) &= 3 + \tfrac{5}{x} \\ 3 + \tfrac{5}{x} &= 0 \\ 3x + 5 &= 0 \\ x &= -\tfrac{5}{3} \end{aligned}$$

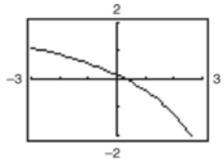
27. (a)



Zero: $x = -\frac{11}{2}$

(b) $$f(x) = \sqrt{2x + 11}$$
$$\sqrt{2x + 11} = 0$$
$$2x + 11 = 0$$
$$x = -\frac{11}{2}$$

29. (a)



Zero: $x = \dfrac{1}{3}$

(b) $$f(x) = \frac{3x - 1}{x - 6}$$
$$\frac{3x - 1}{x - 6} = 0$$
$$3x - 1 = 0$$
$$x = \frac{1}{3}$$

31. $f(x) = \frac{3}{2}x$

The function is increasing on $(-\infty, \infty)$.

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

The function is increasing on $(-\infty, 0)$ and $(2, \infty)$ and decreasing on $(0, 2)$.

35. $f(x) = |x + 1| + |x - 1|$

The function is increasing on $(1, \infty)$.

The function is constant on $(-1, 1)$.

The function is decreasing on $(-\infty, -1)$.

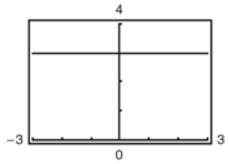
37. $$f(x) = \begin{cases} x + 3, & x \le 0 \\ 3, & 0 < x \le 2 \\ 2x + 1, & x > 2 \end{cases}$$

The function is increasing on $(-\infty, 0)$ and $(2, \infty)$.

The function is constant on $(0, 2)$.

39. $f(x) = 3$

(a)



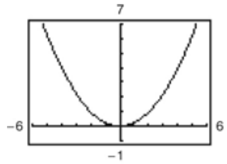
Constant on $(-\infty, \infty)$

(b)

x	−2	−1	0	1	2
$f(x)$	3	3	3	3	3

41. $g(s) = \dfrac{s^2}{4}$

(a)



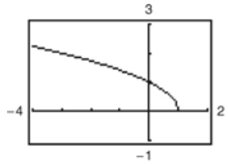
Decreasing on $(-\infty, 0)$; Increasing on $(0, \infty)$

(b)

s	−4	−2	0	2	4
$g(s)$	4	1	0	1	4

43. $f(x) = \sqrt{1 - x}$

(a)



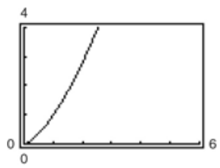
Decreasing on $(-\infty, 1)$

(b)

x	−3	−2	−1	0	1
$f(x)$	2	$\sqrt{3}$	$\sqrt{2}$	1	0

45. $f(x) = x^{3/2}$

(a)

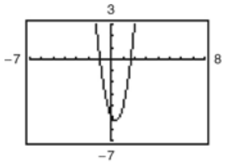


Increasing on $(0, \infty)$

(b)

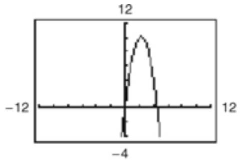
x	0	1	2	3	4
$f(x)$	0	1	2.8	5.2	8

47. $f(x) = 3x^2 - 2x - 5$



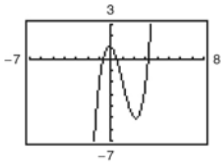
Relative minimum: $\left(\frac{1}{3}, -\frac{16}{3}\right)$ or $(0.33, -5.33)$

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



Relative maximum: $(2.25, 10.125)$

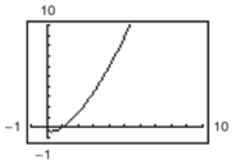
51. $f(x) = x^3 - 3x^2 - x + 1$



Relative maximum: $(-0.15, 1.08)$

Relative minimum: $(2.15, -5.08)$

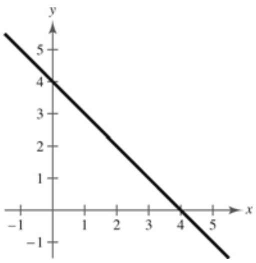
53. $h(x) = (x - 1)\sqrt{x}$



Relative minimum: $(0.33, -0.38)$

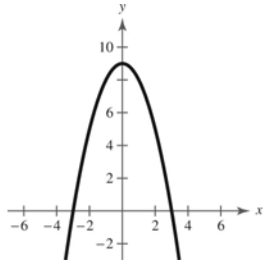
55. $f(x) = 4 - x$

$f(x) \geq 0$ on $(-\infty, 4]$



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

$f(x) \geq 0$ on $[-3, 3]$



59. $f(x) = \sqrt{x - 1}$

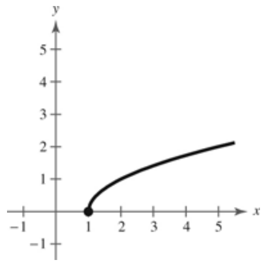
$f(x) \geq 0$ on $[1, \infty)$

$\sqrt{x - 1} \geq 0$

$x - 1 \geq 0$

$x \geq 1$

$[1, \infty)$



61. $f(x) = -2x + 15$

$$\frac{f(3) - f(0)}{3 - 0} = \frac{9 - 15}{3} = -2$$

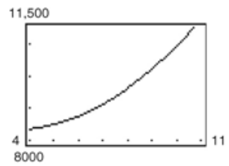
The average rate of change from $x_1 = 0$ to $x_2 = 3$ is -2.

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

$$\frac{f(3) - f(1)}{3 - 1} = \frac{-3 - (-3)}{2} = 0$$

The average rate of change from $x_1 = 1$ to $x_2 = 3$ is 0.

65. (a)



(b) To find the average rate of change of the amount the U.S. Department of Energy spent for research and development from 2005 to 2010, find the average rate of change from $(5, f(5))$ to $(10, f(10))$.

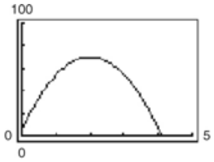
$$\frac{f(10) - f(5)}{10 - 5} = \frac{10{,}925 - 8501.25}{5} = 484.75$$

The amount the U.S. Department of Energy spent for research and development increased by about \$484.75 million each year from 2005 to 2010.

67. $s_0 = 6, v_0 = 64$

(a) $s = -16t^2 + 64t + 6$

(b)



(c) $\dfrac{s(3) - s(0)}{3 - 0} = \dfrac{54 - 6}{3} = 16$

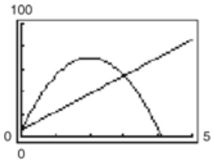
(d) The slope of the secant line is positive.

(e) $s(0) = 6, m = 16$

Secant line: $y - 6 = 16(t - 0)$

$y = 16t + 6$

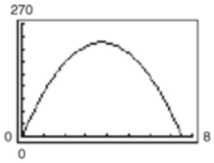
(f)



69. $v_0 = 120, s_0 = 0$

(a) $s = -16t^2 + 120t$

(b)



(c) The average rate of change from $t = 3$ to $t = 5$:

$\dfrac{s(5) - s(3)}{5 - 3} = \dfrac{200 - 216}{2} = -\dfrac{16}{2} = -8$ feet per second

(d) The slope of the secant line through $(3, s(3))$ and $(5, s(5))$ is negative.

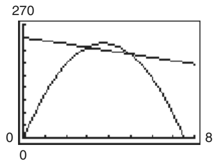
(e) The equation of the secant line: $m = -8$

Using $(5, s(5)) = (5, 200)$ we have

$y - 200 = -8(t - 5)$

$y = -8t + 240.$

(f)



71. $f(x) = x^6 - 2x^2 + 3$

$f(-x) = (-x)^6 - 2(-x)^2 + 3$

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

$= f(x)$

The function is even. y-axis symmetry.

73. $h(x) = x\sqrt{x + 5}$

$h(-x) = (-x)\sqrt{-x + 5}$

$= -x\sqrt{5 - x}$

$\neq h(x)$

$\neq -h(x)$

The function is neither odd nor even. No symmetry.

75. $f(s) = 4s^{3/2}$

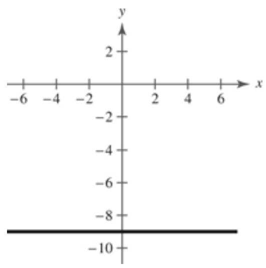
$= 4(-s)^{3/2}$

$\neq f(s)$

$\neq -f(s)$

The function is neither odd nor even. No symmetry.

77.



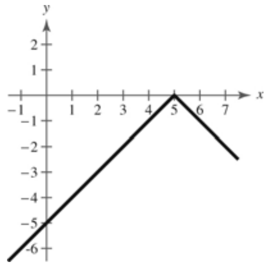
The graph of $f(x) = -9$ is symmetric to the y-axis, which implies $f(x)$ is even.

$f(-x) = -9$

$= f(x)$

The function is even.

79. $f(x) = -|x - 5|$

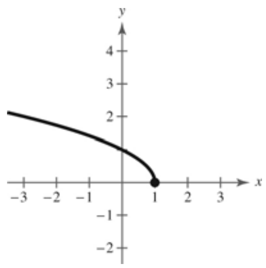


The graph displays no symmetry, which implies $f(x)$ is neither odd nor even.

$$\begin{aligned} f(x) &= -|(-x) - 5| \\ &= -|-x - 5| \\ &\neq f(x) \\ &\neq -f(x) \end{aligned}$$

The function is neither even nor odd.

81. $f(x) = \sqrt{1 - x}$



The graph displays no symmetry, which implies $f(x)$ is neither odd nor even.

$$f(-x) = \sqrt{1 - (-x)} = \sqrt{1 + x} \neq f(x) \neq -f(x)$$

The function is neither even nor odd.

83. $h = \text{top} - \text{bottom}$

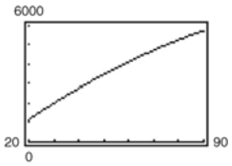
$$\begin{aligned} &= 3 - (4x - x^2) \\ &= 3 - 4x + x^2 \end{aligned}$$

85. $L = \text{right} - \text{left}$

$$= 2 - \sqrt[3]{2y}$$

87. $L = -0.294x^2 + 97.744x - 664.875,\ 20 \leq x \leq 90$

(a)



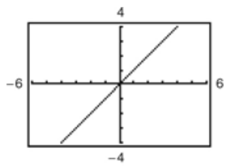
(b) $L = 2000$ when $x \approx 29.9645 \approx 30$ watts.

89. (a) For the average salaries of college professors, a scale of $10,000 would be appropriate.

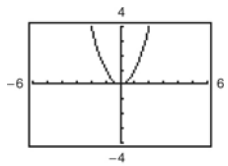
(b) For the population of the United States, use a scale of 10,000,000.

(c) For the percent of the civilian workforce that is unemployed, use a scale of 1%.

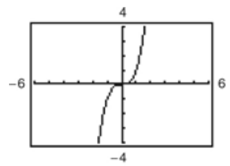
91. (a) $y = x$



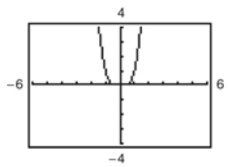
(b) $y = x^2$



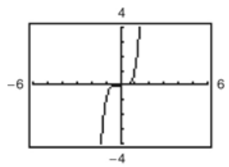
(c) $y = x^3$



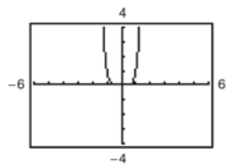
(d) $y = x^4$



(e) $y = x^5$



(f) $y = x^6$



All the graphs pass through the origin. The graphs of the odd powers of x are symmetric with respect to the origin and the graphs of the even powers are symmetric with respect to the y-axis. As the powers increase, the graphs become flatter in the interval $-1 < x < 1$.

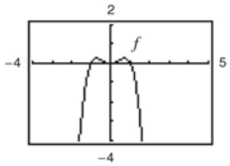
93. False. The function $f(x) = \sqrt{x^2 + 1}$ has a domain of all real numbers.

95. $\left(-\frac{5}{3}, -7\right)$

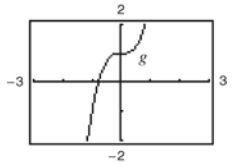
(a) If f is even, another point is $\left(\frac{5}{3}, -7\right)$.

(b) If f is odd, another point is $\left(\frac{5}{3}, 7\right)$.

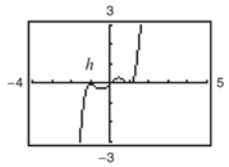
97.



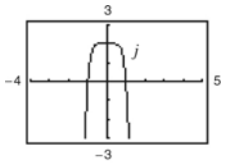
$f(x) = x^2 - x^4$ is even.



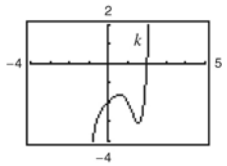
$g(x) = 2x^3 + 1$ is neither.



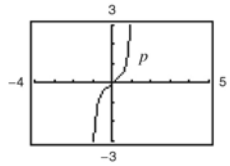
$h(x) = x^5 - 2x^3 + x$ is odd.



$j(x) = 2 - x^6 - x^8$ is even.



$k(x) = x^5 - 2x^4 + x - 2$ is neither.



$p(x) = x^9 + 3x^5 - x^3 + x$ is odd.

Equations of odd functions contain only odd powers of x. Equations of even functions contain only even powers of x. A function that has variables raised to even and odd powers is neither odd nor even.

Section P.7 A Library of Parent Functions

1. $f(x) = [\![x]\!]$

(g) greatest integer function

2. $f(x) = x$

(i) identity function

3. $f(x) = \dfrac{1}{x}$

(h) reciprocal function

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

(a) squaring function

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

(b) square root function

6. $f(x) = c$

(e) constant function

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

(f) absolute value function

8. $f(x) = x^3$

(c) cubic function

9. $f(x) = ax + b$

(d) linear function

11. (a) $f(1) = 4$, $f(0) = 6$

$(1, 4), (0, 6)$

$$m = \frac{6 - 4}{0 - 1} = -2$$

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

$$y = -2x + 6$$

$$f(x) = -2x + 6$$

(b)