

# Chapter 1

## Functions and Their Graphs

### Section 1.1

1.  $(-1, 3)$

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

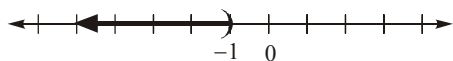
$$= 12 + 10 - \frac{1}{2}$$

$$= \frac{43}{2} \text{ or } 21\frac{1}{2} \text{ or } 21.5$$

3. We must not allow the denominator to be 0.  
 $x + 4 \neq 0 \Rightarrow x \neq -4$ ; Domain:  $\{x \mid x \neq -4\}$ .

4.  $3 - 2x > 5$   
 $-2x > 2$   
 $x < -1$

Solution set:  $\{x \mid x < -1\}$  or  $(-\infty, -1)$

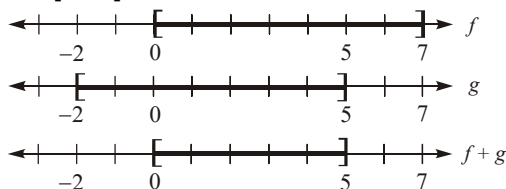


5. independent; dependent

6. range

7.  $[0, 5]$

We need the intersection of the intervals  $[0, 7]$  and  $[-2, 5]$ .



8.  $\neq ; f, g$

9.  $(g - f)(x)$  or  $g(x) - f(x)$

10. False; every function is a relation, but not every relation is a function. For example, the relation  $x^2 + y^2 = 1$  is not a function.

11. True

12. True

13. False; if the domain is not specified, we assume it is the largest set of real numbers for which the value of  $f$  is a real number.

14. False; the domain of  $f(x) = \frac{x^2 - 4}{x}$  is  $\{x \mid x \neq 0\}$ .

15. Function

Domain: {Elvis, Colleen, Kaleigh, Marissa}  
 Range: {Jan. 8, Mar. 15, Sept. 17}

16. Not a function

17. Not a function

18. Function

Domain: {Less than 9<sup>th</sup> grade, 9<sup>th</sup>-12<sup>th</sup> grade, High School Graduate, Some College, College Graduate}  
 Range: {\$18,120, \$23,251, \$36,055, \$45,810, \$67,165}

19. Not a function

20. Function

Domain:  $\{-2, -1, 3, 4\}$   
 Range:  $\{3, 5, 7, 12\}$

21. Function

Domain:  $\{1, 2, 3, 4\}$   
 Range:  $\{3\}$

22. Function

Domain:  $\{0, 1, 2, 3\}$   
 Range:  $\{-2, 3, 7\}$

23. Not a function

24. Not a function

25. Function

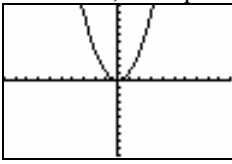
Domain:  $\{-2, -1, 0, 1\}$   
 Range:  $\{0, 1, 4\}$

26. Function

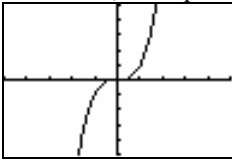
Domain:  $\{-2, -1, 0, 1\}$   
 Range:  $\{3, 4, 16\}$

## Chapter 1: Functions and Their Graphs

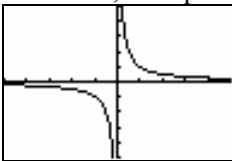
27. Graph  $y = x^2$ . The graph passes the vertical line test. Thus, the equation represents a function.



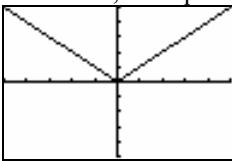
28. Graph  $y = x^3$ . The graph passes the vertical line test. Thus, the equation represents a function.



29. Graph  $y = \frac{1}{x}$ . The graph passes the vertical line test. Thus, the equation represents a function.



30. Graph  $y = |x|$ . The graph passes the vertical line test. Thus, the equation represents a function.



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

Solve for  $y$ :  $y = \pm\sqrt{4 - x^2}$

For  $x = 0$ ,  $y = \pm 2$ . Thus,  $(0, 2)$  and  $(0, -2)$  are on the graph. This is not a function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

32.  $y = \pm\sqrt{1 - 2x}$

For  $x = 0$ ,  $y = \pm 1$ . Thus,  $(0, 1)$  and  $(0, -1)$  are on the graph. This is not a function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

33.  $x = y^2$

Solve for  $y$ :  $y = \pm\sqrt{x}$

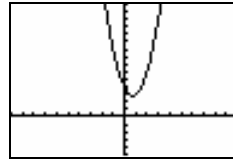
For  $x = 1$ ,  $y = \pm 1$ . Thus,  $(1, 1)$  and  $(1, -1)$  are on the graph. This is not a function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

34.  $x + y^2 = 1$

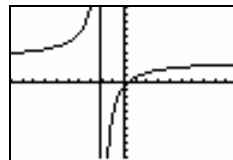
Solve for  $y$ :  $y = \pm\sqrt{1 - x}$

For  $x = 0$ ,  $y = \pm 1$ . Thus,  $(0, 1)$  and  $(0, -1)$  are on the graph. This is not a function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

35. Graph  $y = 2x^2 - 3x + 4$ . The graph passes the vertical line test. Thus, the equation represents a function.



36. Graph  $y = \frac{3x-1}{x+2}$ . The graph passes the vertical line test. Thus, the equation represents a function.



37.  $2x^2 + 3y^2 = 1$

Solve for  $y$ :  $2x^2 + 3y^2 = 1$

$$3y^2 = 1 - 2x^2$$

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

$$y = \pm\sqrt{\frac{1 - 2x^2}{3}}$$

For  $x = 0$ ,  $y = \pm\sqrt{\frac{1}{3}}$ . Thus,  $\left(0, \sqrt{\frac{1}{3}}\right)$  and

$\left(0, -\sqrt{\frac{1}{3}}\right)$  are on the graph. This is not a

function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

38.  $x^2 - 4y^2 = 1$

 Solve for  $y$ :  $x^2 - 4y^2 = 1$ 

$$4y^2 = x^2 - 1$$

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

$$y = \frac{\pm\sqrt{x^2 - 1}}{2}$$

 For  $x = \sqrt{2}$ ,  $y = \pm \frac{1}{2}$ . Thus,  $\left(\sqrt{2}, \frac{1}{2}\right)$  and

 $\left(\sqrt{2}, -\frac{1}{2}\right)$  are on the graph. This is not a

 function, since a distinct  $x$ -value corresponds to two different  $y$ -values.

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

a.  $f(0) = 3(0)^2 + 2(0) - 4 = -4$

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

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

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

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

f. 
$$\begin{aligned} f(x+1) &= 3(x+1)^2 + 2(x+1) - 4 \\ &= 3(x^2 + 2x + 1) + 2x + 2 - 4 \\ &= 3x^2 + 6x + 3 + 2x + 2 - 4 \\ &= 3x^2 + 8x + 1 \end{aligned}$$

g.  $f(2x) = 3(2x)^2 + 2(2x) - 4 = 12x^2 + 4x - 4$

h. 
$$\begin{aligned} f(x+h) &= 3(x+h)^2 + 2(x+h) - 4 \\ &= 3(x^2 + 2xh + h^2) + 2x + 2h - 4 \\ &= 3x^2 + 6xh + 3h^2 + 2x + 2h - 4 \end{aligned}$$

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

a.  $f(0) = -2(0)^2 + 0 - 1 = -1$

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

c.  $f(-1) = -2(-1)^2 + (-1) - 1 = -4$

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

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

f. 
$$\begin{aligned} f(x+1) &= -2(x+1)^2 + (x+1) - 1 \\ &= -2(x^2 + 2x + 1) + x + 1 - 1 \\ &= -2x^2 - 4x - 2 + x \\ &= -2x^2 - 3x - 2 \end{aligned}$$

g.  $f(2x) = -2(2x)^2 + (2x) - 1 = -8x^2 + 2x - 1$

h. 
$$\begin{aligned} f(x+h) &= -2(x+h)^2 + (x+h) - 1 \\ &= -2(x^2 + 2xh + h^2) + x + h - 1 \\ &= -2x^2 - 4xh - 2h^2 + x + h - 1 \end{aligned}$$

41.  $f(x) = \frac{x}{x^2 + 1}$

a.  $f(0) = \frac{0}{0^2 + 1} = \frac{0}{1} = 0$

b.  $f(1) = \frac{1}{1^2 + 1} = \frac{1}{2}$

c.  $f(-1) = \frac{-1}{(-1)^2 + 1} = \frac{-1}{1 + 1} = -\frac{1}{2}$

d.  $f(-x) = \frac{-x}{(-x)^2 + 1} = \frac{-x}{x^2 + 1}$

e.  $-f(x) = -\left(\frac{x}{x^2 + 1}\right) = \frac{-x}{x^2 + 1}$

f. 
$$\begin{aligned} f(x+1) &= \frac{x+1}{(x+1)^2 + 1} \\ &= \frac{x+1}{x^2 + 2x + 1 + 1} \\ &= \frac{x+1}{x^2 + 2x + 2} \end{aligned}$$

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

h.  $f(x+h) = \frac{x+h}{(x+h)^2 + 1} = \frac{x+h}{x^2 + 2xh + h^2 + 1}$

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$$42. f(x) = \frac{x^2 - 1}{x + 4}$$

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

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

$$c. f(-1) = \frac{(-1)^2 - 1}{-1 + 4} = \frac{0}{3} = 0$$

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

$$e. -f(x) = -\left(\frac{x^2 - 1}{x + 4}\right) = \frac{-x^2 + 1}{x + 4}$$

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

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

$$h. f(x+h) = \frac{(x+h)^2 - 1}{(x+h) + 4} = \frac{x^2 + 2xh + h^2 - 1}{x + h + 4}$$

$$43. f(x) = |x| + 4$$

$$a. f(0) = |0| + 4 = 0 + 4 = 4$$

$$b. f(1) = |1| + 4 = 1 + 4 = 5$$

$$c. f(-1) = |-1| + 4 = 1 + 4 = 5$$

$$d. f(-x) = |-x| + 4 = |x| + 4$$

$$e. -f(x) = -(|x| + 4) = -|x| - 4$$

$$f. f(x+1) = |x+1| + 4$$

$$g. f(2x) = |2x| + 4 = 2|x| + 4$$

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

$$44. f(x) = \sqrt{x^2 + x}$$

$$a. f(0) = \sqrt{0^2 + 0} = \sqrt{0} = 0$$

$$b. f(1) = \sqrt{1^2 + 1} = \sqrt{2}$$

$$c. f(-1) = \sqrt{(-1)^2 + (-1)} = \sqrt{1-1} = \sqrt{0} = 0$$

$$d. f(-x) = \sqrt{(-x)^2 + (-x)} = \sqrt{x^2 - x}$$

$$e. -f(x) = -(\sqrt{x^2 + x}) = -\sqrt{x^2 + x}$$

$$f. f(x+1) = \sqrt{(x+1)^2 + (x+1)} = \sqrt{x^2 + 2x + 1 + x + 1} = \sqrt{x^2 + 3x + 2}$$

$$g. f(2x) = \sqrt{(2x)^2 + 2x} = \sqrt{4x^2 + 2x}$$

$$h. f(x+h) = \sqrt{(x+h)^2 + (x+h)} = \sqrt{x^2 + 2xh + h^2 + x + h}$$

$$45. f(x) = \frac{2x+1}{3x-5}$$

$$a. f(0) = \frac{2(0)+1}{3(0)-5} = \frac{0+1}{0-5} = -\frac{1}{5}$$

$$b. f(1) = \frac{2(1)+1}{3(1)-5} = \frac{2+1}{3-5} = \frac{3}{-2} = -\frac{3}{2}$$

$$c. f(-1) = \frac{2(-1)+1}{3(-1)-5} = \frac{-2+1}{-3-5} = \frac{-1}{-8} = \frac{1}{8}$$

$$d. f(-x) = \frac{2(-x)+1}{3(-x)-5} = \frac{-2x+1}{-3x-5} = \frac{2x-1}{3x+5}$$

$$e. -f(x) = -\left(\frac{2x+1}{3x-5}\right) = \frac{-2x-1}{3x-5}$$

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

$$g. f(2x) = \frac{2(2x)+1}{3(2x)-5} = \frac{4x+1}{6x-5}$$

$$h. f(x+h) = \frac{2(x+h)+1}{3(x+h)-5} = \frac{2x+2h+1}{3x+3h-5}$$

$$46. f(x) = 1 - \frac{1}{(x+2)^2}$$

$$\text{a. } f(0) = 1 - \frac{1}{(0+2)^2} = 1 - \frac{1}{4} = \frac{3}{4}$$

$$\text{b. } f(1) = 1 - \frac{1}{(1+2)^2} = 1 - \frac{1}{9} = \frac{8}{9}$$

$$\text{c. } f(-1) = 1 - \frac{1}{(-1+2)^2} = 1 - \frac{1}{1} = 0$$

$$\text{d. } f(-x) = 1 - \frac{1}{(-x+2)^2} = 1 - \frac{1}{(2-x)^2}$$

$$\text{e. } -f(x) = -\left(1 - \frac{1}{(x+2)^2}\right) = \frac{1}{(x+2)^2} - 1$$

$$\text{f. } f(x+1) = 1 - \frac{1}{(x+1+2)^2} = 1 - \frac{1}{(x+3)^2}$$

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

$$\text{h. } f(x+h) = 1 - \frac{1}{(x+h+2)^2}$$

$$47. f(x) = -5x + 4$$

Domain:  $\{x \mid x \text{ is any real number}\}$

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

Domain:  $\{x \mid x \text{ is any real number}\}$

$$49. f(x) = \frac{x}{x^2 + 1}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$50. f(x) = \frac{x^2}{x^2 + 1}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$51. g(x) = \frac{x}{x^2 - 16}$$

$$x^2 - 16 \neq 0$$

$$x^2 \neq 16 \Rightarrow x \neq \pm 4$$

Domain:  $\{x \mid x \neq -4, x \neq 4\}$

$$52. h(x) = \frac{2x}{x^2 - 4}$$

$$x^2 - 4 \neq 0$$

$$x^2 \neq 4 \Rightarrow x \neq \pm 2$$

Domain:  $\{x \mid x \neq -2, x \neq 2\}$

$$53. F(x) = \frac{x-2}{x^3 + x}$$

$$x^3 + x \neq 0$$

$$x(x^2 + 1) \neq 0$$

$$x \neq 0, \quad x^2 \neq -1$$

Domain:  $\{x \mid x \neq 0\}$

$$54. G(x) = \frac{x+4}{x^3 - 4x}$$

$$x^3 - 4x \neq 0$$

$$x(x^2 - 4) \neq 0$$

$$x \neq 0, \quad x^2 \neq 4$$

$$x \neq 0, \quad x \neq \pm 2$$

Domain:  $\{x \mid x \neq -2, x \neq 0, x \neq 2\}$

$$55. h(x) = \sqrt{3x - 12}$$

$$3x - 12 \geq 0$$

$$3x \geq 12$$

$$x \geq 4$$

Domain:  $\{x \mid x \geq 4\}$

$$56. G(x) = \sqrt{1 - x}$$

$$1 - x \geq 0$$

$$-x \geq -1$$

$$x \leq 1$$

Domain:  $\{x \mid x \leq 1\}$

$$57. f(x) = \frac{4}{\sqrt{x-9}}$$

$$x - 9 > 0$$

$$x > 9$$

Domain:  $\{x \mid x > 9\}$

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$$58. \quad f(x) = \frac{x}{\sqrt{x-4}}$$

$$x-4 > 0$$

$$x > 4$$

$$\text{Domain: } \{x \mid x > 4\}$$

$$59. \quad p(x) = \sqrt{\frac{2}{x-1}} = \frac{\sqrt{2}}{\sqrt{x-1}}$$

$$x-1 > 0$$

$$x > 1$$

$$\text{Domain: } \{x \mid x > 1\}$$

$$60. \quad q(x) = \sqrt{-x-2}$$

$$-x-2 \geq 0$$

$$-x \geq 2$$

$$x \leq -2$$

$$\text{Domain: } \{x \mid x \leq -2\}$$

$$61. \quad f(x) = 3x+4 \quad g(x) = 2x-3$$

$$\text{a. } (f+g)(x) = 3x+4+2x-3 = 5x+1$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{b. } (f-g)(x) = (3x+4)-(2x-3)$$

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

$$= x+7$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{c. } (f \cdot g)(x) = (3x+4)(2x-3)$$

$$= 6x^2 - 9x + 8x - 12$$

$$= 6x^2 - x - 12$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{d. } \left(\frac{f}{g}\right)(x) = \frac{3x+4}{2x-3}$$

$$2x-3 \neq 0 \Rightarrow 2x \neq 3 \Rightarrow x \neq \frac{3}{2}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{3}{2}\right\}$$

$$\text{e. } (f+g)(3) = 5(3)+1 = 15+1 = 16$$

$$\text{f. } (f-g)(4) = 4+7 = 11$$

$$\text{g. } (f \cdot g)(2) = 6(2)^2 - 2 - 12 = 24 - 2 - 12 = 10$$

$$\text{h. } \left(\frac{f}{g}\right)(1) = \frac{3(1)+4}{2(1)-3} = \frac{3+4}{2-3} = \frac{7}{-1} = -7$$

$$62. \quad f(x) = 2x+1 \quad g(x) = 3x-2$$

$$\text{a. } (f+g)(x) = 2x+1+3x-2 = 5x-1$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{b. } (f-g)(x) = (2x+1)-(3x-2)$$

$$= 2x+1-3x+2$$

$$= -x+3$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{c. } (f \cdot g)(x) = (2x+1)(3x-2)$$

$$= 6x^2 - 4x + 3x - 2$$

$$= 6x^2 - x - 2$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{d. } \left(\frac{f}{g}\right)(x) = \frac{2x+1}{3x-2}$$

$$3x-2 \neq 0$$

$$3x \neq 2 \Rightarrow x \neq \frac{2}{3}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{2}{3}\right\}$$

$$\text{e. } (f+g)(3) = 5(3)-1 = 15-1 = 14$$

$$\text{f. } (f-g)(4) = -4+3 = -1$$

$$\text{g. } (f \cdot g)(2) = 6(2)^2 - 2 - 2$$

$$= 6(4) - 2 - 2$$

$$= 24 - 2 - 2 = 20$$

$$\text{h. } \left(\frac{f}{g}\right)(1) = \frac{2(1)+1}{3(1)-2} = \frac{2+1}{3-2} = \frac{3}{1} = 3$$

$$63. \quad f(x) = x-1 \quad g(x) = 2x^2$$

$$\text{a. } (f+g)(x) = x-1+2x^2 = 2x^2+x-1$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{b. } (f-g)(x) = (x-1)-(2x^2)$$

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

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

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{c. } (f \cdot g)(x) = (x-1)(2x^2) = 2x^3 - 2x^2$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\text{d. } \left(\frac{f}{g}\right)(x) = \frac{x-1}{2x^2}$$

$$\text{Domain: } \{x \mid x \neq 0\}.$$

$$\begin{aligned} \text{e. } (f+g)(3) &= 2(3)^2 + 3 - 1 \\ &= 2(9) + 3 - 1 \\ &= 18 + 3 - 1 = 20 \end{aligned}$$

$$\begin{aligned} \text{f. } (f-g)(4) &= -2(4)^2 + 4 - 1 \\ &= -2(16) + 4 - 1 \\ &= -32 + 4 - 1 = -29 \end{aligned}$$

$$\begin{aligned} \text{g. } (f \cdot g)(2) &= 2(2)^3 - 2(2)^2 \\ &= 2(8) - 2(4) \\ &= 16 - 8 = 8 \end{aligned}$$

$$\text{h. } \left(\frac{f}{g}\right)(1) = \frac{1-1}{2(1)^2} = \frac{0}{2(1)} = \frac{0}{2} = 0$$

$$64. \quad f(x) = 2x^2 + 3 \quad g(x) = 4x^3 + 1$$

$$\begin{aligned} \text{a. } (f+g)(x) &= 2x^2 + 3 + 4x^3 + 1 \\ &= 4x^3 + 2x^2 + 4 \\ \text{Domain: } &\{x \mid x \text{ is any real number}\}. \end{aligned}$$

$$\begin{aligned} \text{b. } (f-g)(x) &= (2x^2 + 3) - (4x^3 + 1) \\ &= 2x^2 + 3 - 4x^3 - 1 \\ &= -4x^3 + 2x^2 + 2 \\ \text{Domain: } &\{x \mid x \text{ is any real number}\}. \end{aligned}$$

$$\begin{aligned} \text{c. } (f \cdot g)(x) &= (2x^2 + 3)(4x^3 + 1) \\ &= 8x^5 + 12x^3 + 2x^2 + 3 \\ \text{Domain: } &\{x \mid x \text{ is any real number}\}. \end{aligned}$$

$$\begin{aligned} \text{d. } \left(\frac{f}{g}\right)(x) &= \frac{2x^2 + 3}{4x^3 + 1} \\ 4x^3 + 1 &\neq 0 \\ 4x^3 &\neq -1 \\ x^3 &\neq -\frac{1}{4} \Rightarrow x \neq \sqrt[3]{-\frac{1}{4}} = -\frac{\sqrt[3]{2}}{2} \\ \text{Domain: } &\left\{x \mid x \neq -\frac{\sqrt[3]{2}}{2}\right\}. \end{aligned}$$

$$\begin{aligned} \text{e. } (f+g)(3) &= 4(3)^3 + 2(3)^2 + 4 \\ &= 4(27) + 2(9) + 4 \\ &= 108 + 18 + 4 = 130 \end{aligned}$$

$$\begin{aligned} \text{f. } (f-g)(4) &= -4(4)^3 + 2(4)^2 + 2 \\ &= -4(64) + 2(16) + 2 \\ &= -256 + 32 + 2 = -222 \end{aligned}$$

$$\begin{aligned} \text{g. } (f \cdot g)(2) &= 8(2)^5 + 12(2)^3 + 2(2)^2 + 3 \\ &= 8(32) + 12(8) + 2(4) + 3 \\ &= 256 + 96 + 8 + 3 = 363 \end{aligned}$$

$$\text{h. } \left(\frac{f}{g}\right)(1) = \frac{2(1)^2 + 3}{4(1)^3 + 1} = \frac{2(1) + 3}{4(1) + 1} = \frac{2 + 3}{4 + 1} = \frac{5}{5} = 1$$

$$65. \quad f(x) = \sqrt{x} \quad g(x) = 3x - 5$$

$$\begin{aligned} \text{a. } (f+g)(x) &= \sqrt{x} + 3x - 5 \\ \text{Domain: } &\{x \mid x \geq 0\}. \end{aligned}$$

$$\begin{aligned} \text{b. } (f-g)(x) &= \sqrt{x} - (3x - 5) = \sqrt{x} - 3x + 5 \\ \text{Domain: } &\{x \mid x \geq 0\}. \end{aligned}$$

$$\begin{aligned} \text{c. } (f \cdot g)(x) &= \sqrt{x}(3x - 5) = 3x\sqrt{x} - 5\sqrt{x} \\ \text{Domain: } &\{x \mid x \geq 0\}. \end{aligned}$$

$$\begin{aligned} \text{d. } \left(\frac{f}{g}\right)(x) &= \frac{\sqrt{x}}{3x-5} \\ x &\geq 0 \text{ and } 3x - 5 \neq 0 \\ 3x &\neq 5 \Rightarrow x \neq \frac{5}{3} \\ \text{Domain: } &\left\{x \mid x \geq 0 \text{ and } x \neq \frac{5}{3}\right\}. \end{aligned}$$

$$\begin{aligned} \text{e. } (f+g)(3) &= \sqrt{3} + 3(3) - 5 \\ &= \sqrt{3} + 9 - 5 = \sqrt{3} + 4 \end{aligned}$$

$$\begin{aligned} \text{f. } (f-g)(4) &= \sqrt{4} - 3(4) + 5 \\ &= 2 - 12 + 5 = -5 \end{aligned}$$

$$\begin{aligned} \text{g. } (f \cdot g)(2) &= 3(2)\sqrt{2} - 5\sqrt{2} \\ &= 6\sqrt{2} - 5\sqrt{2} = \sqrt{2} \end{aligned}$$

$$\text{h. } \left(\frac{f}{g}\right)(1) = \frac{\sqrt{1}}{3(1) - 5} = \frac{1}{3 - 5} = \frac{1}{-2} = -\frac{1}{2}$$

## Chapter 1: Functions and Their Graphs

66.  $f(x) = |x|$        $g(x) = x$

a.  $(f + g)(x) = |x| + x$

Domain:  $\{x \mid x \text{ is any real number}\}$ .

b.  $(f - g)(x) = |x| - x$

Domain:  $\{x \mid x \text{ is any real number}\}$ .

c.  $(f \cdot g)(x) = |x| \cdot x = x|x|$

Domain:  $\{x \mid x \text{ is any real number}\}$ .

d.  $\left(\frac{f}{g}\right)(x) = \frac{|x|}{x}$

Domain:  $\{x \mid x \neq 0\}$ .

e.  $(f + g)(3) = |3| + 3 = 3 + 3 = 6$

f.  $(f - g)(4) = |4| - 4 = 4 - 4 = 0$

g.  $(f \cdot g)(2) = 2|2| = 2 \cdot 2 = 4$

h.  $\left(\frac{f}{g}\right)(1) = \frac{|1|}{1} = \frac{1}{1} = 1$

67.  $f(x) = 1 + \frac{1}{x}$        $g(x) = \frac{1}{x}$

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

Domain:  $\{x \mid x \neq 0\}$ .

b.  $(f - g)(x) = 1 + \frac{1}{x} - \frac{1}{x} = 1$

Domain:  $\{x \mid x \neq 0\}$ .

c.  $(f \cdot g)(x) = \left(1 + \frac{1}{x}\right)\frac{1}{x} = \frac{1}{x} + \frac{1}{x^2}$

Domain:  $\{x \mid x \neq 0\}$ .

d.  $\left(\frac{f}{g}\right)(x) = \frac{1 + \frac{1}{x}}{\frac{1}{x}} = \frac{x+1}{\frac{1}{x}} = \frac{x+1}{x} \cdot \frac{x}{1} = x+1$

Domain:  $\{x \mid x \neq 0\}$ .

e.  $(f + g)(3) = 1 + \frac{2}{3} = \frac{5}{3}$

f.  $(f - g)(4) = 1$

g.  $(f \cdot g)(2) = \frac{1}{2} + \frac{1}{(2)^2} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$

h.  $\left(\frac{f}{g}\right)(1) = 1 + 1 = 2$

68.  $f(x) = \sqrt{x-1}$        $g(x) = \sqrt{4-x}$

a.  $(f + g)(x) = \sqrt{x-1} + \sqrt{4-x}$

$x-1 \geq 0$  and  $4-x \geq 0$

$x \geq 1$  and  $-x \geq -4$

$x \leq 4$

Domain:  $\{x \mid 1 \leq x \leq 4\}$ .

b.  $(f - g)(x) = \sqrt{x-1} - \sqrt{4-x}$

$x-1 \geq 0$  and  $4-x \geq 0$

$x \geq 1$  and  $-x \geq -4$

$x \leq 4$

Domain:  $\{x \mid 1 \leq x \leq 4\}$ .

c.  $(f \cdot g)(x) = (\sqrt{x-1})(\sqrt{4-x})$

$= \sqrt{-x^2 + 5x - 4}$

$x-1 \geq 0$  and  $4-x \geq 0$

$x \geq 1$  and  $-x \geq -4$

$x \leq 4$

Domain:  $\{x \mid 1 \leq x \leq 4\}$ .

d.  $\left(\frac{f}{g}\right)(x) = \frac{\sqrt{x-1}}{\sqrt{4-x}} = \sqrt{\frac{x-1}{4-x}}$

$x-1 \geq 0$  and  $4-x > 0$

$x \geq 1$  and  $-x > -4$

$x < 4$

Domain:  $\{x \mid 1 \leq x < 4\}$ .

e.  $(f + g)(3) = \sqrt{3-1} + \sqrt{4-3}$

$= \sqrt{2} + \sqrt{1} = \sqrt{2} + 1$

f.  $(f - g)(4) = \sqrt{4-1} - \sqrt{4-4}$

$= \sqrt{3} - \sqrt{0} = \sqrt{3} - 0 = \sqrt{3}$

g.  $(f \cdot g)(2) = \sqrt{-(2)^2 + 5(2) - 4}$

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

h.  $\left(\frac{f}{g}\right)(1) = \sqrt{\frac{1-1}{4-1}} = \sqrt{\frac{0}{3}} = \sqrt{0} = 0$



$$69. \quad f(x) = \frac{2x+3}{3x-2} \quad g(x) = \frac{4x}{3x-2}$$

$$\begin{aligned} \text{a.} \quad (f+g)(x) &= \frac{2x+3}{3x-2} + \frac{4x}{3x-2} \\ &= \frac{2x+3+4x}{3x-2} = \frac{6x+3}{3x-2} \end{aligned}$$

$$3x-2 \neq 0$$

$$3x \neq 2 \Rightarrow x \neq \frac{2}{3}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{2}{3}\right\}.$$

$$\begin{aligned} \text{b.} \quad (f-g)(x) &= \frac{2x+3}{3x-2} - \frac{4x}{3x-2} \\ &= \frac{2x+3-4x}{3x-2} = \frac{-2x+3}{3x-2} \end{aligned}$$

$$3x-2 \neq 0$$

$$3x \neq 2 \Rightarrow x \neq \frac{2}{3}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{2}{3}\right\}.$$

$$\text{c.} \quad (f \cdot g)(x) = \left(\frac{2x+3}{3x-2}\right)\left(\frac{4x}{3x-2}\right) = \frac{8x^2+12x}{(3x-2)^2}$$

$$3x-2 \neq 0$$

$$3x \neq 2 \Rightarrow x \neq \frac{2}{3}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{2}{3}\right\}.$$

$$\text{d.} \quad \left(\frac{f}{g}\right)(x) = \frac{\frac{2x+3}{3x-2}}{\frac{4x}{3x-2}} = \frac{2x+3}{3x-2} \cdot \frac{3x-2}{4x} = \frac{2x+3}{4x}$$

$$3x-2 \neq 0 \quad \text{and} \quad x \neq 0$$

$$3x \neq 2$$

$$x \neq \frac{2}{3}$$

$$\text{Domain: } \left\{x \mid x \neq \frac{2}{3} \text{ and } x \neq 0\right\}.$$

$$\text{e.} \quad (f+g)(3) = \frac{6(3)+3}{3(3)-2} = \frac{18+3}{9-2} = \frac{21}{7} = 3$$

$$\text{f.} \quad (f-g)(4) = \frac{-2(4)+3}{3(4)-2} = \frac{-8+3}{12-2} = \frac{-5}{10} = -\frac{1}{2}$$

$$\begin{aligned} \text{g.} \quad (f \cdot g)(2) &= \frac{8(2)^2+12(2)}{(3(2)-2)^2} \\ &= \frac{8(4)+24}{(6-2)^2} = \frac{32+24}{(4)^2} = \frac{56}{16} = \frac{7}{2} \end{aligned}$$

$$\text{h.} \quad \left(\frac{f}{g}\right)(1) = \frac{2(1)+3}{4(1)} = \frac{2+3}{4} = \frac{5}{4}$$

$$70. \quad f(x) = \sqrt{x+1} \quad g(x) = \frac{2}{x}$$

$$\begin{aligned} \text{a.} \quad (f+g)(x) &= \sqrt{x+1} + \frac{2}{x} \\ x+1 &\geq 0 \quad \text{and} \quad x \neq 0 \\ x &\geq -1 \end{aligned}$$

$$\text{Domain: } \{x \mid x \geq -1, \text{ and } x \neq 0\}.$$

$$\begin{aligned} \text{b.} \quad (f-g)(x) &= \sqrt{x+1} - \frac{2}{x} \\ x+1 &\geq 0 \quad \text{and} \quad x \neq 0 \\ x &\geq -1 \end{aligned}$$

$$\text{Domain: } \{x \mid x \geq -1, \text{ and } x \neq 0\}.$$

$$\begin{aligned} \text{c.} \quad (f \cdot g)(x) &= \sqrt{x+1} \cdot \frac{2}{x} = \frac{2\sqrt{x+1}}{x} \\ x+1 &\geq 0 \quad \text{and} \quad x \neq 0 \\ x &\geq -1 \end{aligned}$$

$$\text{Domain: } \{x \mid x \geq -1, \text{ and } x \neq 0\}.$$

$$\begin{aligned} \text{d.} \quad \left(\frac{f}{g}\right)(x) &= \frac{\sqrt{x+1}}{\frac{2}{x}} = \frac{x\sqrt{x+1}}{2} \\ x+1 &\geq 0 \quad \text{and} \quad x \neq 0 \\ x &\geq -1 \end{aligned}$$

$$\text{Domain: } \{x \mid x \geq -1, \text{ and } x \neq 0\}.$$

$$\text{e.} \quad (f+g)(3) = \sqrt{3+1} + \frac{2}{3} = \sqrt{4} + \frac{2}{3} = 2 + \frac{2}{3} = \frac{8}{3}$$

$$\text{f.} \quad (f-g)(4) = \sqrt{4+1} - \frac{2}{4} = \sqrt{5} - \frac{1}{2}$$

$$\text{g.} \quad (f \cdot g)(2) = \frac{2\sqrt{2+1}}{2} = \frac{2\sqrt{3}}{2} = \sqrt{3}$$

$$\text{h.} \quad \left(\frac{f}{g}\right)(1) = \frac{1\sqrt{1+1}}{2} = \frac{\sqrt{2}}{2}$$

**Chapter 1: Functions and Their Graphs**

$$71. f(x) = 3x + 1 \quad (f + g)(x) = 6 - \frac{1}{2}x$$

$$6 - \frac{1}{2}x = 3x + 1 + g(x)$$

$$5 - \frac{7}{2}x = g(x)$$

$$g(x) = 5 - \frac{7}{2}x$$

$$72. f(x) = \frac{1}{x} \quad \left(\frac{f}{g}\right)(x) = \frac{x+1}{x^2-x}$$

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

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

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

$$73. f(x) = 4x + 3$$

$$\frac{f(x+h) - f(x)}{h} = \frac{4(x+h) + 3 - (4x + 3)}{h}$$

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

$$= \frac{4h}{h} = 4$$

$$74. f(x) = -3x + 1$$

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

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

$$= \frac{-3h}{h} = -3$$

$$75. f(x) = x^2 - x + 4$$

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

$$= \frac{x^2 + 2xh + h^2 - x - h + 4 - x^2 + x - 4}{h}$$

$$= \frac{2xh + h^2 - h}{h}$$

$$= 2x + h - 1$$

$$76. f(x) = x^2 + 5x - 1$$

$$\frac{f(x+h) - f(x)}{h} = \frac{(x+h)^2 + 5(x+h) - 1 - (x^2 + 5x - 1)}{h}$$

$$= \frac{x^2 + 2xh + h^2 + 5x + 5h - 1 - x^2 - 5x + 1}{h}$$

$$= \frac{2xh + h^2 + 5h}{h} = 2x + h + 5$$

$$77. f(x) = x^3 - 2$$

$$\frac{f(x+h) - f(x)}{h} = \frac{(x+h)^3 - 2 - (x^3 - 2)}{h}$$

$$= \frac{x^3 + 3x^2h + 3xh^2 + h^3 - 2 - x^3 + 2}{h}$$

$$= \frac{3x^2h + 3xh^2 + h^3}{h} = 3x^2 + 3xh + h^2$$

$$78. f(x) = \frac{1}{x+3}$$

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

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

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

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

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

$$79. f(x) = 2x^3 + Ax^2 + 4x - 5 \text{ and } f(2) = 5$$

$$f(2) = 2(2)^3 + A(2)^2 + 4(2) - 5$$

$$5 = 16 + 4A + 8 - 5$$

$$5 = 4A + 19$$

$$-14 = 4A$$

$$A = \frac{-14}{4} = -\frac{7}{2}$$

## Section 1.1: Functions

80.  $f(x) = 3x^2 - Bx + 4$  and  $f(-1) = 12$  :

$$f(-1) = 3(-1)^2 - B(-1) + 4$$

$$12 = 3 + B + 4$$

$$B = 5$$

81.  $f(x) = \frac{3x+8}{2x-A}$  and  $f(0) = 2$

$$f(0) = \frac{3(0)+8}{2(0)-A}$$

$$2 = \frac{8}{-A}$$

$$-2A = 8$$

$$A = -4$$

82.  $f(x) = \frac{2x-B}{3x+4}$  and  $f(2) = \frac{1}{2}$

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

$$\frac{1}{2} = \frac{4-B}{10}$$

$$5 = 4 - B$$

$$B = -1$$

83.  $f(x) = \frac{2x-A}{x-3}$  and  $f(4) = 0$

$$f(4) = \frac{2(4)-A}{4-3}$$

$$0 = \frac{8-A}{1}$$

$$0 = 8 - A$$

$$A = 8$$

$f$  is undefined when  $x = 3$ .

84.  $f(x) = \frac{x-B}{x-A}$ ,  $f(2) = 0$  and  $f(1)$  is undefined

$$1 - A = 0 \Rightarrow A = 1$$

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

$$0 = \frac{2-B}{1}$$

$$0 = 2 - B$$

$$B = 2$$

85. Let  $x$  represent the length of the rectangle.

Then,  $\frac{x}{2}$  represents the width of the rectangle

since the length is twice the width. The function

for the area is:  $A(x) = x \cdot \frac{x}{2} = \frac{x^2}{2} = \frac{1}{2}x^2$

86. Let  $x$  represent the length of one of the two equal sides. The function for the area is:

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

87. Let  $x$  represent the number of hours worked.

The function for the gross salary is:

$$G(x) = 10x$$

88. Let  $x$  represent the number of items sold.

The function for the gross salary is:

$$G(x) = 10x + 100$$

89. a.  $P$  is the dependent variable;  $a$  is the independent variable

b.  $P(20) = 0.015(20)^2 - 4.962(20) + 290.580$   
 $= 6 - 99.24 + 290.580$   
 $= 197.34$

In 2005 there are 197.34 million people who are 20 years of age or older.

c.  $P(0) = 0.015(0)^2 - 4.962(0) + 290.580$   
 $= 290.580$

In 2005 there are 290.580 million people.

90. a.  $N$  is the dependent variable;  $r$  is the independent variable

b.  $N(3) = -1.44(3)^2 + 14.52(3) - 14.96$   
 $= -12.96 + 43.56 - 14.96$   
 $= 15.64$

In 2005, there are 15.64 million housing units with 3 rooms.

c. It is unreasonable to evaluate  $N(0)$  because a housing unit cannot have 0 rooms

## Chapter 1: Functions and Their Graphs

91. a.  $H(1) = 20 - 4.9(1)^2$   
 $= 20 - 4.9 = 15.1$  meters  
 $H(1.1) = 20 - 4.9(1.1)^2$   
 $= 20 - 4.9(1.21)$   
 $= 20 - 5.929 = 14.071$  meters  
 $H(1.2) = 20 - 4.9(1.2)^2$   
 $= 20 - 4.9(1.44)$   
 $= 20 - 7.056 = 12.944$  meters  
 $H(1.3) = 20 - 4.9(1.3)^2$   
 $= 20 - 4.9(1.69)$   
 $= 20 - 8.281 = 11.719$  meters

b.  $H(x) = 15$ :  
 $15 = 20 - 4.9x^2$   
 $-5 = -4.9x^2$   
 $x^2 \approx 1.0204$   
 $x \approx 1.01$  seconds

$H(x) = 10$ :  
 $10 = 20 - 4.9x^2$   
 $-10 = -4.9x^2$   
 $x^2 \approx 2.0408$   
 $x \approx 1.43$  seconds

$H(x) = 5$ :  
 $5 = 20 - 4.9x^2$   
 $-15 = -4.9x^2$   
 $x^2 \approx 3.0612$   
 $x \approx 1.75$  seconds

c.  $H(x) = 0$   
 $0 = 20 - 4.9x^2$   
 $-20 = -4.9x^2$   
 $x^2 \approx 4.0816$   
 $x \approx 2.02$  seconds

92. a.  $H(1) = 20 - 13(1)^2 = 20 - 13 = 7$  meters  
 $H(1.1) = 20 - 13(1.1)^2 = 20 - 13(1.21)$   
 $= 20 - 15.73 = 4.27$  meters  
 $H(1.2) = 20 - 13(1.2)^2 = 20 - 13(1.44)$   
 $= 20 - 18.72 = 1.28$  meters

b.  $H(x) = 15$   
 $15 = 20 - 13x^2$   
 $-5 = -13x^2$   
 $x^2 \approx 0.3846$   
 $x \approx 0.62$  seconds

$H(x) = 10$   
 $10 = 20 - 13x^2$   
 $-10 = -13x^2$   
 $x^2 \approx 0.7692$   
 $x \approx 0.88$  seconds

$H(x) = 5$   
 $5 = 20 - 13x^2$   
 $-15 = -13x^2$   
 $x^2 \approx 1.1538$   
 $x \approx 1.07$  seconds

c.  $H(x) = 0$   
 $0 = 20 - 13x^2$   
 $-20 = -13x^2$   
 $x^2 \approx 1.5385$   
 $x \approx 1.24$  seconds

93.  $C(x) = 100 + \frac{x}{10} + \frac{36,000}{x}$

a.  $C(500) = 100 + \frac{500}{10} + \frac{36,000}{500}$   
 $= 100 + 50 + 72$   
 $= \$222$

b.  $C(450) = 100 + \frac{450}{10} + \frac{36,000}{450}$   
 $= 100 + 45 + 80$   
 $= \$225$

c.  $C(600) = 100 + \frac{600}{10} + \frac{36,000}{600}$   
 $= 100 + 60 + 60$   
 $= \$220$

d.  $C(400) = 100 + \frac{400}{10} + \frac{36,000}{400}$   
 $= 100 + 40 + 90$   
 $= \$230$

## Section 1.2: The Graph of a Function

94.  $A(x) = 4x\sqrt{1-x^2}$

a. 
$$A\left(\frac{1}{3}\right) = 4 \cdot \frac{1}{3} \sqrt{1 - \left(\frac{1}{3}\right)^2} = \frac{4}{3} \sqrt{\frac{8}{9}} = \frac{4}{3} \cdot \frac{2\sqrt{2}}{3}$$
$$= \frac{8\sqrt{2}}{9} \approx 1.26 \text{ ft}^2$$

b. 
$$A\left(\frac{1}{2}\right) = 4 \cdot \frac{1}{2} \sqrt{1 - \left(\frac{1}{2}\right)^2} = 2 \sqrt{\frac{3}{4}} = 2 \cdot \frac{\sqrt{3}}{2}$$
$$= \sqrt{3} \approx 1.73 \text{ ft}^2$$

c. 
$$A\left(\frac{2}{3}\right) = 4 \cdot \frac{2}{3} \sqrt{1 - \left(\frac{2}{3}\right)^2} = \frac{8}{3} \sqrt{\frac{5}{9}} = \frac{8}{3} \cdot \frac{\sqrt{5}}{3}$$
$$= \frac{8\sqrt{5}}{9} \approx 1.99 \text{ ft}^2$$

95.  $R(x) = \left(\frac{L}{P}\right)(x) = \frac{L(x)}{P(x)}$

96.  $T(x) = (V + P)(x) = V(x) + P(x)$

97.  $H(x) = (P \cdot I)(x) = P(x) \cdot I(x)$

98.  $N(x) = (I - T)(x) = I(x) - T(x)$

99. a. 
$$P(x) = R(x) - C(x)$$
$$= (-1.2x^2 + 220x) - (0.05x^3 - 2x^2 + 65x + 500)$$
$$= -1.2x^2 + 220x - 0.05x^3 + 2x^2 - 65x - 500$$
$$= -0.05x^3 + 0.8x^2 + 155x - 500$$

b. 
$$P(15) = -0.05(15)^3 + 0.8(15)^2 + 155(15) - 500$$
$$= -168.75 + 180 + 2325 - 500$$
$$= \$1836.25$$

c. When 15 hundred cell phones are sold, the profit is \$1836.25.

100. a. 
$$P(x) = R(x) - C(x)$$
$$= 30x - (0.1x^2 + 7x + 400)$$
$$= 30x - 0.1x^2 - 7x - 400$$
$$= -0.1x^2 + 23x - 400$$

b. 
$$P(30) = -0.1(30)^2 + 23(30) - 400$$
$$= -90 + 690 - 400$$
$$= \$200$$

c. When 30 clocks are sold, the profit is \$200.

101. a.  $h(x) = 2x$

$$h(a+b) = 2(a+b) = 2a+2b$$
$$= h(a) + h(b)$$

$h(x) = 2x$  has the property.

b.  $g(x) = x^2$

$$g(a+b) = (a+b)^2 = a^2 + 2ab + b^2$$

Since

$$a^2 + 2ab + b^2 \neq a^2 + b^2 = g(a) + g(b),$$

$g(x) = x^2$  does not have the property.

c.  $F(x) = 5x - 2$

$$F(a+b) = 5(a+b) - 2 = 5a + 5b - 2$$

Since

$$5a + 5b - 2 \neq 5a - 2 + 5b - 2 = F(a) + F(b),$$

$F(x) = 5x - 2$  does not have the property.

d.  $G(x) = \frac{1}{x}$

$$G(a+b) = \frac{1}{a+b} \neq \frac{1}{a} + \frac{1}{b} = G(a) + G(b)$$

$G(x) = \frac{1}{x}$  does not have the property.

102. No. The domain of  $f$  is  $\{x \mid x \text{ is any real number}\}$ , but the domain of  $g$  is  $\{x \mid x \neq -1\}$ .

103. Answers will vary.

## Section 1.2

1.  $x^2 + 4y^2 = 16$

$x$ -intercepts:

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

$$x^2 = 16$$

$$x = \pm 4 \Rightarrow (-4, 0), (4, 0)$$

$y$ -intercepts:

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

$$4y^2 = 16$$

$$y^2 = 4$$

$$y = \pm 2 \Rightarrow (0, -2), (0, 2)$$

## Chapter 1: Functions and Their Graphs

2. False;  $x = 2y - 2$   
 $-2 = 2y - 2$   
 $0 = 2y$   
 $0 = y$   
 The point  $(-2, 0)$  is on the graph.
3. vertical
4.  $f(5) = -3$
5.  $f(x) = ax^2 + 4$   
 $a(-1)^2 + 4 = 2 \Rightarrow a = -2$
6. False; it would fail the vertical line test.
7. False; e.g.  $y = \frac{1}{x}$ .
8. True
9. a.  $f(0) = 3$  since  $(0, 3)$  is on the graph.  
 $f(-6) = -3$  since  $(-6, -3)$  is on the graph.  
 b.  $f(6) = 0$  since  $(6, 0)$  is on the graph.  
 $f(11) = 1$  since  $(11, 1)$  is on the graph.  
 c.  $f(3)$  is positive since  $f(3) \approx 3.7$ .  
 d.  $f(-4)$  is negative since  $f(-4) \approx -1$ .  
 e.  $f(x) = 0$  when  $x = -3$ ,  $x = 6$ , and  $x = 10$ .  
 f.  $f(x) > 0$  when  $-3 < x < 6$ , and  $10 < x \leq 11$ .  
 g. The domain of  $f$  is  $\{x \mid -6 \leq x \leq 11\}$  or  $[-6, 11]$ .  
 h. The range of  $f$  is  $\{y \mid -3 \leq y \leq 4\}$  or  $[-3, 4]$ .  
 i. The  $x$ -intercepts are  $(-3, 0)$ ,  $(6, 0)$ , and  $(10, 0)$ .  
 j. The  $y$ -intercept is  $(0, 3)$ .  
 k. The line  $y = \frac{1}{2}$  intersects the graph 3 times.  
 l. The line  $x = 5$  intersects the graph 1 time.  
 m.  $f(x) = 3$  when  $x = 0$  and  $x = 4$ .  
 n.  $f(x) = -2$  when  $x = -5$  and  $x = 8$ .  
 o.  $f(x) = 0$  when  $x = -3$ ,  $x = 6$ , and  $x = 10$ .
10. a.  $f(0) = 0$  since  $(0, 0)$  is on the graph.  
 $f(6) = 0$  since  $(6, 0)$  is on the graph.  
 b.  $f(2) = -2$  since  $(2, -2)$  is on the graph.  
 $f(-2) = 1$  since  $(-2, 1)$  is on the graph.  
 c.  $f(3)$  is negative since  $f(3) \approx -1$ .  
 d.  $f(-1)$  is positive since  $f(-1) \approx 1.0$ .  
 e.  $f(x) = 0$  when  $x = 0$ ,  $x = 4$ , and  $x = 6$ .  
 f.  $f(x) < 0$  when  $0 < x < 4$ .  
 g. The domain of  $f$  is  $\{x \mid -4 \leq x \leq 6\}$  or  $[-4, 6]$ .  
 h. The range of  $f$  is  $\{y \mid -2 \leq y \leq 3\}$  or  $[-2, 3]$ .  
 i. The  $x$ -intercepts are  $(0, 0)$ ,  $(4, 0)$ , and  $(6, 0)$ .  
 j. The  $y$ -intercept is  $(0, 0)$ .  
 k. The line  $y = -1$  intersects the graph 2 times.  
 l. The line  $x = 1$  intersects the graph 1 time.  
 m.  $f(x) = 3$  when  $x = 5$ .  
 n.  $f(x) = -2$  when  $x = 2$ .  
 o.  $f(x) = 0$  when  $x = 0$ ,  $x = 4$ , and  $x = 6$ .
11. Not a function since vertical lines will intersect the graph in more than one point.
12. Function  
 a. Domain:  $\{x \mid x \text{ is any real number}\}$  ;  
 Range:  $\{y \mid y > 0\}$   
 b. Intercepts:  $(0, 1)$   
 c. None
13. Function  
 a. Domain:  $\{x \mid -\pi \leq x \leq \pi\}$  ;  
 Range:  $\{y \mid -1 \leq y \leq 1\}$   
 b. Intercepts:  $\left(-\frac{\pi}{2}, 0\right)$ ,  $\left(\frac{\pi}{2}, 0\right)$ ,  $(0, 1)$   
 c. Symmetry about  $y$ -axis.

## Section 1.2: The Graph of a Function

### 14. Function

- a. Domain:  $\{x \mid -\pi \leq x \leq \pi\}$ ;  
Range:  $\{y \mid -1 \leq y \leq 1\}$
- b. Intercepts:  $(-\pi, 0)$ ,  $(\pi, 0)$ ,  $(0, 0)$
- c. Symmetry about the origin.

15. Not a function since vertical lines will intersect the graph in more than one point.

16. Not a function since vertical lines will intersect the graph in more than one point.

### 17. Function

- a. Domain:  $\{x \mid x > 0\}$ ;  
Range:  $\{y \mid y \text{ is any real number}\}$
- b. Intercepts:  $(1, 0)$
- c. None

### 18. Function

- a. Domain:  $\{x \mid 0 \leq x \leq 4\}$ ;  
Range:  $\{y \mid 0 \leq y \leq 3\}$
- b. Intercepts:  $(0, 0)$
- c. None

### 19. Function

- a. Domain:  $\{x \mid x \text{ is any real number}\}$ ;  
Range:  $\{y \mid y \leq 2\}$
- b. Intercepts:  $(-3, 0)$ ,  $(3, 0)$ ,  $(0, 2)$
- c. Symmetry about y-axis.

### 20. Function

- a. Domain:  $\{x \mid x \geq -3\}$ ;  
Range:  $\{y \mid y \geq 0\}$
- b. Intercepts:  $(-3, 0)$ ,  $(2, 0)$ ,  $(0, 2)$
- c. None

### 21. Function

- a. Domain:  $\{x \mid x \text{ is any real number}\}$ ;  
Range:  $\{y \mid y \geq -3\}$
- b. Intercepts:  $(1, 0)$ ,  $(3, 0)$ ,  $(0, 9)$
- c. None

### 22. Function

- a. Domain:  $\{x \mid x \text{ is any real number}\}$ ;  
Range:  $\{y \mid y \leq 5\}$
- b. Intercepts:  $(-1, 0)$ ,  $(2, 0)$ ,  $(0, 4)$
- c. None

### 23. $f(x) = 2x^2 - x - 1$

- a.  $f(-1) = 2(-1)^2 - (-1) - 1 = 2$   
The point  $(-1, 2)$  is on the graph of  $f$ .
- b.  $f(-2) = 2(-2)^2 - (-2) - 1 = 9$   
The point  $(-2, 9)$  is on the graph of  $f$ .
- c. Solve for  $x$ :  
 $-1 = 2x^2 - x - 1$   
 $0 = 2x^2 - x$   
 $0 = x(2x - 1) \Rightarrow x = 0, x = \frac{1}{2}$   
 $(0, -1)$  and  $(\frac{1}{2}, -1)$  are on the graph of  $f$ .
- d. The domain of  $f$  is  $\{x \mid x \text{ is any real number}\}$ .
- e. x-intercepts:  
 $f(x) = 0 \Rightarrow 2x^2 - x - 1 = 0$   
 $(2x + 1)(x - 1) = 0 \Rightarrow x = -\frac{1}{2}, x = 1$   
 $(-\frac{1}{2}, 0)$  and  $(1, 0)$
- f. y-intercept:  
 $f(0) = 2(0)^2 - 0 - 1 = -1 \Rightarrow (0, -1)$
- g. zeros:  
 $f(x) = 0$   
 $2x^2 - x - 1 = 0$   
 $(2x + 1)(x - 1) = 0 \Rightarrow x = -\frac{1}{2}, x = 1$

### 24. $f(x) = -3x^2 + 5x$

- a.  $f(-1) = -3(-1)^2 + 5(-1) = -8 \neq 2$   
The point  $(-1, 2)$  is not on the graph of  $f$ .
- b.  $f(-2) = -3(-2)^2 + 5(-2) = -22$   
The point  $(-2, -22)$  is on the graph of  $f$ .

## Chapter 1: Functions and Their Graphs

- c. Solve for  $x$ :

$$-2 = -3x^2 + 5x \Rightarrow 3x^2 - 5x - 2 = 0$$

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

$(2, -2)$  and  $(-\frac{1}{3}, -2)$  on the graph of  $f$ .

- d. The domain of  $f$  is  $\{x \mid x \text{ is any real number}\}$ .

- e.  $x$ -intercepts:

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

$$x(-3x+5) = 0 \Rightarrow x = 0, x = \frac{5}{3}$$

$(0, 0)$  and  $(\frac{5}{3}, 0)$

- f.  $y$ -intercept:

$$f(0) = -3(0)^2 + 5(0) = 0 \Rightarrow (0, 0)$$

- g. zeros:

$$f(x) = 0$$

$$-3x^2 + 5x = 0$$

$$-x(3x-5) = 0 \Rightarrow x = 0, \frac{5}{3}$$

25.  $f(x) = \frac{x+2}{x-6}$

a.  $f(3) = \frac{3+2}{3-6} = -\frac{5}{3} \neq 14$

The point  $(3, 14)$  is not on the graph of  $f$ .

b.  $f(4) = \frac{4+2}{4-6} = \frac{6}{-2} = -3$

The point  $(4, -3)$  is on the graph of  $f$ .

- c. Solve for  $x$ :

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

$$2x - 12 = x + 2$$

$$x = 14$$

$(14, 2)$  is a point on the graph of  $f$ .

- d. The domain of  $f$  is  $\{x \mid x \neq 6\}$ .

- e.  $x$ -intercepts:

$$f(x) = 0 \Rightarrow \frac{x+2}{x-6} = 0$$

$$x+2 = 0 \Rightarrow x = -2 \Rightarrow (-2, 0)$$

- f.  $y$ -intercept:  $f(0) = \frac{0+2}{0-6} = -\frac{1}{3} \Rightarrow (0, -\frac{1}{3})$

- g. zeros:

$$f(x) = 0 \Rightarrow \frac{x+2}{x-6} = 0$$

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

26.  $f(x) = \frac{x^2+2}{x+4}$

a.  $f(1) = \frac{1^2+2}{1+4} = \frac{3}{5}$

The point  $(1, \frac{3}{5})$  is on the graph of  $f$ .

b.  $f(0) = \frac{0^2+2}{0+4} = \frac{2}{4} = \frac{1}{2}$

The point  $(0, \frac{1}{2})$  is on the graph of  $f$ .

- c. Solve for  $x$ :

$$\frac{1}{2} = \frac{x^2+2}{x+4} \Rightarrow x+4 = 2x^2+4$$

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

$$x(2x-1) = 0 \Rightarrow x = 0 \text{ or } x = \frac{1}{2}$$

$(0, \frac{1}{2})$  and  $(\frac{1}{2}, \frac{1}{2})$  are on the graph of  $f$ .

- d. The domain of  $f$  is  $\{x \mid x \neq -4\}$ .

- e.  $x$ -intercepts:

$$f(x) = 0 \Rightarrow \frac{x^2+2}{x+4} = 0 \Rightarrow x^2+2 = 0$$

This is impossible, so there are no  $x$ -intercepts.

- f.  $y$ -intercept:

$$f(0) = \frac{0^2+2}{0+4} = \frac{2}{4} = \frac{1}{2} \Rightarrow (0, \frac{1}{2})$$

- g. zeros:

$$f(x) = 0 \Rightarrow \frac{x^2+2}{x+4} = 0 \Rightarrow x^2+2 = 0$$

This is impossible, so there are no  $x$ -intercepts.

27.  $f(x) = \frac{2x^2}{x^4+1}$

a.  $f(-1) = \frac{2(-1)^2}{(-1)^4+1} = \frac{2}{2} = 1$

The point  $(-1, 1)$  is on the graph of  $f$ .



## Section 1.2: The Graph of a Function

b.  $f(2) = \frac{2(2)^2}{(2)^4 + 1} = \frac{8}{17}$

The point  $\left(2, \frac{8}{17}\right)$  is on the graph of  $f$ .

c. Solve for  $x$ :

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

$$x^4 + 1 = 2x^2$$

$$x^4 - 2x^2 + 1 = 0$$

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

$$x^2 - 1 = 0 \Rightarrow x = \pm 1$$

$(1, 1)$  and  $(-1, 1)$  are on the graph of  $f$ .

d. The domain of  $f$  is  $\{x \mid x \text{ is any real number}\}$ .

e.  $x$ -intercept:

$$f(x) = 0 \Rightarrow \frac{2x^2}{x^4 + 1} = 0$$

$$2x^2 = 0 \Rightarrow x = 0 \Rightarrow (0, 0)$$

f.  $y$ -intercept:

$$f(0) = \frac{2(0)^2}{0^4 + 1} = \frac{0}{0 + 1} = 0 \Rightarrow (0, 0)$$

g. zeros:

$$f(x) = 0 \Rightarrow \frac{2x^2}{x^4 + 1} = 0$$

$$2x^2 = 0 \Rightarrow x = 0$$

28.  $f(x) = \frac{2x}{x-2}$

a.  $f\left(\frac{1}{2}\right) = \frac{2\left(\frac{1}{2}\right)}{\frac{1}{2} - 2} = \frac{1}{-\frac{3}{2}} = -\frac{2}{3}$

The point  $\left(\frac{1}{2}, -\frac{2}{3}\right)$  is on the graph of  $f$ .

b.  $f(4) = \frac{2(4)}{4-2} = \frac{8}{2} = 4$

The point  $(4, 4)$  is on the graph of  $f$ .

c. Solve for  $x$ :

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

$(-2, 1)$  is a point on the graph of  $f$ .

d. The domain of  $f$  is  $\{x \mid x \neq 2\}$ .

e.  $x$ -intercept:

$$f(x) = 0 \Rightarrow \frac{2x}{x-2} = 0 \Rightarrow 2x = 0$$

$$\Rightarrow x = 0 \Rightarrow (0, 0)$$

f.  $y$ -intercept:  $f(0) = \frac{0}{0-2} = 0 \Rightarrow (0, 0)$

g. zeros:

$$f(x) = 0 \Rightarrow \frac{2x}{x-2} = 0 \Rightarrow 2x = 0 \Rightarrow x = 0$$

29.  $h(x) = \frac{-32x^2}{130^2} + x$

a.  $h(100) = \frac{-32(100)^2}{130^2} + 100$   
 $= \frac{-320,000}{16,900} + 100 \approx 81.07$  feet

b.  $h(300) = \frac{-32(300)^2}{130^2} + 300$   
 $= \frac{-2,880,000}{16,900} + 300 \approx 129.59$  feet

c.  $h(500) = \frac{-32(500)^2}{130^2} + 500$   
 $= \frac{-8,000,000}{16,900} + 500 \approx 26.63$  feet

d. Solving  $h(x) = \frac{-32x^2}{130^2} + x = 0$

$$\frac{-32x^2}{130^2} + x = 0$$

$$x\left(\frac{-32x}{130^2} + 1\right) = 0$$

$$x = 0 \quad \text{or} \quad \frac{-32x}{130^2} + 1 = 0$$

$$1 = \frac{32x}{130^2}$$

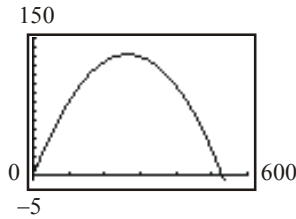
$$130^2 = 32x$$

$$x = \frac{130^2}{32} = 528.125 \text{ feet}$$

Therefore, the golf ball travels 528.125 feet.

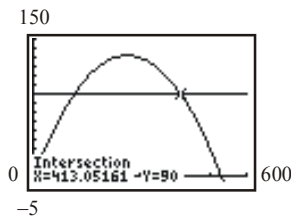
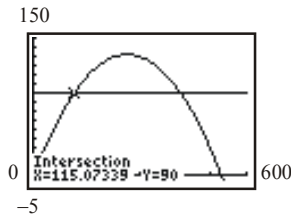
## Chapter 1: Functions and Their Graphs

e.  $y_1 = \frac{-32x^2}{130^2} + x$



f. Use INTERSECT on the graphs of

$y_1 = \frac{-32x^2}{130^2} + x$  and  $y_2 = 90$ .



The ball reaches a height of 90 feet twice. The first time is when the ball has traveled approximately 115.07 feet, and the second time is when the ball has traveled about 413.05 feet.

g. The ball travels approximately 275 feet before it reaches its maximum height of approximately 131.8 feet.

X	Y1
200	124.26
225	129.14
250	131.66
275	131.8
300	129.59
325	125
350	118.05

X=275

h. The ball travels approximately 264 feet before it reaches its maximum height of approximately 132.03 feet.

X	Y1
260	132
261	132.01
262	132.02
263	132.03
264	132.03
265	132.03
266	132.02

Y1=132.029112426

X	Y1
260	132
261	132.01
262	132.02
263	132.03
264	132.03
265	132.03
266	132.02

Y1=132.029585799

30.  $A(x) = 4x\sqrt{1-x^2}$

a. Domain of  $A(x) = 4x\sqrt{1-x^2}$ ; we know that  $x$  must be greater than or equal to zero, since  $x$  represents a length. We also need  $1-x^2 \geq 0$ , since this expression occurs under a square root. In fact, to avoid Area = 0, we require  $x > 0$  and  $1-x^2 > 0$ .

Solve:  $1-x^2 > 0$

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

Case1:  $1+x > 0$  and  $1-x > 0$

$x > -1$  and  $x < 1$

(i.e.  $-1 < x < 1$ )

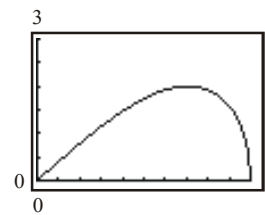
Case2:  $1+x < 0$  and  $1-x < 0$

$x < -1$  and  $x > 1$

(which is impossible)

Therefore the domain of  $A$  is  $\{x \mid 0 < x < 1\}$ .

b. Graphing  $A(x) = 4x\sqrt{1-x^2}$



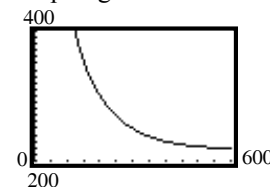
c. When  $x = 0.7$  feet, the cross-sectional area is maximized at approximately 1.9996 square feet. Therefore, the length of the base of the beam should be 1.4 feet in order to maximize the cross-sectional area.

X	Y1
.3	1.1447
.4	1.4664
.5	1.7321
.6	1.92
.7	1.9996
.8	1.92
.9	1.5692

X=.7

31.  $C(x) = 100 + \frac{x}{10} + \frac{36000}{x}$

a. Graphing:



## Section 1.2: The Graph of a Function

- b.TblStart = 0;  $\Delta Tbl = 50$

X	Y1
0	ERROR
50	825
100	470
150	255
200	300
250	269
300	250

- c. The cost per passenger is minimized to about \$220 when the ground speed is roughly 600 miles per hour.

X	Y1
450	225
500	222
550	220.45
600	220
650	220.38
700	221.43
750	223

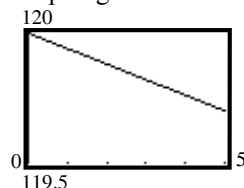
$$32. W(h) = m \left( \frac{4000}{4000 + h} \right)^2$$

- a.  $h = 14110$  feet  $\approx 2.67$  miles ;

$$W(2.67) = 120 \left( \frac{4000}{4000 + 2.67} \right)^2 \approx 119.84$$

On Pike's Peak, Amy will weigh about 119.84 pounds.

- b. Graphing:



- c. Create a TABLE:

X	Y1
0	120
.5	119.97
1	119.94
1.5	119.91
2	119.88
2.5	119.85
3	119.82

The weight  $W$  will vary from 120 pounds to about 119.7 pounds.

- d. By refining the table, Amy will weigh 119.95 lbs at a height of about 0.8 miles (4224 feet).

X	Y1
.5	119.97
.6	119.96
.7	119.95
.8	119.95
.9	119.95
1	119.94
1.1	119.93

- e. Yes, 4224 feet is reasonable.

33. a.  $(f + g)(2) = f(2) + g(2) = 2 + 1 = 3$

b.  $(f + g)(4) = f(4) + g(4) = 1 + (-3) = -2$

c.  $(f - g)(6) = f(6) - g(6) = 0 - 1 = -1$

d.  $(g - f)(6) = g(6) - f(6) = 1 - 0 = 1$

e.  $(f \cdot g)(2) = f(2) \cdot g(2) = 2(1) = 2$

f.  $\left( \frac{f}{g} \right)(4) = \frac{f(4)}{g(4)} = \frac{1}{-3} = -\frac{1}{3}$

34. Answers will vary. From a graph, the domain can be found by visually locating the  $x$ -values for which the graph is defined. The range can be found in a similar fashion by visually locating the  $y$ -values for which the function is defined. If an equation is given, the domain can be found by locating any restricted values and removing them from the set of real numbers. The range can be found by using known properties of the graph of the equation, or estimated by means of a table of values.

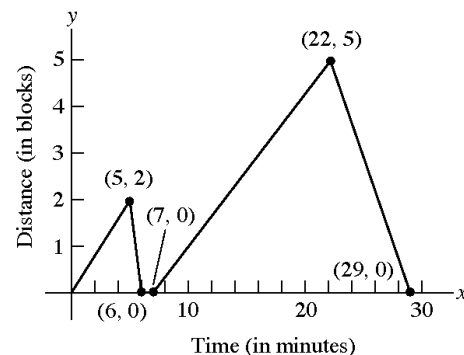
35. The graph of a function can have any number of  $x$ -intercepts. The graph of a function can have at most one  $y$ -intercept.

36. Yes, the graph of a single point is the graph of a function since it would pass the vertical line test. The equation of such a function would be something like the following:  $f(x) = 2$ , where  $x = 7$ .

37. (a) III; (b) IV; (c) I; (d) V; (e) II

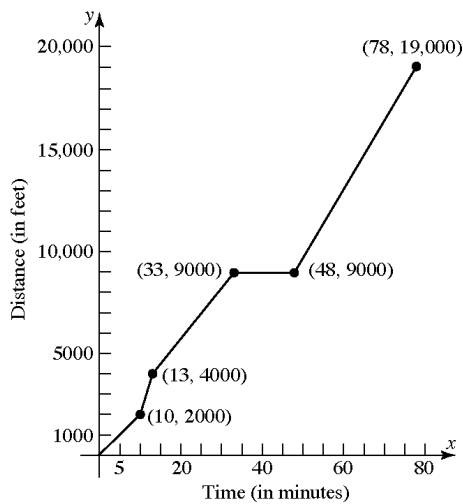
38. (a) II; (b) V; (c) IV; (d) III; (e) I

- 39.



## Chapter 1: Functions and Their Graphs

40.



41. a. 2 hours elapsed; Kevin was between 0 and 3 miles from home.  
 b. 0.5 hours elapsed; Kevin was 3 miles from home.  
 c. 0.3 hours elapsed; Kevin was between 0 and 3 miles from home.  
 d. 0.2 hours elapsed; Kevin was at home.  
 e. 0.9 hours elapsed; Kevin was between 0 and 2.8 miles from home.  
 f. 0.3 hours elapsed; Kevin was 2.8 miles from home.  
 g. 1.1 hours elapsed; Kevin was between 0 and 2.8 miles from home.  
 h. The farthest distance Kevin is from home is 3 miles.  
 i. Kevin returned home 2 times.
42. a. Michael travels fastest between 7 and 7.4 minutes. That is,  $(7, 7.4)$ .  
 b. Michael's speed is zero between 4.2 and 6 minutes. That is,  $(4.2, 6)$ .  
 c. Between 0 and 2 minutes, Michael's speed increased from 0 to 30 miles/hour.  
 d. Between 4.2 and 6 minutes, Michael was stopped (i.e., his speed was 0 miles/hour).  
 e. Between 7 and 7.4 minutes, Michael was traveling at a steady rate of 50 miles/hour.  
 f. Michael's speed is constant between 2 and 4 minutes, between 4.2 and 6 minutes, between 7 and 7.4 minutes, and between 7.6 and 8 minutes. That is, on the intervals  $(2, 4)$ ,  $(4.2, 6)$ ,  $(7, 7.4)$ , and  $(7.6, 8)$ .

43. Answers (graphs) will vary. Points of the form  $(5, y)$  and of the form  $(x, 0)$  cannot be on the graph of the function.

44. The only such function is  $f(x) = 0$  because it is the only function for which  $f(x) = -f(x)$ . Any other such graph would fail the vertical line test.

### Section 1.3

1.  $2 < x < 5$

2.  $\text{slope} = \frac{\Delta y}{\Delta x} = \frac{8-3}{3-(-2)} = \frac{5}{5} = 1$

3.  $x$ -axis:  $y \rightarrow -y$

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

$$-y = 5x^2 - 1$$

$$y = -5x^2 + 1 \text{ different}$$

$y$ -axis:  $x \rightarrow -x$

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

$$y = 5x^2 - 1 \text{ same}$$

origin:  $x \rightarrow -x$  and  $y \rightarrow -y$

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

$$-y = 5x^2 - 1$$

$$y = -5x^2 + 1 \text{ different}$$

The equation has symmetry with respect to the  $y$ -axis only.

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

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

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

5.  $y = x^2 - 9$

$x$ -intercepts:

$$0 = x^2 - 9$$

$$x^2 = 9 \rightarrow x = \pm 3$$

$y$ -intercept:

$$y = (0)^2 - 9 = -9$$

The intercepts are  $(-3, 0)$ ,  $(3, 0)$ , and  $(0, -9)$ .

6. increasing

### Section 1.3: Properties of Functions

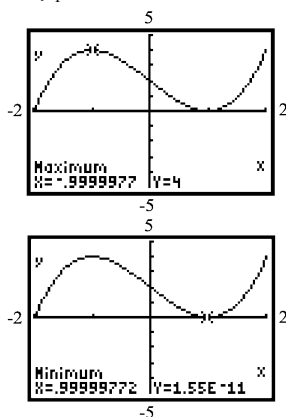
7. even; odd
8. True
9. True
10. False; odd functions are symmetric with respect to the origin. Even functions are symmetric with respect to the  $y$ -axis.
11. Yes
12. No, it is increasing.
13. No, it only increases on  $(5, 10)$ .
14. Yes
15.  $f$  is increasing on the intervals  $(-8, -2)$ ,  $(0, 2)$ ,  $(5, \infty)$ .
16.  $f$  is decreasing on the intervals:  $(-\infty, -8)$ ,  $(-2, 0)$ ,  $(2, 5)$ .
17. Yes. The local maximum at  $x = 2$  is 10.
18. No. There is a local minimum at  $x = 5$ ; the local minimum is 0.
19.  $f$  has local maxima at  $x = -2$  and  $x = 2$ . The local maxima are 6 and 10, respectively.
20.  $f$  has local minima at  $x = -8$ ,  $x = 0$  and  $x = 5$ . The local minima are  $-4$ , 0, and 0, respectively.
21.
  - a. Intercepts:  $(-2, 0)$ ,  $(2, 0)$ , and  $(0, 3)$ .
  - b. Domain:  $\{x \mid -4 \leq x \leq 4\}$  or  $[-4, 4]$ ;  
Range:  $\{y \mid 0 \leq y \leq 3\}$  or  $[0, 3]$ .
  - c. Increasing:  $(-2, 0)$  and  $(2, 4)$ ;  
Decreasing:  $(-4, -2)$  and  $(0, 2)$ .
  - d. Since the graph is symmetric with respect to the  $y$ -axis, the function is even.
22.
  - a. Intercepts:  $(-1, 0)$ ,  $(1, 0)$ , and  $(0, 2)$ .
  - b. Domain:  $\{x \mid -3 \leq x \leq 3\}$  or  $[-3, 3]$ ;  
Range:  $\{y \mid 0 \leq y \leq 3\}$  or  $[0, 3]$ .
  - c. Increasing:  $(-1, 0)$  and  $(1, 3)$ ;  
Decreasing:  $(-3, -1)$  and  $(0, 1)$ .
  - d. Since the graph is symmetric with respect to the  $y$ -axis, the function is even.
23.
  - a. Intercepts:  $(0, 1)$ .
  - b. Domain:  $\{x \mid x \text{ is any real number}\}$ ;  
Range:  $\{y \mid y > 0\}$  or  $(0, \infty)$ .
  - c. Increasing:  $(-\infty, \infty)$ ; Decreasing: never.
  - d. Since the graph is not symmetric with respect to the  $y$ -axis or the origin, the function is neither even nor odd.
24.
  - a. Intercepts:  $(1, 0)$ .
  - b. Domain:  $\{x \mid x > 0\}$  or  $(0, \infty)$ ;  
Range:  $\{y \mid y \text{ is any real number}\}$ .
  - c. Increasing:  $(0, \infty)$ ; Decreasing: never.
  - d. Since the graph is not symmetric with respect to the  $y$ -axis or the origin, the function is neither even nor odd.
25.
  - a. Intercepts:  $(-\pi, 0)$ ,  $(\pi, 0)$ , and  $(0, 0)$ .
  - b. Domain:  $\{x \mid -\pi \leq x \leq \pi\}$  or  $[-\pi, \pi]$ ;  
Range:  $\{y \mid -1 \leq y \leq 1\}$  or  $[-1, 1]$ .
  - c. Increasing:  $\left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$ ;  
Decreasing:  $\left(-\pi, -\frac{\pi}{2}\right)$  and  $\left(\frac{\pi}{2}, \pi\right)$ .
  - d. Since the graph is symmetric with respect to the origin, the function is odd.
26.
  - a. Intercepts:  $\left(-\frac{\pi}{2}, 0\right)$ ,  $\left(\frac{\pi}{2}, 0\right)$ , and  $(0, 1)$ .
  - b. Domain:  $\{x \mid -\pi \leq x \leq \pi\}$  or  $[-\pi, \pi]$ ;  
Range:  $\{y \mid -1 \leq y \leq 1\}$  or  $[-1, 1]$ .
  - c. Increasing:  $(-\pi, 0)$ ; Decreasing:  $(0, \pi)$ .
  - d. Since the graph is symmetric with respect to the  $y$ -axis, the function is even.
27.
  - a. Intercepts:  $\left(\frac{1}{2}, 0\right)$ ,  $\left(\frac{5}{2}, 0\right)$ , and  $\left(0, \frac{1}{2}\right)$ .
  - b. Domain:  $\{x \mid -3 \leq x \leq 3\}$  or  $[-3, 3]$ ;  
Range:  $\{y \mid -1 \leq y \leq 2\}$  or  $[-1, 2]$ .

## Chapter 1: Functions and Their Graphs

- c. Increasing:  $(2, 3)$ ; Decreasing:  $(-1, 1)$ ;  
Constant:  $(-3, -1)$  and  $(1, 2)$
- d. Since the graph is not symmetric with respect to the  $y$ -axis or the origin, the function is neither even nor odd.
28. a. Intercepts:  $(-2.3, 0)$ ,  $(3, 0)$ , and  $(0, 1)$ .  
b. Domain:  $\{x \mid -3 \leq x \leq 3\}$  or  $[-3, 3]$ ;  
Range:  $\{y \mid -2 \leq y \leq 2\}$  or  $[-2, 2]$ .  
c. Increasing:  $(-3, -2)$  and  $(0, 2)$ ;  
Decreasing:  $(2, 3)$ ; Constant:  $(-2, 0)$ .  
d. Since the graph is not symmetric with respect to the  $y$ -axis or the origin, the function is neither even nor odd.
29. a.  $f$  has a local maximum of 3 at  $x = 0$ .  
b.  $f$  has a local minimum of 0 at both  $x = -2$  and  $x = 2$ .
30. a.  $f$  has a local maximum of 2 at  $x = 0$ .  
b.  $f$  has a local minimum of 0 at both  $x = -1$  and  $x = 1$ .
31. a.  $f$  has a local maximum of 1 at  $x = \frac{\pi}{2}$ .  
b.  $f$  has a local minimum of  $-1$  at  $x = -\frac{\pi}{2}$ .
32. a.  $f$  has a local maximum of 1 at  $x = 0$ .  
b.  $f$  has a local minimum of  $-1$  both at  $x = -\pi$  and  $x = \pi$ .
33.  $f(x) = 4x^3$   
 $f(-x) = 4(-x)^3 = -4x^3 = -f(x)$   
Therefore,  $f$  is odd.
34.  $f(x) = 2x^4 - x^2$   
 $f(-x) = 2(-x)^4 - (-x)^2 = 2x^4 - x^2 = f(x)$   
Therefore,  $f$  is even.
35.  $g(x) = -3x^2 - 5$   
 $g(-x) = -3(-x)^2 - 5 = -3x^2 - 5 = g(x)$   
Therefore,  $g$  is even.
36.  $h(x) = 3x^3 + 5$   
 $h(-x) = 3(-x)^3 + 5 = -3x^3 + 5$   
 $h$  is neither even nor odd.
37.  $F(x) = \sqrt[3]{x}$   
 $F(-x) = \sqrt[3]{-x} = -\sqrt[3]{x} = -F(x)$   
Therefore,  $F$  is odd.
38.  $G(x) = \sqrt{x}$   
 $G(-x) = \sqrt{-x}$   
 $G$  is neither even nor odd.
39.  $f(x) = x + |x|$   
 $f(-x) = -x + |-x| = -x + |x|$   
 $f$  is neither even nor odd.
40.  $f(x) = \sqrt[3]{2x^2 + 1}$   
 $f(-x) = \sqrt[3]{2(-x)^2 + 1} = \sqrt[3]{2x^2 + 1} = f(x)$   
Therefore,  $f$  is even.
41.  $g(x) = \frac{1}{x^2}$   
 $g(-x) = \frac{1}{(-x)^2} = \frac{1}{x^2} = g(x)$   
Therefore,  $g$  is even.
42.  $h(x) = \frac{x}{x^2 - 1}$   
 $h(-x) = \frac{-x}{(-x)^2 - 1} = \frac{-x}{x^2 - 1} = -h(x)$   
Therefore,  $h$  is odd.
43.  $h(x) = \frac{-x^3}{3x^2 - 9}$   
 $h(-x) = \frac{-(-x)^3}{3(-x)^2 - 9} = \frac{x^3}{3x^2 - 9} = -h(x)$   
Therefore,  $h$  is odd.
44.  $F(x) = \frac{2x}{|x|}$   
 $F(-x) = \frac{2(-x)}{|-x|} = \frac{-2x}{|x|} = -F(x)$   
Therefore,  $F$  is odd.

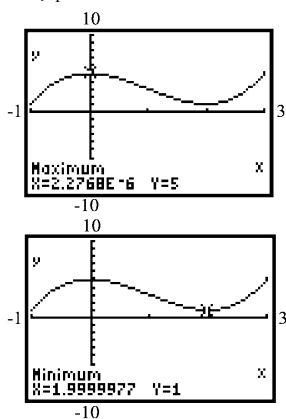
### Section 1.3: Properties of Functions

45.  $f(x) = x^3 - 3x + 2$  on the interval  $(-2, 2)$   
Use MAXIMUM and MINIMUM on the graph of  $y_1 = x^3 - 3x + 2$ .



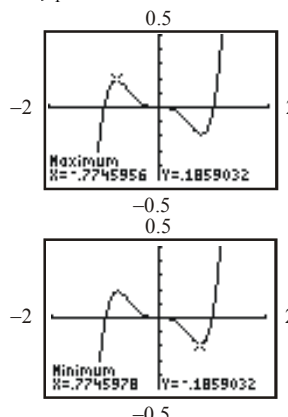
local maximum at:  $(-1, 4)$ ;  
local minimum at:  $(1, 0)$   
 $f$  is increasing on:  $(-2, -1)$  and  $(1, 2)$ ;  
 $f$  is decreasing on:  $(-1, 1)$

46.  $f(x) = x^3 - 3x^2 + 5$  on the interval  $(-1, 3)$   
Use MAXIMUM and MINIMUM on the graph of  $y_1 = x^3 - 3x^2 + 5$ .



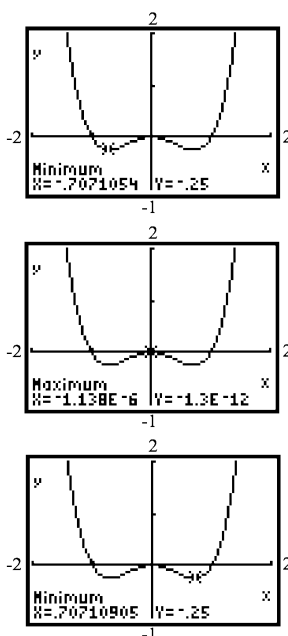
local maximum at:  $(0.5, 5)$ ;  
local minimum at:  $(2, 1)$   
 $f$  is increasing on:  $(-1, 0)$  and  $(2, 3)$ ;  
 $f$  is decreasing on:  $(0, 2)$

47.  $f(x) = x^5 - x^3$  on the interval  $(-2, 2)$   
Use MAXIMUM and MINIMUM on the graph of  $y_1 = x^5 - x^3$ .



local maximum at:  $(-0.77, 0.19)$ ;  
local minimum at:  $(0.77, -0.19)$ ;  
 $f$  is increasing on:  $(-2, -0.77)$  and  $(0.77, 2)$ ;  
 $f$  is decreasing on:  $(-0.77, 0.77)$

48.  $f(x) = x^4 - x^2$  on the interval  $(-2, 2)$   
Use MAXIMUM and MINIMUM on the graph of  $y_1 = x^4 - x^2$ .

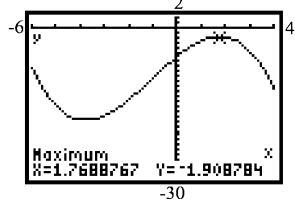
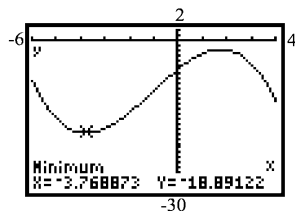


local maximum at:  $(0, 0)$ ;  
local minimum at:  $(-0.71, -0.25)$ ,  $(0.71, -0.25)$   
 $f$  is increasing on:  $(-0.71, 0)$  and  $(0.71, 2)$ ;  
 $f$  is decreasing on:  $(-2, -0.71)$  and  $(0, 0.71)$

## Chapter 1: Functions and Their Graphs

49.  $f(x) = -0.2x^3 - 0.6x^2 + 4x - 6$  on the interval  $(-6, 4)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = -0.2x^3 - 0.6x^2 + 4x - 6$ .



local maximum at:  $(1.77, -1.91)$ ;

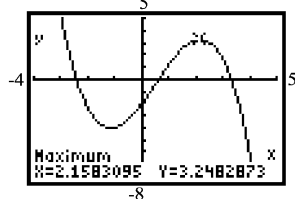
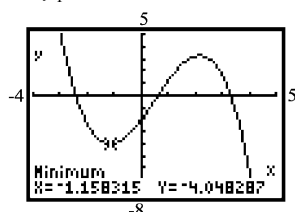
local minimum at:  $(-3.77, -18.89)$

$f$  is increasing on:  $(-3.77, 1.77)$ ;

$f$  is decreasing on:  $(-6, -3.77)$  and  $(1.77, 4)$

50.  $f(x) = -0.4x^3 + 0.6x^2 + 3x - 2$  on the interval  $(-4, 5)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = -0.4x^3 + 0.6x^2 + 3x - 2$ .



local maximum at:  $(2.16, 3.25)$ ;

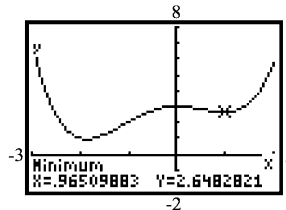
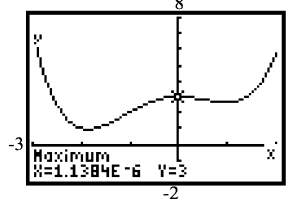
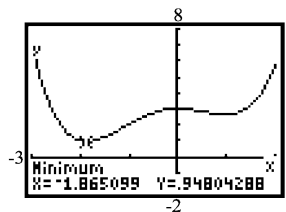
local minimum at:  $(-1.16, -4.05)$

$f$  is increasing on:  $(-1.16, 2.16)$ ;

$f$  is decreasing on:  $(-4, -1.16)$  and  $(2.16, 5)$

51.  $f(x) = 0.25x^4 + 0.3x^3 - 0.9x^2 + 3$  on the interval  $(-3, 2)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = 0.25x^4 + 0.3x^3 - 0.9x^2 + 3$ .



local maximum at:  $(0, 3)$ ;

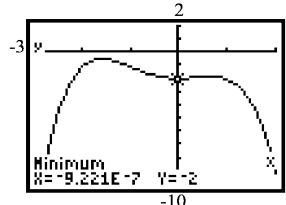
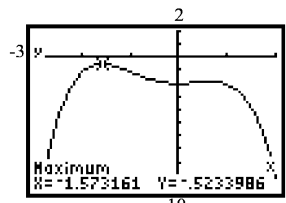
local minimum at:  $(-1.87, 0.95)$ ,  $(0.97, 2.65)$

$f$  is increasing on:  $(-1.87, 0)$  and  $(0.97, 2)$ ;

$f$  is decreasing on:  $(-3, -1.87)$  and  $(0, 0.97)$

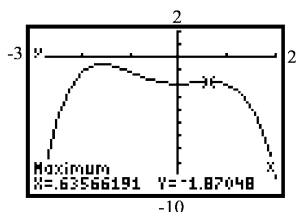
52.  $f(x) = -0.4x^4 - 0.5x^3 + 0.8x^2 - 2$  on the interval  $(-3, 2)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = -0.4x^4 - 0.5x^3 + 0.8x^2 - 2$ .





### Section 1.3: Properties of Functions



local maxima at:  $(-1.57, -0.52)$ ,  $(0.64, -1.87)$ ;

local minimum at:  $(0, -2)$

$f$  is increasing on:  $(-3, -1.57)$  and  $(0, 0.64)$ ;

$f$  is decreasing on:  $(-1.57, 0)$  and  $(0.64, 2)$

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

- a. Average rate of change of  $f$  from  $x = 0$  to  $x = 2$

$$\begin{aligned}\frac{f(2) - f(0)}{2 - 0} &= \frac{(-2(2)^2 + 4) - (-2(0)^2 + 4)}{2} \\ &= \frac{(-4) - (4)}{2} = \frac{-8}{2} = -4\end{aligned}$$

- b. Average rate of change of  $f$  from  $x = 1$  to  $x = 3$ :

$$\begin{aligned}\frac{f(3) - f(1)}{3 - 1} &= \frac{(-2(3)^2 + 4) - (-2(1)^2 + 4)}{2} \\ &= \frac{(-14) - (2)}{2} = \frac{-16}{2} = -8\end{aligned}$$

- c. Average rate of change of  $f$  from  $x = 1$  to  $x = 4$ :

$$\begin{aligned}\frac{f(4) - f(1)}{4 - 1} &= \frac{(-2(4)^2 + 4) - (-2(1)^2 + 4)}{3} \\ &= \frac{(-28) - (2)}{3} = \frac{-30}{3} = -10\end{aligned}$$

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

- a. Average rate of change of  $f$  from  $x = 0$  to  $x = 2$ :

$$\begin{aligned}\frac{f(2) - f(0)}{2 - 0} &= \frac{(-(2)^3 + 1) - (-(0)^3 + 1)}{2} \\ &= \frac{-7 - 1}{2} = \frac{-8}{2} = -4\end{aligned}$$

- b. Average rate of change of  $f$  from  $x = 1$  to  $x = 3$ :

$$\begin{aligned}\frac{f(3) - f(1)}{3 - 1} &= \frac{(-(3)^3 + 1) - (-(1)^3 + 1)}{2} \\ &= \frac{-26 - (0)}{2} = \frac{-26}{2} = -13\end{aligned}$$

- c. Average rate of change of  $f$  from  $x = -1$  to  $x = 1$ :

$$\begin{aligned}\frac{f(1) - f(-1)}{1 - (-1)} &= \frac{(-(1)^3 + 1) - (-(-1)^3 + 1)}{2} \\ &= \frac{0 - 2}{2} = \frac{-2}{2} = -1\end{aligned}$$

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

- a. Average rate of change of  $g$  from  $x = -3$  to  $x = -2$ :

$$\begin{aligned}\frac{g(-2) - g(-3)}{-2 - (-3)} &= \frac{[(-2)^3 - 2(-2) + 1] - [(-3)^3 - 2(-3) + 1]}{1} \\ &= \frac{(-3) - (-20)}{1} = \frac{17}{1} = 17\end{aligned}$$

- b. Average rate of change of  $g$  from  $x = -1$  to  $x = 1$ :

$$\begin{aligned}\frac{g(1) - g(-1)}{1 - (-1)} &= \frac{[(1)^3 - 2(1) + 1] - [(-1)^3 - 2(-1) + 1]}{2} \\ &= \frac{(0) - (2)}{2} = \frac{-2}{2} = -1\end{aligned}$$

- c. Average rate of change of  $g$  from  $x = 1$  to  $x = 3$ :

$$\begin{aligned}\frac{g(3) - g(1)}{3 - 1} &= \frac{[(3)^3 - 2(3) + 1] - [(1)^3 - 2(1) + 1]}{2} \\ &= \frac{(22) - (0)}{2} = \frac{22}{2} = 11\end{aligned}$$

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

- a. Average rate of change of  $h$  from  $x = -1$  to  $x = 1$ :

$$\begin{aligned}\frac{h(1) - h(-1)}{1 - (-1)} &= \frac{[(1)^2 - 2(1) + 3] - [(-1)^2 - 2(-1) + 3]}{2} \\ &= \frac{(2) - (6)}{2} = \frac{-4}{2} = -2\end{aligned}$$

## Chapter 1: Functions and Their Graphs

- b. Average rate of change of  $h$  from  $x = 0$  to  $x = 2$ :

$$\begin{aligned}\frac{h(2) - h(0)}{2 - 0} &= \frac{[(2)^2 - 2(2) + 3] - [(0)^2 - 2(0) + 3]}{2} \\ &= \frac{(3) - (3)}{2} = \frac{0}{2} = 0\end{aligned}$$

- c. Average rate of change of  $h$  from  $x = 2$  to  $x = 5$ :

$$\begin{aligned}\frac{h(5) - h(2)}{5 - 2} &= \frac{[(5)^2 - 2(5) + 3] - [(2)^2 - 2(2) + 3]}{3} \\ &= \frac{(18) - (3)}{3} = \frac{15}{3} = 5\end{aligned}$$

57.  $f(x) = 5x - 2$

- a. Average rate of change of  $f$  from 1 to  $x$ :

$$\begin{aligned}\frac{f(x) - f(1)}{x - 1} &= \frac{(5x - 2) - (5(1) - 2)}{x - 1} \\ &= \frac{5x - 2 - 3}{x - 1} \\ &= \frac{5x - 5}{x - 1} = \frac{5(x - 1)}{x - 1} = 5\end{aligned}$$

- b. The average rate of change of  $f$  from 1 to  $x$  is a constant 5. Thus, the average rate of change of  $f$  from 1 to 3 is 5. The slope of the secant line joining  $(1, f(1))$  and  $(3, f(3))$  is 5.

- c. We use the point-slope form to find the equation of the secant line:

$$\begin{aligned}y - y_1 &= m_{\text{sec}}(x - x_1) \\ y - 3 &= 5(x - 1) \\ y - 3 &= 5x - 5 \\ y &= 5x - 2\end{aligned}$$

58.  $f(x) = -4x + 1$

- a. Average rate of change of  $f$  from 2 to  $x$ :

$$\begin{aligned}\frac{f(x) - f(2)}{x - 2} &= \frac{(-4x + 1) - (-4(2) + 1)}{x - 2} \\ &= \frac{-4x + 1 - (-7)}{x - 2} \\ &= \frac{-4x + 8}{x - 2} = \frac{-4(x - 2)}{x - 2} = -4\end{aligned}$$

- b. The average rate of change of  $f$  from 2 to  $x$  is given by  $-4$ . Therefore, the average rate of change of  $f$  from 2 to 5 is  $-4$ . The slope of the secant line joining  $(2, f(2))$  and

$$(5, f(5)) \text{ is } -4.$$

- c. We use the point-slope form to find the equation of the secant line:

$$\begin{aligned}y - y_1 &= m_{\text{sec}}(x - x_1) \\ y - (-7) &= -4(x - 2) \\ y + 7 &= -4x + 8 \\ y &= -4x + 1\end{aligned}$$

59.  $g(x) = x^2 - 2$

- a. Average rate of change of  $g$  from  $-2$  to  $x$ :

$$\begin{aligned}\frac{g(x) - g(-2)}{x - (-2)} &= \frac{[x^2 - 2] - [(-2)^2 - 2]}{x + 2} \\ &= \frac{(x^2 - 2) - (2)}{x + 2} = \frac{x^2 - 4}{x + 2} \\ &= \frac{(x + 2)(x - 2)}{x + 2} = x - 2\end{aligned}$$

- b. The average rate of change of  $g$  from  $-2$  to  $x$  is given by  $x - 2$ . Therefore, the average rate of change of  $g$  from  $-2$  to 1 is  $1 - 2 = -1$ . The slope of the secant line joining  $(-2, g(-2))$  and  $(1, g(1))$  is  $-1$ .

- c. We use the point-slope form to find the equation of the secant line:

$$\begin{aligned}y - y_1 &= m_{\text{sec}}(x - x_1) \\ y - 2 &= -1(x - (-2)) \\ y - 2 &= -x - 2 \\ y &= -x\end{aligned}$$

60.  $g(x) = x^2 + 1$

- a. Average rate of change of  $g$  from  $-1$  to  $x$ :

$$\begin{aligned}\frac{g(x) - g(-1)}{x - (-1)} &= \frac{[x^2 + 1] - [(-1)^2 + 1]}{x + 1} \\ &= \frac{(x^2 + 1) - (2)}{x + 1} = \frac{x^2 - 1}{x + 1} \\ &= \frac{(x - 1)(x + 1)}{x + 1} = x - 1\end{aligned}$$

### Section 1.3: Properties of Functions

- b. The average rate of change of  $g$  from  $-1$  to  $x$  is given by  $x - 1$ . Therefore, the average rate of change of  $g$  from  $-1$  to  $2$  is  $2 - 1 = 1$ . The slope of the secant line joining  $(-1, g(-1))$  and  $(2, g(2))$  is  $1$ .

- c. We use the point-slope form to find the equation of the secant line:

$$y - y_1 = m_{\text{sec}}(x - x_1)$$

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

$$y - 2 = x + 1$$

$$y = x + 3$$

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

- a. Average rate of change of  $h$  from  $2$  to  $x$ :

$$\begin{aligned} \frac{h(x) - h(2)}{x - 2} &= \frac{[x^2 - 2x] - [(2)^2 - 2(2)]}{x - 2} \\ &= \frac{(x^2 - 2x) - (0)}{x - 2} \\ &= \frac{x^2 - 2x}{x - 2} = \frac{x(x - 2)}{x - 2} = x \end{aligned}$$

- b. The average rate of change of  $h$  from  $2$  to  $x$  is given by  $x$ . Therefore, the average rate of change of  $h$  from  $2$  to  $4$  is  $4$ . The slope of the secant line joining  $(2, h(2))$  and

$$(4, h(4)) \text{ is } 4.$$

- c. We use the point-slope form to find the equation of the secant line:

$$y - y_1 = m_{\text{sec}}(x - x_1)$$

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

$$y = 4x - 8$$

62.  $h(x) = -2x^2 + x$

- a. Average rate of change from  $0$  to  $x$ :

$$\begin{aligned} \frac{h(x) - h(0)}{x - 0} &= \frac{[-2x^2 + x] - [-2(0)^2 + 0]}{x} \\ &= \frac{(-2x^2 + x) - (0)}{x} = \frac{-2x^2 + x}{x} \\ &= \frac{x(-2x + 1)}{x} = -2x + 1 \end{aligned}$$

- b. The average rate of change of  $h$  from  $0$  to  $x$  is given by  $-2x + 1$ . Therefore, the average rate of change of  $h$  from  $0$  to  $3$  is  $-2(3) + 1 = -5$ . The slope of the secant line joining  $(0, h(0))$  and  $(3, h(3))$  is  $-5$ .

- c. We use the point-slope form to find the equation of the secant line:

$$y - y_1 = m_{\text{sec}}(x - x_1)$$

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

$$y = -5x$$

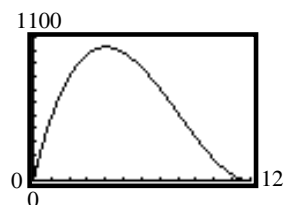
63. a. length =  $24 - 2x$ ; width =  $24 - 2x$ ; height =  $x$

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

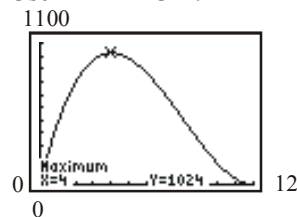
- b.  $V(3) = 3(24 - 2(3))^2 = 3(18)^2$   
 $= 3(324) = 972 \text{ cu.in.}$

- c.  $V(10) = 10(24 - 2(10))^2 = 10(4)^2$   
 $= 10(16) = 160 \text{ cu.in.}$

- d.  $y_1 = x(24 - 2x)^2$



Use MAXIMUM.



The volume is largest when  $x = 4$  inches.

64. a. Let  $A$  = amount of material,  
 $x$  = length of the base,  $h$  = height, and  
 $V$  = volume.

$$V = x^2 h = 10 \Rightarrow h = \frac{10}{x^2}$$

$$\text{Total Area } A = (\text{Area}_{\text{base}}) + (4)(\text{Area}_{\text{side}})$$

$$= x^2 + 4xh$$

$$= x^2 + 4x\left(\frac{10}{x^2}\right)$$

$$= x^2 + \frac{40}{x}$$

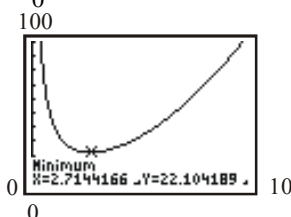
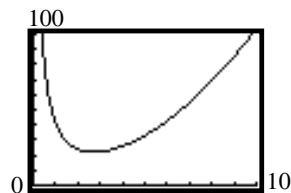
$$A(x) = x^2 + \frac{40}{x}$$

- b.  $A(1) = 1^2 + \frac{40}{1} = 1 + 40 = 41 \text{ ft}^2$

## Chapter 1: Functions and Their Graphs

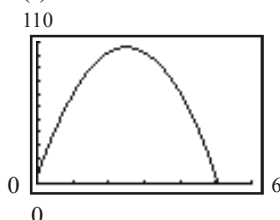
c.  $A(2) = 2^2 + \frac{40}{2} = 4 + 20 = 24 \text{ ft}^2$

d.  $y_1 = x^2 + \frac{40}{x}$

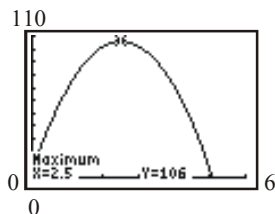


The amount of material is least when  $x = 2.71$  ft.

65. a.  $s(t) = -16t^2 + 80t + 6$

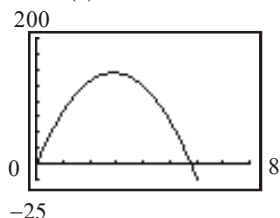


- b. Use MAXIMUM. The maximum height occurs when  $t = 2.5$  seconds.

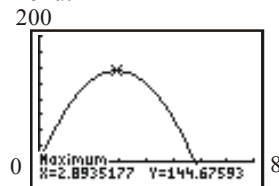


- c. From the graph, the maximum height is 106 feet.

66. a.  $y = s(t) = -17.28t^2 + 100t$



- b. Use the Maximum option on the CALC menu.

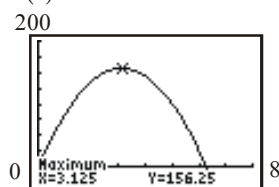


-25

The object reaches its maximum height after about 2.89 seconds.

- c. From the graph in part (b), the maximum height is about 144.68 feet.

d.  $s(t) = -16t^2 + 100t$

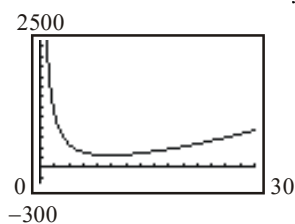


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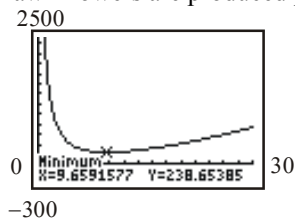
On Earth, the object would reach a maximum height of 156.25 feet after 3.125 seconds. The maximum height is slightly higher than on Saturn.

67.  $\bar{C}(x) = 0.3x^2 + 21x - 251 + \frac{2500}{x}$

a.  $y_1 = 0.3x^2 + 21x - 251 + \frac{2500}{x}$



- b. Use MINIMUM. Rounding to the nearest whole number, the average cost is minimized when approximately 10 lawnmowers are produced per hour.

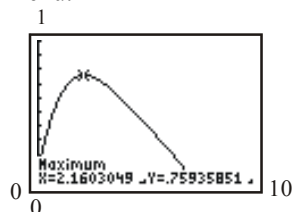


-300

- c. The minimum average cost is approximately \$239.

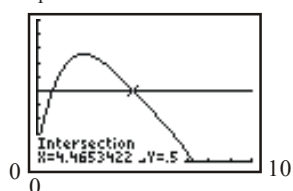
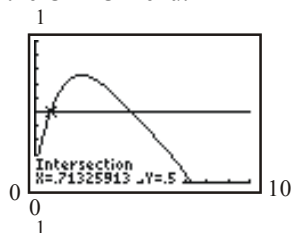
## Section 1.3: Properties of Functions

68. a.  $C(t) = -.002t^4 + .039t^3 - .285t^2 + .766t + .085$   
Graph the function on a graphing utility and use the Maximum option from the CALC menu.



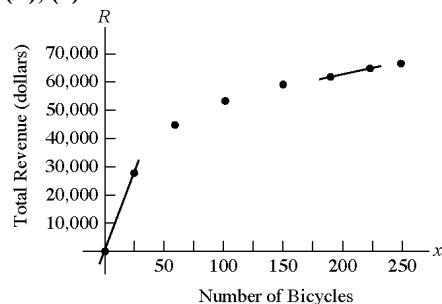
The concentration will be highest after about 2.16 hours.

- b. Enter the function in Y1 and 0.5 in Y2.  
Graph the two equations in the same window and use the Intersect option from the CALC menu.



After taking the medication, the woman can feed her child within the first 0.71 hours (about 42 minutes) or after 4.47 hours (about 4 hours 28 minutes) have elapsed.

69. (a), (b), (e)



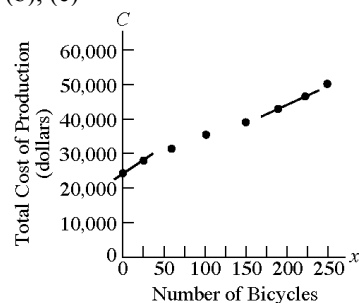
- c. Average rate of change =  $\frac{28000 - 0}{25 - 0} = \frac{28000}{25}$   
 $= 1120$  dollars/bicycle

- d. For each additional bicycle sold between 0 and 25, the total revenue increases by (an average of) \$1120.

f. Average rate of change =  $\frac{64835 - 62360}{223 - 190} = \frac{2475}{33}$   
 $= 75$  dollars per bicycle

- g. For each additional bicycle sold between 190 and 223, the total revenue increases by (an average of) \$75.  
h. The average rate of change of revenue is decreasing as the number of bicycles increases.

70. (a), (b), (e)



c. Average rate of change =  $\frac{27750 - 24000}{25 - 0}$   
 $= \frac{3750}{25} = 150$  dollars/bicycle

- d. For each additional bicycle made between 0 and 25, the total production cost increases by (an average of) \$150.

f. Average rate of change =  $\frac{46500 - 42750}{223 - 190} = \frac{3750}{33}$   
 $\approx 113.64$  dollars/bicycle

- g. For each additional bicycle made between 190 and 223, the total production cost increases by (an average of) \$113.64.  
h. The average rate of change of cost is decreasing as the number of bicycles increases.

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

- a. Average rate of change of  $f$  from  $x = 0$  to  $x = 1$ :

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

## Chapter 1: Functions and Their Graphs

- b. Average rate of change of  $f$  from  $x = 0$  to  $x = 0.5$  :

$$\frac{f(0.5) - f(0)}{0.5 - 0} = \frac{(0.5)^2 - 0^2}{0.5} = \frac{0.25}{0.5} = 0.5$$

- c. Average rate of change of  $f$  from  $x = 0$  to  $x = 0.1$  :

$$\frac{f(0.1) - f(0)}{0.1 - 0} = \frac{(0.1)^2 - 0^2}{0.1} = \frac{0.01}{0.1} = 0.1$$

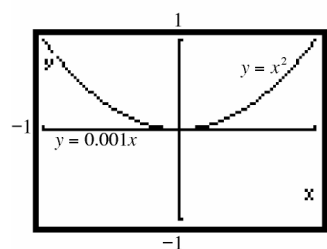
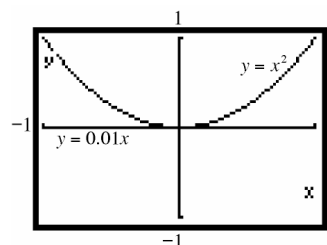
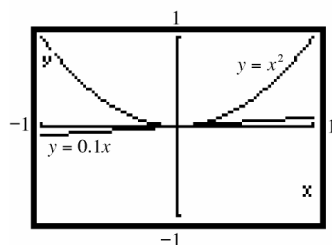
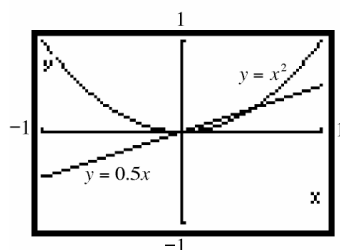
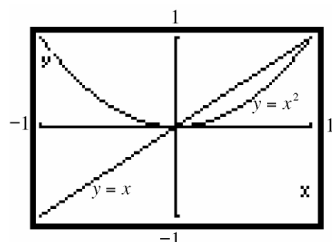
- d. Average rate of change of  $f$  from  $x = 0$  to  $x = 0.01$  :

$$\begin{aligned} \frac{f(0.01) - f(0)}{0.01 - 0} &= \frac{(0.01)^2 - 0^2}{0.01} \\ &= \frac{0.0001}{0.01} = 0.01 \end{aligned}$$

- e. Average rate of change of  $f$  from  $x = 0$  to  $x = 0.001$  :

$$\begin{aligned} \frac{f(0.001) - f(0)}{0.001 - 0} &= \frac{(0.001)^2 - 0^2}{0.001} \\ &= \frac{0.000001}{0.001} = 0.001 \end{aligned}$$

- f. Graphing the secant lines:



- g. The secant lines are beginning to look more and more like the tangent line to the graph of  $f$  at the point where  $x = 0$  .
- h. The slopes of the secant lines are getting smaller and smaller. They seem to be approaching the number zero.

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

- a. Average rate of change of  $f$  from  $x = 1$  to  $x = 2$  :

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

- b. Average rate of change of  $f$  from  $x = 1$  to  $x = 1.5$  :

$$\frac{f(1.5) - f(1)}{1.5 - 1} = \frac{(1.5)^2 - 1^2}{0.5} = \frac{1.25}{0.5} = 2.5$$

- c. Average rate of change of  $f$  from  $x = 1$  to  $x = 1.1$  :

$$\frac{f(1.1) - f(1)}{1.1 - 1} = \frac{(1.1)^2 - 1^2}{0.1} = \frac{0.21}{0.1} = 2.1$$

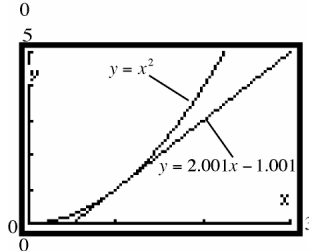
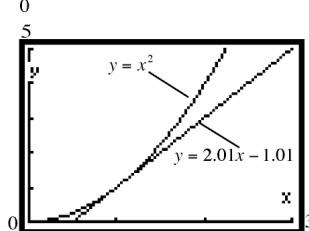
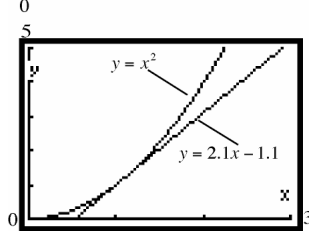
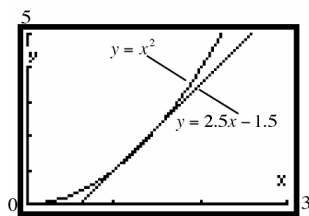
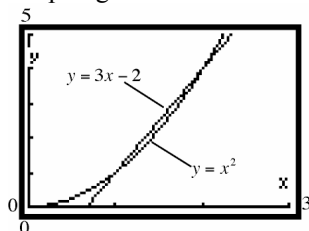
- d. Average rate of change of  $f$  from  $x = 1$  to  $x = 1.01$  :

$$\frac{f(1.01) - f(1)}{1.01 - 1} = \frac{(1.01)^2 - 1^2}{0.01} = \frac{0.0201}{0.01} = 2.01$$

- e. Average rate of change of  $f$  from  $x = 1$  to  $x = 1.001$  :

$$\begin{aligned} \frac{f(1.001) - f(1)}{1.001 - 1} &= \frac{(1.001)^2 - 1^2}{0.001} \\ &= \frac{0.002001}{0.001} = 2.001 \end{aligned}$$

f. Graphing the secant lines:



g. The secant lines are beginning to look more and more like the tangent line to the graph of  $f$  at the point where  $x = 1$ .

h. The slopes of the secant lines are getting smaller and smaller. They seem to be approaching the number 2.

73.  $f(x) = 2x + 5$

$$\begin{aligned} \text{a. } m_{\text{sec}} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{2(x+h) + 5 - 2x - 5}{h} = \frac{2h}{h} = 2 \end{aligned}$$

b. When  $x = 1$ :

$$h = 0.5 \Rightarrow m_{\text{sec}} = 2$$

$$h = 0.1 \Rightarrow m_{\text{sec}} = 2$$

$$h = 0.01 \Rightarrow m_{\text{sec}} = 2$$

$$\text{as } h \rightarrow 0, m_{\text{sec}} \rightarrow 2$$

c. Using the point  $(1, f(1)) = (1, 7)$  and slope,

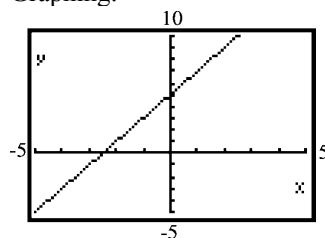
$$m = 2, \text{ we get the secant line:}$$

$$y - 7 = 2(x - 1)$$

$$y - 7 = 2x - 2$$

$$y = 2x + 5$$

d. Graphing:



The graph and the secant line coincide.

74.  $f(x) = -3x + 2$

$$\begin{aligned} \text{a. } m_{\text{sec}} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{-3(x+h) + 2 - (-3x + 2)}{h} = \frac{-3h}{h} = -3 \end{aligned}$$

b. When  $x = 1$ ,

$$h = 0.5 \Rightarrow m_{\text{sec}} = -3$$

$$h = 0.1 \Rightarrow m_{\text{sec}} = -3$$

$$h = 0.01 \Rightarrow m_{\text{sec}} = -3$$

$$\text{as } h \rightarrow 0, m_{\text{sec}} \rightarrow -3$$

c. Using point  $(1, f(1)) = (1, -1)$  and

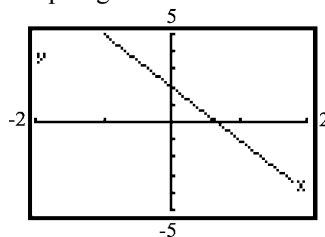
slope  $= -3$ , we get the secant line:

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

$$y + 1 = -3x + 3$$

$$y = -3x + 2$$

d. Graphing:



The graph and the secant line coincide.

## Chapter 1: Functions and Their Graphs

75.  $f(x) = x^2 + 2x$

a. 
$$m_{\text{sec}} = \frac{f(x+h) - f(x)}{h}$$

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

$$= \frac{x^2 + 2xh + h^2 + 2x + 2h - x^2 - 2x}{h}$$

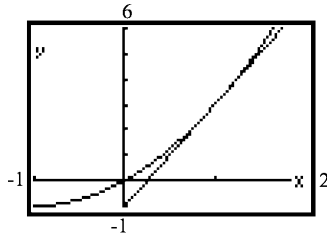
$$= \frac{2xh + h^2 + 2h}{h}$$

$$= 2x + h + 2$$

b. When  $x = 1$ ,  
 $h = 0.5 \Rightarrow m_{\text{sec}} = 2 \cdot 1 + 0.5 + 2 = 4.5$   
 $h = 0.1 \Rightarrow m_{\text{sec}} = 2 \cdot 1 + 0.1 + 2 = 4.1$   
 $h = 0.01 \Rightarrow m_{\text{sec}} = 2 \cdot 1 + 0.01 + 2 = 4.01$   
as  $h \rightarrow 0$ ,  $m_{\text{sec}} \rightarrow 2 \cdot 1 + 0 + 2 = 4$

c. Using point  $(1, f(1)) = (1, 3)$  and slope = 4.01, we get the secant line:  
 $y - 3 = 4.01(x - 1)$   
 $y - 3 = 4.01x - 4.01$   
 $y = 4.01x - 1.01$

d. Graphing:



76.  $f(x) = 2x^2 + x$

a. 
$$m_{\text{sec}} = \frac{f(x+h) - f(x)}{h}$$

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

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

$$= \frac{2x^2 + 4xh + 2h^2 + x + h - 2x^2 - x}{h}$$

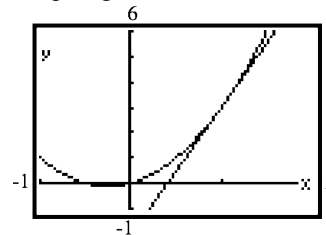
$$= \frac{4xh + 2h^2 + h}{h}$$

$$= 4x + 2h + 1$$

b. When  $x = 1$ ,  
 $h = 0.5 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.5) + 1 = 6$   
 $h = 0.1 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.1) + 1 = 5.2$   
 $h = 0.01 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.01) + 1 = 5.02$   
as  $h \rightarrow 0$ ,  $m_{\text{sec}} \rightarrow 4 \cdot 1 + 2(0) + 1 = 5$

c. Using point  $(1, f(1)) = (1, 3)$  and slope = 5.02, we get the secant line:  
 $y - 3 = 5.02(x - 1)$   
 $y - 3 = 5.02x - 5.02$   
 $y = 5.02x - 2.02$

d. Graphing:



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

a. 
$$m_{\text{sec}} = \frac{f(x+h) - f(x)}{h}$$

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

$$= \frac{2(x^2 + 2xh + h^2) - 3x - 3h + 1 - 2x^2 + 3x - 1}{h}$$

$$= \frac{2x^2 + 4xh + 2h^2 - 3x - 3h + 1 - 2x^2 + 3x - 1}{h}$$

$$= \frac{4xh + 2h^2 - 3h}{h}$$

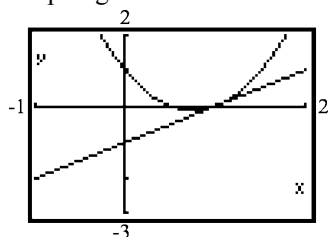
$$= 4x + 2h - 3$$

b. When  $x = 1$ ,  
 $h = 0.5 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.5) - 3 = 2$   
 $h = 0.1 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.1) - 3 = 1.2$   
 $h = 0.01 \Rightarrow m_{\text{sec}} = 4 \cdot 1 + 2(0.01) - 3 = 1.02$   
as  $h \rightarrow 0$ ,  $m_{\text{sec}} \rightarrow 4 \cdot 1 + 2(0) - 3 = 1$

c. Using point  $(1, f(1)) = (1, 0)$  and slope = 1.02, we get the secant line:  
 $y - 0 = 1.02(x - 1)$   
 $y = 1.02x - 1.02$



d. Graphing:



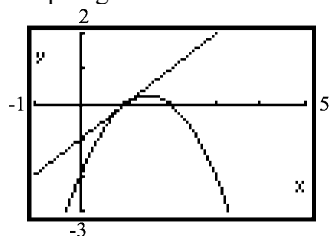
78.  $f(x) = -x^2 + 3x - 2$

$$\begin{aligned} \text{a. } m_{\text{sec}} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{-(x+h)^2 + 3(x+h) - 2 - (-x^2 + 3x - 2)}{h} \\ &= \frac{-(x^2 + 2xh + h^2) + 3x + 3h - 2 + x^2 - 3x + 2}{h} \\ &= \frac{-x^2 - 2xh - h^2 + 3x + 3h - 2 + x^2 - 3x + 2}{h} \\ &= \frac{-2xh - h^2 + 3h}{h} \\ &= -2x - h + 3 \end{aligned}$$

b. When  $x = 1$ ,  
 $h = 0.5 \Rightarrow m_{\text{sec}} = -2 \cdot 1 - 0.5 + 3 = 0.5$   
 $h = 0.1 \Rightarrow m_{\text{sec}} = -2 \cdot 1 - 0.1 + 3 = 0.9$   
 $h = 0.01 \Rightarrow m_{\text{sec}} = -2 \cdot 1 - 0.01 + 3 = 0.99$   
 as  $h \rightarrow 0$ ,  $m_{\text{sec}} \rightarrow -2 \cdot 1 - 0 + 3 = 1$

c. Using point  $(1, f(1)) = (1, 0)$  and  
 slope  $= 0.99$ , we get the secant line:  
 $y - 0 = 0.99(x - 1)$   
 $y = 0.99x - 0.99$

d. Graphing:



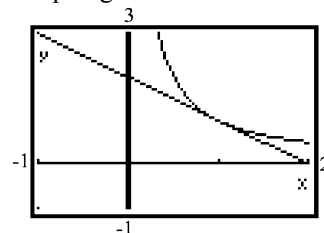
79.  $f(x) = \frac{1}{x}$

$$\begin{aligned} \text{a. } m_{\text{sec}} &= \frac{f(x+h) - f(x)}{h} \\ &= \frac{\left(\frac{1}{x+h} - \frac{1}{x}\right)}{h} = \frac{\left(\frac{x - (x+h)}{(x+h)x}\right)}{h} \\ &= \frac{\left(\frac{x - x - h}{(x+h)x}\right)\left(\frac{1}{h}\right)}{\left(\frac{-h}{(x+h)x}\right)\left(\frac{1}{h}\right)} \\ &= -\frac{1}{(x+h)x} \end{aligned}$$

b. When  $x = 1$ ,  
 $h = 0.5 \Rightarrow m_{\text{sec}} = -\frac{1}{(1+0.5)(1)} = -\frac{1}{1.5} = -\frac{2}{3} \approx -0.667$   
 $h = 0.1 \Rightarrow m_{\text{sec}} = -\frac{1}{(1+0.1)(1)} = -\frac{1}{1.1} = -\frac{10}{11} \approx -0.909$   
 $h = 0.01 \Rightarrow m_{\text{sec}} = -\frac{1}{(1+0.01)(1)} = -\frac{1}{1.01} = -\frac{100}{101} \approx -0.990$   
 as  $h \rightarrow 0$ ,  $m_{\text{sec}} \rightarrow -\frac{1}{(1+0)(1)} = -\frac{1}{1} = -1$

c. Using point  $(1, f(1)) = (1, 1)$  and  
 slope  $= -\frac{100}{101}$ , we get the secant line:  
 $y - 1 = -\frac{100}{101}(x - 1)$   
 $y - 1 = -\frac{100}{101}x + \frac{100}{101}$   
 $y = -\frac{100}{101}x + \frac{201}{101}$

d. Graphing:



## Chapter 1: Functions and Their Graphs

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

a. 
$$m_{\text{sec}} = \frac{f(x+h) - f(x)}{h}$$

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

$$= \frac{\left( \frac{x^2 - (x+h)^2}{(x+h)^2 x^2} \right)}{h}$$

$$= \left( \frac{x^2 - (x^2 + 2xh + h^2)}{(x+h)^2 x^2} \right) \left( \frac{1}{h} \right)$$

$$= \left( \frac{-2xh - h^2}{(x+h)^2 x^2} \right) \left( \frac{1}{h} \right)$$

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

b. When  $x = 1$ ,

$$h = 0.5 \Rightarrow m_{\text{sec}} = \frac{-2 \cdot 1 - 0.5}{(1 + 0.5)^2 1^2} \approx -1.1111$$

$$h = 0.1 \Rightarrow m_{\text{sec}} = \frac{-2 \cdot 1 - 0.1}{(1 + 0.1)^2 1^2} \approx -1.7355$$

$$h = 0.01 \Rightarrow m_{\text{sec}} = \frac{-2 \cdot 1 - 0.01}{(1 + 0.01)^2 1^2} \approx -1.9704$$

$$\text{as } h \rightarrow 0, m_{\text{sec}} \rightarrow \frac{-2 \cdot 1 - 0}{(1 + 0)^2 1^2} = -2$$

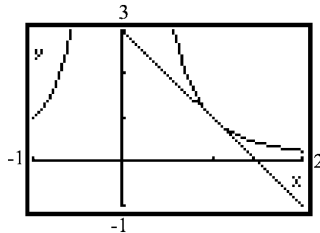
c. Using point  $(1, f(1)) = (1, 1)$  and slope  $= -1.9704$ , we get the secant line:

$$y - 1 = -1.9704(x - 1)$$

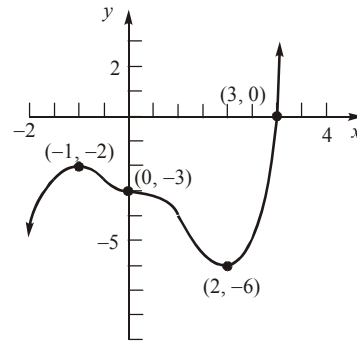
$$y - 1 = -1.9704x + 1.9704$$

$$y = -1.9704x + 2.9704$$

d. Graphing:



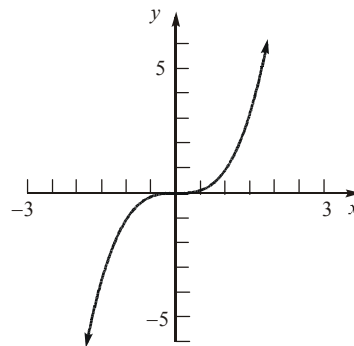
81. Answers will vary. One possibility follows:



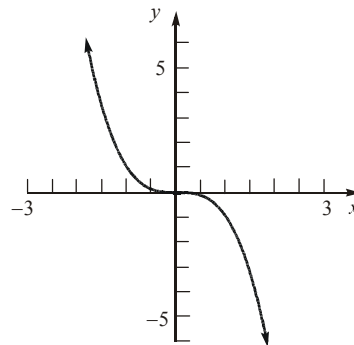
82. Answers will vary. See solution to Problem 81 for one possibility.

83. A function that is increasing on an interval can have at most one  $x$ -intercept on the interval. The graph of  $f$  could not "turn" and cross it again or it would start to decrease.

84. An increasing function is a function whose graph goes up as you read from left to right.



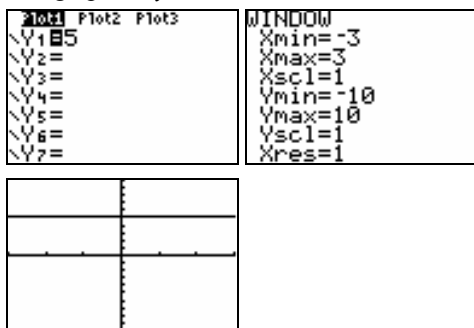
A decreasing function is a function whose graph goes down as you read from left to right.



## Section 1.4: Library of Functions; Piecewise-defined Functions

85. To be an even function we need  $f(-x) = f(x)$  and to be an odd function we need  $f(-x) = -f(x)$ . In order for a function be both even and odd, we would need  $f(x) = -f(x)$ . This is only possible if  $f(x) = 0$ .

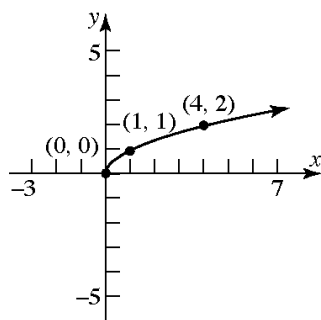
86. The graph of  $y = 5$  is a horizontal line.



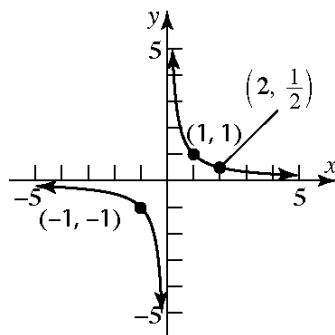
The local maximum is  $y = 5$  and it occurs at each  $x$ -value in the interval.

### Section 1.4

1.  $y = \sqrt{x}$



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



3.  $y = x^3 - 8$

y-intercept:

Let  $x = 0$ , then  $y = (0)^3 - 8 = -8$ .

x-intercept:

Let  $y = 0$ , then  $0 = x^3 - 8$

$$x^3 = 8$$

$$x = 2$$

The intercepts are  $(0, -8)$  and  $(2, 0)$ .

4. less

5. piecewise-defined

6. True

7. False; the cube root function is odd and increasing on the interval  $(-\infty, \infty)$ .

8. False; the domain and range of the reciprocal function are both the set of real numbers except for 0.

9. C

10. A

11. E

12. G

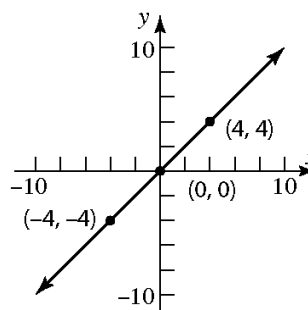
13. B

14. D

15. F

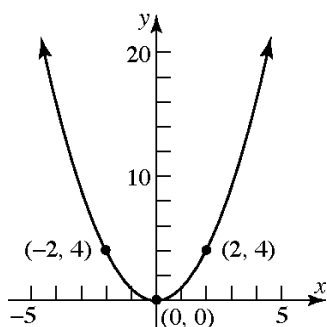
16. H

17.  $f(x) = x$

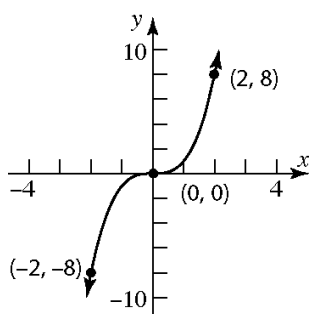


## Chapter 1: Functions and Their Graphs

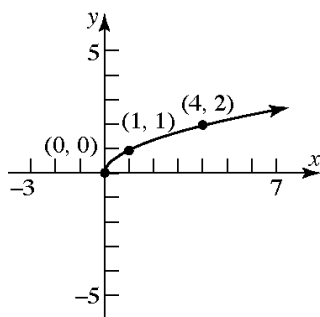
18.  $f(x) = x^2$



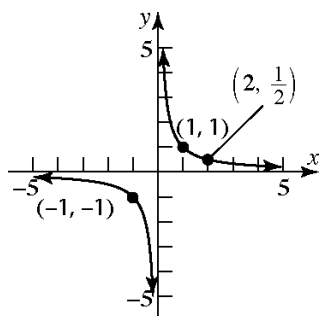
19.  $f(x) = x^3$



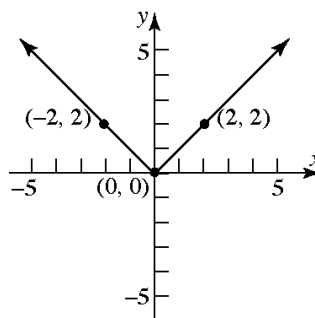
20.  $f(x) = \sqrt{x}$



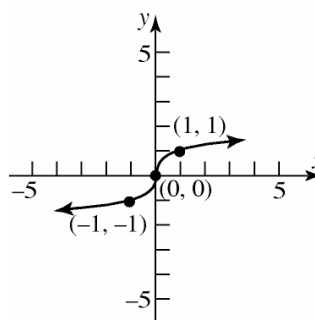
21.  $f(x) = \frac{1}{x}$



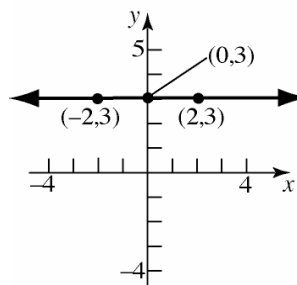
22.  $f(x) = |x|$



23.  $f(x) = \sqrt[3]{x}$



24.  $f(x) = 3$



25. a.  $f(-2) = (-2)^2 = 4$

b.  $f(0) = 2$

c.  $f(2) = 2(2) + 1 = 5$

26. a.  $f(-1) = (-1)^3 = -1$

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

c.  $f(1) = 3(1) + 2 = 5$

27. a.  $f(1.2) = \text{int}(2(1.2)) = \text{int}(2.4) = 2$

b.  $f(1.6) = \text{int}(2(1.6)) = \text{int}(3.2) = 3$

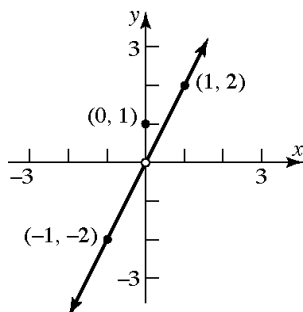
c.  $f(-1.8) = \text{int}(2(-1.8)) = \text{int}(-3.6) = -4$

# Section 1.4: Library of Functions; Piecewise-defined Functions

28. a.  $f(1.2) = \text{int}\left(\frac{1.2}{2}\right) = \text{int}(0.6) = 0$   
 b.  $f(1.6) = \text{int}\left(\frac{1.6}{2}\right) = \text{int}(0.8) = 0$   
 c.  $f(-1.8) = \text{int}\left(\frac{-1.8}{2}\right) = \text{int}(-0.9) = -1$

29.  $f(x) = \begin{cases} 2x & \text{if } x \neq 0 \\ 1 & \text{if } x = 0 \end{cases}$

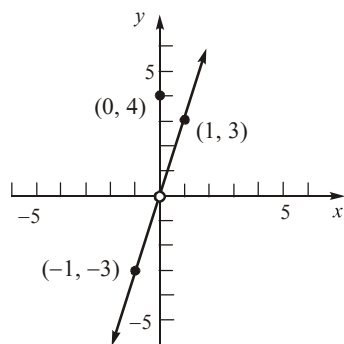
- a. Domain:  $\{x \mid x \text{ is any real number}\}$   
 b.  $x$ -intercept: none  
 $y$ -intercept:  $(0, 1)$   
 c. Graph:



- d. Range:  $\{y \mid y \neq 0\}; (-\infty, 0) \text{ or } (0, \infty)$

30.  $f(x) = \begin{cases} 3x & \text{if } x \neq 0 \\ 4 & \text{if } x = 0 \end{cases}$

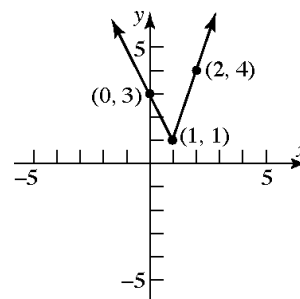
- a. Domain:  $\{x \mid x \text{ is any real number}\}$   
 b.  $x$ -intercept: none  
 $y$ -intercept:  $(0, 4)$   
 c. Graph:



- d. Range:  $\{y \mid y \neq 0\}; (-\infty, 0) \text{ or } (0, \infty)$

31.  $f(x) = \begin{cases} -2x+3 & \text{if } x < 1 \\ 3x-2 & \text{if } x \geq 1 \end{cases}$

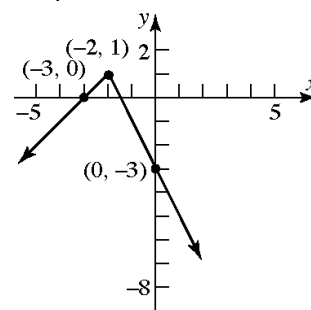
- a. Domain:  $\{x \mid x \text{ is any real number}\}$   
 b.  $x$ -intercept: none  
 $y$ -intercept:  $(0, 3)$   
 c. Graph:



- d. Range:  $\{y \mid y \geq 1\}; [1, \infty)$

32.  $f(x) = \begin{cases} x+3 & \text{if } x < -2 \\ -2x-3 & \text{if } x \geq -2 \end{cases}$

- a. Domain:  $\{x \mid x \text{ is any real number}\}$   
 b.  $x$ -intercepts:  $(-3, 0), \left(-\frac{3}{2}, 0\right)$   
 $y$ -intercept:  $(0, -3)$   
 c. Graph:



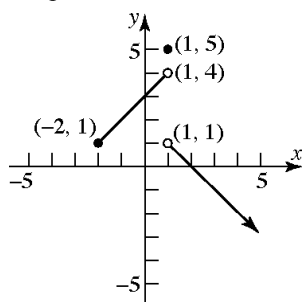
- d. Range:  $\{y \mid y \leq 1\}; (-\infty, 1]$

33.  $f(x) = \begin{cases} x+3 & \text{if } -2 \leq x < 1 \\ 5 & \text{if } x = 1 \\ -x+2 & \text{if } x > 1 \end{cases}$

- a. Domain:  $\{x \mid x \geq -2\}; [-2, \infty)$   
 b.  $x$ -intercept:  $(2, 0)$   
 $y$ -intercept:  $(0, 3)$

## Chapter 1: Functions and Their Graphs

c. Graph:



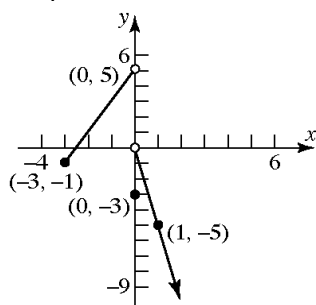
d. Range:  $\{y \mid y < 4 \text{ and } y = 5\}$ ;  $(-\infty, 4)$  or  $\{5\}$

34. 
$$f(x) = \begin{cases} 2x + 5 & \text{if } -3 \leq x < 0 \\ -3 & \text{if } x = 0 \\ -5x & \text{if } x > 0 \end{cases}$$

a. Domain:  $\{x \mid x \geq -3\}$ ;  $[-3, \infty)$

b.  $x$ -intercept:  $(-2.5, 0)$   
 $y$ -intercept:  $(0, -3)$

c. Graph:



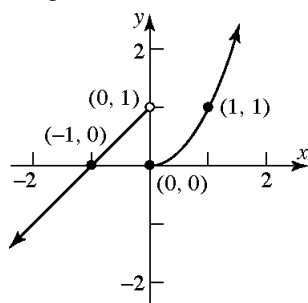
d. Range:  $\{y \mid y < 5\}$ ;  $(-\infty, 5)$

35. 
$$f(x) = \begin{cases} 1 + x & \text{if } x < 0 \\ x^2 & \text{if } x \geq 0 \end{cases}$$

a. Domain:  $\{x \mid x \text{ is any real number}\}$

b.  $x$ -intercepts:  $(-1, 0)$ ,  $(0, 0)$   
 $y$ -intercept:  $(0, 0)$

c. Graph:



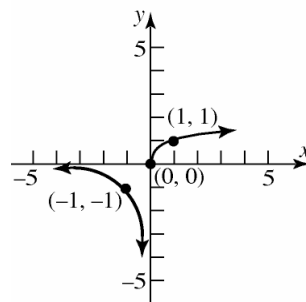
d. Range:  $\{y \mid y \text{ is any real number}\}$

36. 
$$f(x) = \begin{cases} \frac{1}{x} & \text{if } x < 0 \\ \sqrt[3]{x} & \text{if } x \geq 0 \end{cases}$$

a. Domain:  $\{x \mid x \text{ is any real number}\}$

b.  $x$ -intercept:  $(0, 0)$   
 $y$ -intercept:  $(0, 0)$

c. Graph:



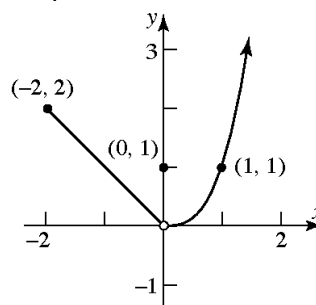
d. Range:  $\{y \mid y \text{ is any real number}\}$

37. 
$$f(x) = \begin{cases} |x| & \text{if } -2 \leq x < 0 \\ 1 & \text{if } x = 0 \\ x^3 & \text{if } x > 0 \end{cases}$$

a. Domain:  $\{x \mid x \geq -2\}$ ;  $[-2, \infty)$

b.  $x$ -intercept: none  
 $y$ -intercept:  $(0, 1)$

c. Graph:



d. Range:  $\{y \mid y > 0\}$ ;  $(0, \infty)$

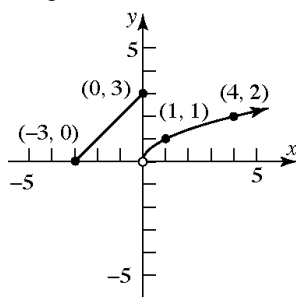
38. 
$$f(x) = \begin{cases} 3 + x & \text{if } -3 \leq x < 0 \\ 3 & \text{if } x = 0 \\ \sqrt{x} & \text{if } x > 0 \end{cases}$$

a. Domain:  $\{x \mid x \geq -3\}$ ;  $[-3, \infty)$

b.  $x$ -intercept:  $(-3, 0)$   
 $y$ -intercept:  $(0, 3)$

## Section 1.4: Library of Functions; Piecewise-defined Functions

c. Graph:



d. Range:  $\{y \mid y \geq 0\}; [0, \infty)$

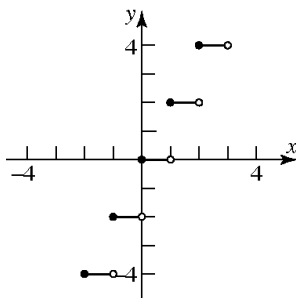
39.  $f(x) = 2 \operatorname{int}(x)$

a. Domain:  $\{x \mid x \text{ is any real number}\}$

b.  $x$ -intercepts: all ordered pairs  $(x, 0)$  when  $0 \leq x < 1$ .

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

c. Graph:



d. Range:  $\{y \mid y \text{ is an even integer}\}$

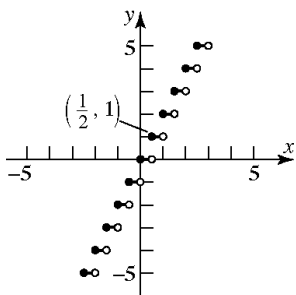
40.  $f(x) = \operatorname{int}(2x)$

a. Domain:  $\{x \mid x \text{ is any real number}\}$

b.  $x$ -intercepts: all ordered pairs  $(x, 0)$  when  $0 \leq x < \frac{1}{2}$ .

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

c. Graph:



d. Range:  $\{y \mid y \text{ is an integer}\}$

41. Answers may vary. One possibility follows:

$$f(x) = \begin{cases} -x & \text{if } -1 \leq x \leq 0 \\ \frac{1}{2}x & \text{if } 0 < x \leq 2 \end{cases}$$

42. Answers may vary. One possibility follows:

$$f(x) = \begin{cases} x & \text{if } -1 \leq x \leq 0 \\ 1 & \text{if } 0 < x \leq 2 \end{cases}$$

43. Answers may vary. One possibility follows:

$$f(x) = \begin{cases} -x & \text{if } x \leq 0 \\ -x + 2 & \text{if } 0 < x \leq 2 \end{cases}$$

44. Answers may vary. One possibility follows:

$$f(x) = \begin{cases} 2x + 2 & \text{if } -1 \leq x \leq 0 \\ x & \text{if } x > 0 \end{cases}$$

$$45. C = \begin{cases} 35 & \text{if } 0 < x \leq 300 \\ 0.40x - 85 & \text{if } x > 300 \end{cases}$$

a.  $C(200) = \$35.00$

b.  $C(365) = 0.40(365) - 85 = \$61.00$

c.  $C(301) = 0.40(301) - 85 = \$35.40$

$$46. F(x) = \begin{cases} 3 & \text{if } 0 < x \leq 3 \\ 5 \operatorname{int}(x+1) + 1 & \text{if } 3 < x < 9 \\ 50 & \text{if } 9 \leq x \leq 24 \end{cases}$$

a.  $F(2) = 3$

Parking for 2 hours costs \$3.

b.  $F(7) = 5 \operatorname{int}(7+1) + 1 = 41$

Parking for 7 hours costs \$41.

c.  $F(15) = 50$

Parking for 15 hours costs \$50.

d.  $24 \text{ min} \cdot \frac{1 \text{ hr}}{60 \text{ min}} = 0.4 \text{ hr}$

$$F(8.4) = 5 \operatorname{int}(8.4+1) + 1 = 5(9) + 1 = 46$$

Parking for 8 hours and 24 minutes costs \$46.

## Chapter 1: Functions and Their Graphs

47. a. Charge for 50 therms:

$$C = 9.45 + 0.7958(50) + 0.36375(50) \\ = \$67.43$$

- b. Charge for 500 therms:

$$C = 9.45 + 0.36375(50) + 0.11445(450) \\ + 0.7958(500) \\ = \$477.04$$

- c. For  $0 \leq x \leq 50$ :

$$C = 9.45 + 0.36375x + 0.7958x \\ = 1.15955x + 9.45$$

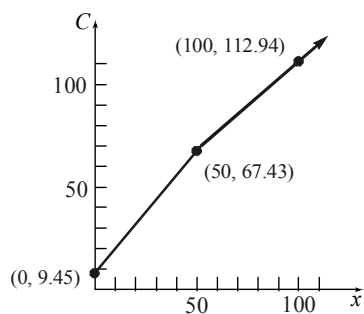
For  $x > 50$ :

$$C = 9.45 + 0.36375(50) + 0.11445(x - 50) \\ + 0.7958x \\ = 9.45 + 18.1875 + 0.11445x - 5.7225 \\ + 0.7958x \\ = 0.91025x + 21.915$$

The monthly charge function:

$$C = \begin{cases} 1.15955x + 9.45 & \text{for } 0 \leq x \leq 50 \\ 0.91025x + 21.915 & \text{for } x > 50 \end{cases}$$

- d. Graph:



48. a. Charge for 40 therms:

$$C = 6.45 + 0.2012(20) + 0.1117(20) \\ + 0.7727(40) \\ = \$43.62$$

- b. Charge for 202 therms:

$$C = 6.45 + 0.2012(20) + 0.1117(30) \\ + 0.0374(152) + 0.7727(202) \\ = \$175.60$$

- c. For  $0 \leq x \leq 20$ :

$$C = 6.45 + 0.2012x + 0.7727x \\ = 6.45 + 0.9739x$$

For  $20 < x \leq 50$ :

$$C = 6.45 + 0.2012(20) + 0.1117(x - 20) \\ + 0.7727x \\ = 6.45 + 4.024 + 0.1117x - 2.234 \\ + 0.7727x \\ = 8.24 + 0.8844x$$

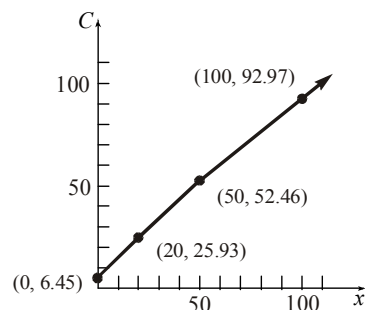
For  $x > 50$ :

$$C = 6.45 + 0.2012(20) + 0.1117(30) \\ + 0.0374(x - 50) + 0.7727x \\ = 6.45 + 4.024 + 3.351 + 0.0374x - 1.87 \\ + 0.7727x \\ = 11.955 + 0.8101x$$

The monthly charge function:

$$C(x) = \begin{cases} 0.9739x + 6.45 & \text{if } 0 \leq x \leq 20 \\ 0.8844x + 8.24 & \text{if } 20 < x \leq 50 \\ 0.8101x + 11.955 & \text{if } x > 50 \end{cases}$$

- d. Graph:





## Section 1.4: Library of Functions; Piecewise-defined Functions

49. For schedule X:

$$f(x) = \begin{cases} 0.10x & \text{if } 0 < x \leq 7300 \\ 730 + 0.15(x - 7300) & \text{if } 7300 < x \leq 29,700 \\ 4090 + 0.25(x - 29,700) & \text{if } 29,700 < x \leq 71,950 \\ 14,652.50 + 0.28(x - 71,950) & \text{if } 71,950 < x \leq 150,150 \\ 36,548.50 + 0.33(x - 150,150) & \text{if } 150,150 < x \leq 326,450 \\ 92,727.50 + 0.35(x - 326,450) & \text{if } x > 326,450 \end{cases}$$

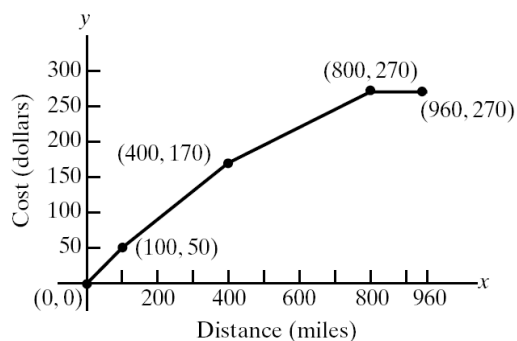
50. For Schedule Y-1:

$$f(x) = \begin{cases} 0.10x & \text{if } 0 < x \leq 14,600 \\ 1460 + 0.15(x - 14,600) & \text{if } 14,600 < x \leq 59,400 \\ 8180 + 0.25(x - 59,400) & \text{if } 59,400 < x \leq 119,950 \\ 23,317.50 + 0.28(x - 119,950) & \text{if } 119,950 < x \leq 182,800 \\ 40,915.50 + 0.33(x - 182,800) & \text{if } 182,800 < x \leq 326,450 \\ 88,320 + 0.35(x - 326,450) & \text{if } x > 326,450 \end{cases}$$

51. a. Let  $x$  represent the number of miles and  $C$  be the cost of transportation.

$$C(x) = \begin{cases} 0.50x & \text{if } 0 \leq x \leq 100 \\ 0.50(100) + 0.40(x - 100) & \text{if } 100 < x \leq 400 \\ 0.50(100) + 0.40(300) + 0.25(x - 400) & \text{if } 400 < x \leq 800 \\ 0.50(100) + 0.40(300) + 0.25(400) + 0(x - 800) & \text{if } 800 < x \leq 960 \end{cases}$$

$$C(x) = \begin{cases} 0.50x & \text{if } 0 \leq x \leq 100 \\ 10 + 0.40x & \text{if } 100 < x \leq 400 \\ 70 + 0.25x & \text{if } 400 < x \leq 800 \\ 270 & \text{if } 800 < x \leq 960 \end{cases}$$



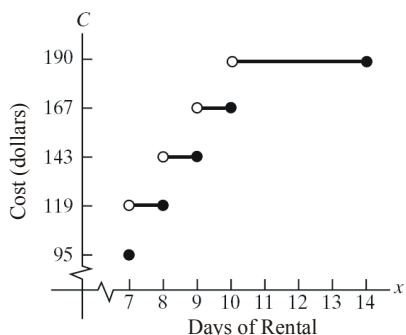
b. For hauls between 100 and 400 miles the cost is:  $C(x) = 10 + 0.40x$ .

c. For hauls between 400 and 800 miles the cost is:  $C(x) = 70 + 0.25x$ .

## Chapter 1: Functions and Their Graphs

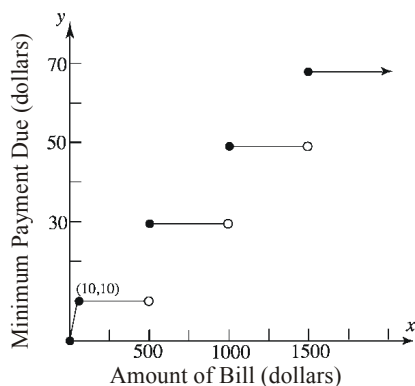
52. Let  $x$  = number of days car is used. The cost of renting is given by

$$C(x) = \begin{cases} 95 & \text{if } x = 7 \\ 119 & \text{if } 7 < x \leq 8 \\ 143 & \text{if } 8 < x \leq 9 \\ 167 & \text{if } 9 < x \leq 10 \\ 190 & \text{if } 10 < x \leq 14 \end{cases}$$



53. Let  $x$  = the amount of the bill in dollars. The minimum payment due is given by

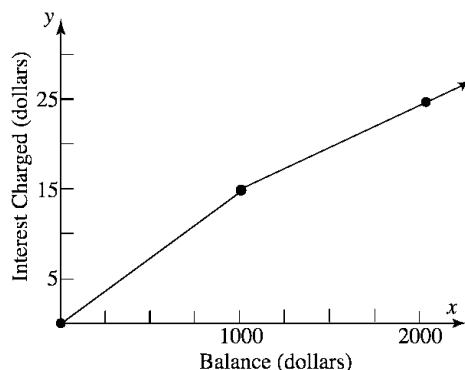
$$f(x) = \begin{cases} x & \text{if } x < 10 \\ 10 & \text{if } 10 \leq x < 500 \\ 30 & \text{if } 500 \leq x < 1000 \\ 50 & \text{if } 1000 \leq x < 1500 \\ 70 & \text{if } x \geq 1500 \end{cases}$$



54. Let  $x$  = the balance of the bill in dollars. The monthly interest charge is given by

$$g(x) = \begin{cases} 0.015x & \text{if } 0 \leq x \leq 1000 \\ 15 + 0.01(x - 1000) & \text{if } x > 1000 \end{cases}$$

$$= \begin{cases} 0.015x & \text{if } 0 \leq x \leq 1000 \\ 5 + 0.01x & \text{if } x > 1000 \end{cases}$$



55. a.  $W = 10^\circ\text{C}$

b.  $W = 33 - \frac{(10.45 + 10\sqrt{5} - 5)(33 - 10)}{22.04} \approx 4^\circ\text{C}$

c.  $W = 33 - \frac{(10.45 + 10\sqrt{15} - 15)(33 - 10)}{22.04} \approx -3^\circ\text{C}$

d.  $W = 33 - 1.5958(33 - 10) = -4^\circ\text{C}$

- e. When  $0 \leq v < 1.79$ , the wind speed is so small that there is no effect on the temperature.

- f. When the wind speed exceeds 20, the wind chill depends only on the temperature.

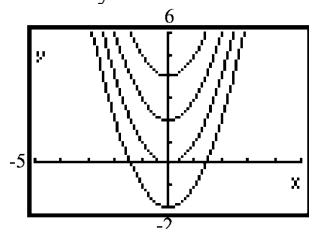
56. a.  $W = -10^\circ\text{C}$

b.  $W = 33 - \frac{(10.45 + 10\sqrt{5} - 5)(33 - (-10))}{22.04} \approx -21^\circ\text{C}$

c.  $W = 33 - \frac{(10.45 + 10\sqrt{15} - 15)(33 - (-10))}{22.04} \approx -34^\circ\text{C}$

d.  $W = 33 - 1.5958(33 - (-10)) = -36^\circ\text{C}$

57. Each graph is that of  $y = x^2$ , but shifted vertically.

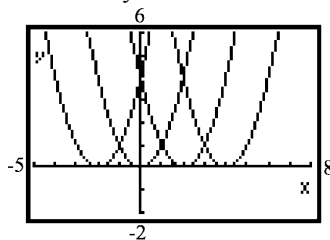


If  $y = x^2 + k$ ,  $k > 0$ , the shift is up  $k$  units; if  $y = x^2 + k$ ,  $k < 0$ , the shift is down  $|k|$  units.

## Section 1.4: Library of Functions; Piecewise-defined Functions

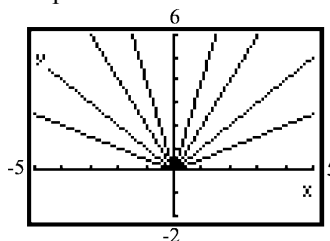
The graph of  $y = x^2 - 4$  is the same as the graph of  $y = x^2$ , but shifted down 4 units. The graph of  $y = x^2 + 5$  is the graph of  $y = x^2$ , but shifted up 5 units.

58. Each graph is that of  $y = x^2$ , but shifted horizontally.



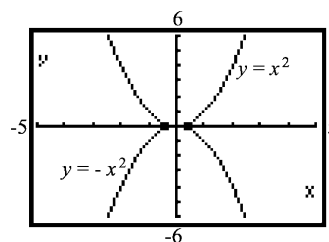
If  $y = (x - k)^2$ ,  $k > 0$ , the shift is to the right  $k$  units; if  $y = (x - k)^2$ ,  $k < 0$ , the shift is to the left  $|k|$  units. The graph of  $y = (x + 4)^2$  is the same as the graph of  $y = x^2$ , but shifted to the left 4 units. The graph of  $y = (x - 5)^2$  is the graph of  $y = x^2$ , but shifted to the right 5 units.

59. Each graph is that of  $y = |x|$ , but either compressed or stretched vertically.

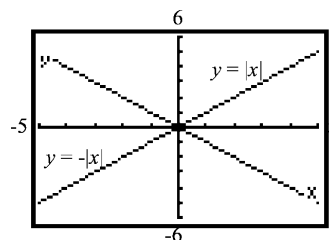


If  $y = k|x|$  and  $k > 1$ , the graph is stretched vertically; if  $y = k|x|$  and  $0 < k < 1$ , the graph is compressed vertically. The graph of  $y = \frac{1}{4}|x|$  is the same as the graph of  $y = |x|$ , but compressed vertically. The graph of  $y = 5|x|$  is the same as the graph of  $y = |x|$ , but stretched vertically.

60. The graph of  $y = -x^2$  is the reflection of the graph of  $y = x^2$  about the  $x$ -axis.

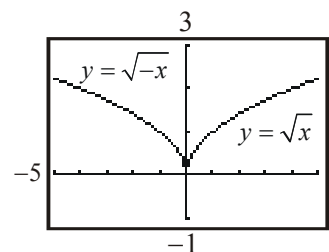


The graph of  $y = -|x|$  is the reflection of the graph of  $y = |x|$  about the  $x$ -axis.

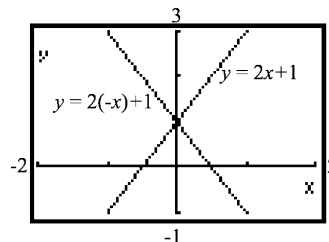


Multiplying a function by  $-1$  causes the graph to be a reflection about the  $x$ -axis of the original function's graph.

61. The graph of  $y = \sqrt{-x}$  is the reflection about the  $y$ -axis of the graph of  $y = \sqrt{x}$ .



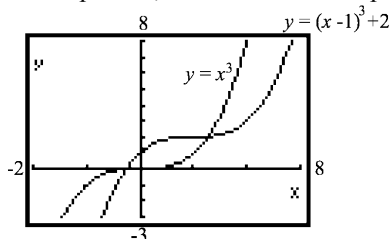
The same type of reflection occurs when graphing  $y = 2x + 1$  and  $y = 2(-x) + 1$ .



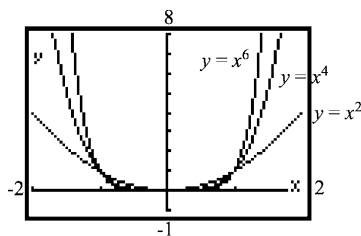
The graph of  $y = f(-x)$  is the reflection about the  $y$ -axis of the graph of  $y = f(x)$ .

## Chapter 1: Functions and Their Graphs

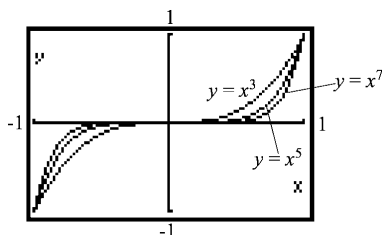
62. The graph of  $y = (x-1)^3 + 2$  is a shifting of the graph of  $y = x^3$  one unit to the right and two units up. Yes, the result could be predicted.



63. The graphs of  $y = x^n$ ,  $n$  a positive even integer, are all U-shaped and open upward. All go through the points  $(-1, 1)$ ,  $(0, 0)$ , and  $(1, 1)$ . As  $n$  increases, the graph of the function is narrower for  $|x| > 1$  and flatter for  $|x| < 1$ .



64. The graphs of  $y = x^n$ ,  $n$  a positive odd integer, all have the same general shape. All go through the points  $(-1, -1)$ ,  $(0, 0)$ , and  $(1, 1)$ . As  $n$  increases, the graph of the function increases at a greater rate for  $|x| > 1$  and is flatter around 0 for  $|x| < 1$ .



65.  $f(x) = \begin{cases} 1 & \text{if } x \text{ is rational} \\ 0 & \text{if } x \text{ is irrational} \end{cases}$

Yes, it is a function.

Domain =  $\{x \mid x \text{ is any real number}\}$

Range =  $\{0, 1\}$

y-intercept:  $x = 0 \Rightarrow x$  is rational  $\Rightarrow y = 1$  So the y-intercept is  $(0, 1)$ .

x-intercept:  $y = 0 \Rightarrow x$  is irrational So the graph has infinitely many x-intercepts, namely, there is an x-intercept at each irrational value of  $x$ .

$$f(-x) = 1 = f(x) \text{ when } x \text{ is rational;}$$

$$f(-x) = 0 = f(x) \text{ when } x \text{ is irrational.}$$

Thus,  $f$  is even.

The graph of  $f$  consists of 2 infinite clusters of distinct points, extending horizontally in both directions. One cluster is located 1 unit above the  $x$ -axis, and the other is located along the  $x$ -axis.

66. For  $0 < x < 1$ , the graph of  $y = x^r$ ,  $r$  rational and  $r > 0$ , flattens down toward the  $x$ -axis as  $r$  gets bigger. For  $x > 1$ , the graph of  $y = x^r$  increases at a greater rate as  $r$  gets bigger.

### Section 1.5

- horizontal; right
- $y$
- $-5$ ,  $-2$ , and  $2$
- True; the graph of  $y = -f(x)$  is the reflection about the  $x$ -axis of the graph of  $y = f(x)$ .
- False; to obtain the graph of  $y = f(x+2) - 3$  you shift the graph of  $y = f(x)$  to the *left* 2 units and down 3 units.
- True; to obtain the graph of  $y = 2f(x)$  we multiply the  $y$ -coordinates of the graph of  $y = f(x)$  by 2. Since the  $y$ -coordinate of  $x$ -intercepts is 0 and  $2 \cdot 0 = 0$ , multiplying by a constant does not change the  $x$ -intercepts.
- B
- E
- H
- D
- I
- A
- L

## Section 1.5: Graphing Techniques: Transformations

14. C

15. F

16. J

17. G

18. K

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

20.  $y = (x + 4)^3$

21.  $y = x^3 + 4$

22.  $y = x^3 - 4$

23.  $y = (-x)^3 = -x^3$

24.  $y = -x^3$

25.  $y = 4x^3$

26.  $y = \left(\frac{1}{4}x\right)^3 = \frac{1}{64}x^3$

27. (1)  $y = \sqrt{x} + 2$

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

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

28. (1)  $y = -\sqrt{x}$

(2)  $y = -\sqrt{x - 3}$

(3)  $y = -\sqrt{x - 3} - 2$

29. (1)  $y = -\sqrt{x}$

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

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

30. (1)  $y = \sqrt{x} + 2$

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

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

31. (c); To go from  $y = f(x)$  to  $y = -f(x)$  we reflect about the  $x$ -axis. This means we change the sign of the  $y$ -coordinate for each point on the graph of  $y = f(x)$ . Thus, the point  $(3, 0)$  would remain the same.

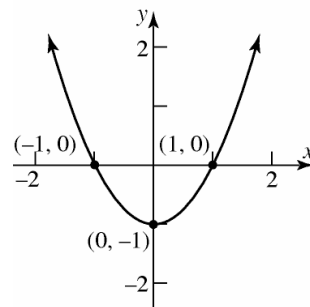
32. (d); To go from  $y = f(x)$  to  $y = f(-x)$ , we reflect each point on the graph of  $y = f(x)$  about the  $y$ -axis. This means we change the sign of the  $x$ -coordinate for each point on the graph of  $y = f(x)$ . Thus, the point  $(3, 0)$  would become  $(-3, 0)$ .

33. (c); To go from  $y = f(x)$  to  $y = 2f(x)$ , we multiply the  $y$ -coordinate of each point on the graph of  $y = f(x)$  by 2. Thus, the point  $(0, 3)$  would become  $(0, 6)$ .

34. (a); To go from  $y = f(x)$  to  $y = \frac{1}{2}f(x)$ , we multiply the  $y$ -coordinate of each point on the graph of  $y = f(x)$  by  $\frac{1}{2}$ . Thus, the point  $(3, 0)$  would remain  $(3, 0)$ .

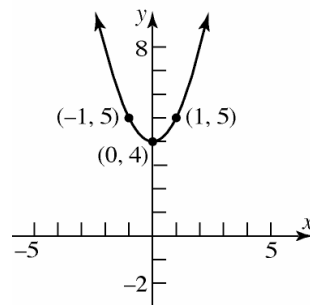
35.  $f(x) = x^2 - 1$

Using the graph of  $y = x^2$ , vertically shift downward 1 unit.



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

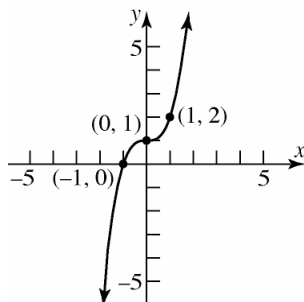
Using the graph of  $y = x^2$ , vertically shift upward 4 units.



## Chapter 1: Functions and Their Graphs

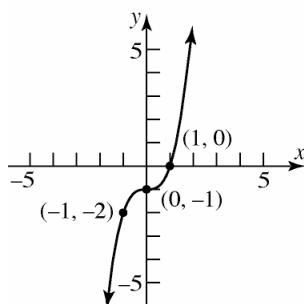
37.  $g(x) = x^3 + 1$

Using the graph of  $y = x^3$ , vertically shift upward 1 unit.



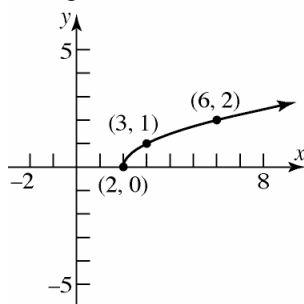
38.  $g(x) = x^3 - 1$

Using the graph of  $y = x^3$ , vertically shift downward 1 unit.



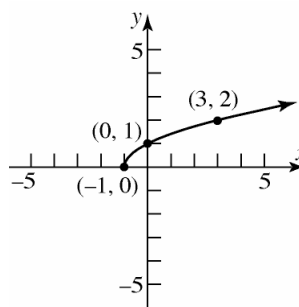
39.  $h(x) = \sqrt{x-2}$

Using the graph of  $y = \sqrt{x}$ , horizontally shift to the right 2 units.



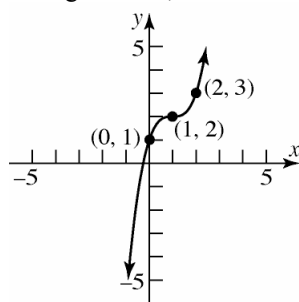
40.  $h(x) = \sqrt{x+1}$

Using the graph of  $y = \sqrt{x}$ , horizontally shift to the left 1 unit.



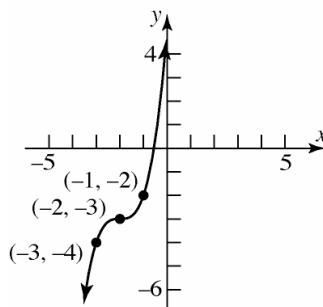
41.  $f(x) = (x-1)^3 + 2$

Using the graph of  $y = x^3$ , horizontally shift to the right 1 unit, then vertically shift up 2 units.



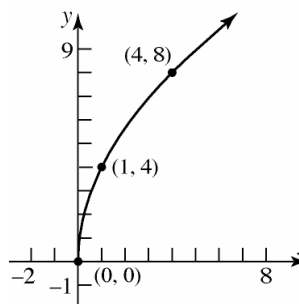
42.  $f(x) = (x+2)^3 - 3$

Using the graph of  $y = x^3$ , horizontally shift to the left 2 units, then vertically shift down 3 units.



43.  $g(x) = 4\sqrt{x}$

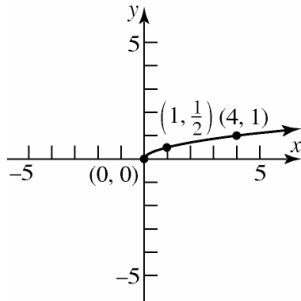
Using the graph of  $y = \sqrt{x}$ , vertically stretch by a factor of 4.



# Section 1.5: Graphing Techniques: Transformations

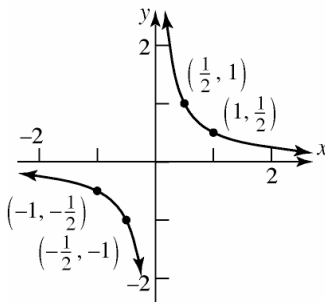
44.  $g(x) = \frac{1}{2}\sqrt{x}$

Using the graph of  $y = \sqrt{x}$ , vertically compress by a factor of  $\frac{1}{2}$ .



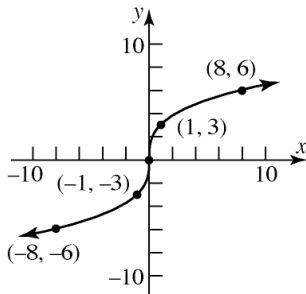
45.  $h(x) = \frac{1}{2x} = \left(\frac{1}{2}\right)\left(\frac{1}{x}\right)$

Using the graph of  $y = \frac{1}{x}$ , vertically compress by a factor of  $\frac{1}{2}$ .



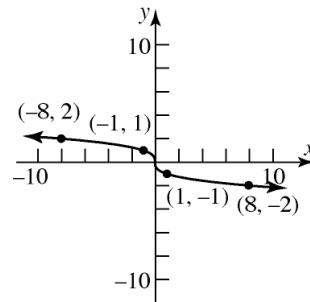
46.  $h(x) = 3\sqrt[3]{x}$

Using the graph of  $y = \sqrt[3]{x}$ , vertically stretch by a factor of 3.



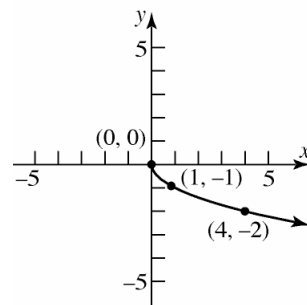
47.  $f(x) = -\sqrt[3]{x}$

Reflect the graph of  $y = \sqrt[3]{x}$ , about the x-axis.



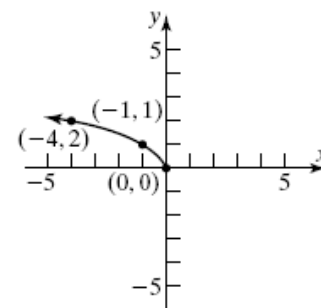
48.  $f(x) = -\sqrt{x}$

Reflect the graph of  $y = \sqrt{x}$ , about the x-axis.



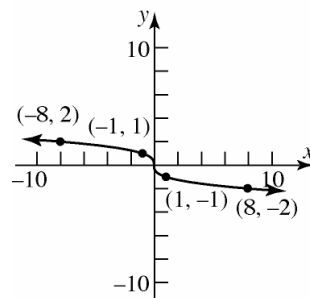
49.  $g(x) = \sqrt{-x}$

Reflect the graph of  $y = \sqrt{x}$  about the y-axis.



50.  $g(x) = \sqrt[3]{-x}$

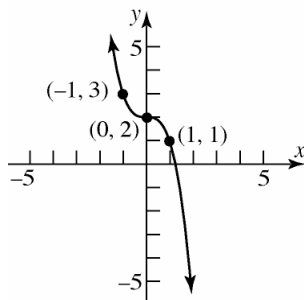
Reflect the graph of  $y = \sqrt[3]{x}$ , about the y-axis.



## Chapter 1: Functions and Their Graphs

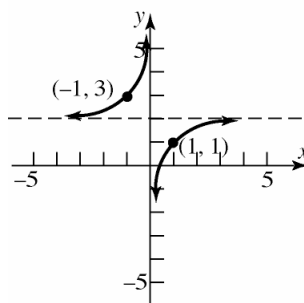
51.  $h(x) = -x^3 + 2$

Reflect the graph of  $y = x^3$  about the  $x$ -axis, then shift vertically upward 2 units.



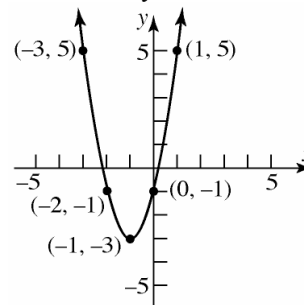
52.  $h(x) = \frac{1}{-x} + 2$

Reflect the graph of  $y = \frac{1}{x}$  about the  $y$ -axis, then shift vertically upward 2 units.



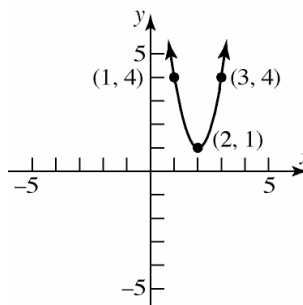
53.  $f(x) = 2(x+1)^2 - 3$

Using the graph of  $y = x^2$ , horizontally shift to the left 1 unit, vertically stretch by a factor of 2, and vertically shift downward 3 units.



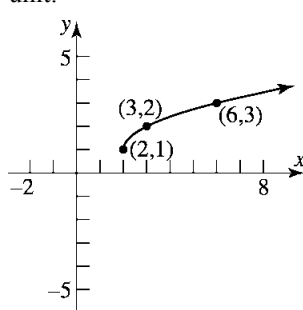
54.  $f(x) = 3(x-2)^2 + 1$

Using the graph of  $y = x^2$ , horizontally shift to the right 2 units, vertically stretch by a factor of 3, and vertically shift upward 1 unit.



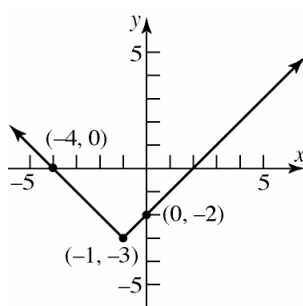
55.  $g(x) = \sqrt{x-2} + 1$

Using the graph of  $y = \sqrt{x}$ , horizontally shift to the right 2 units and vertically shift upward 1 unit.



56.  $g(x) = |x+1| - 3$

Using the graph of  $y = |x|$ , horizontally shift to the left 1 unit and vertically shift downward 3 units.

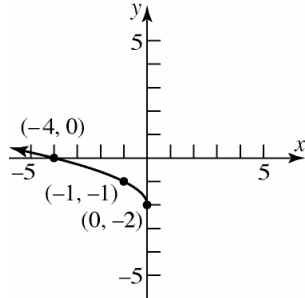




## Section 1.5: Graphing Techniques: Transformations

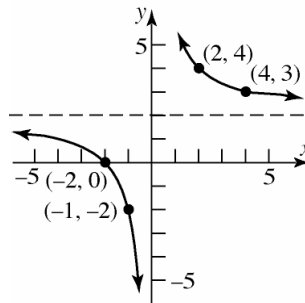
57.  $h(x) = \sqrt{-x} - 2$

Reflect the graph of  $y = \sqrt{x}$  about the  $y$ -axis and vertically shift downward 2 units.



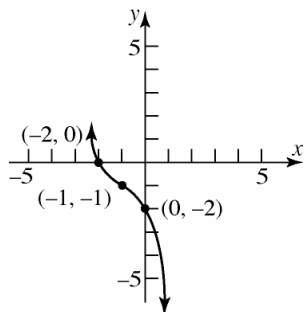
58.  $h(x) = \frac{4}{x} + 2 = 4\left(\frac{1}{x}\right) + 2$

Stretch the graph of  $y = \frac{1}{x}$  vertically by a factor of 4 and vertically shift upward 2 units.



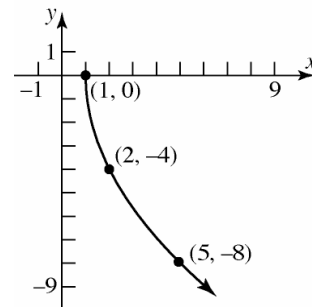
59.  $f(x) = -(x+1)^3 - 1$

Using the graph of  $y = x^3$ , horizontally shift to the left 1 unit, reflect the graph about the  $x$ -axis, and vertically shift downward 1 unit.



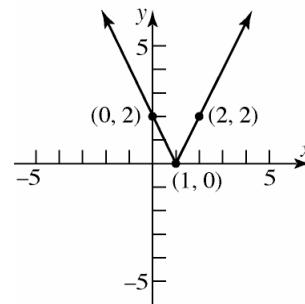
60.  $f(x) = -4\sqrt{x-1}$

Using the graph of  $y = \sqrt{x}$ , horizontally shift to the right 1 unit, reflect the graph about the  $x$ -axis, and stretch vertically by a factor of 4.



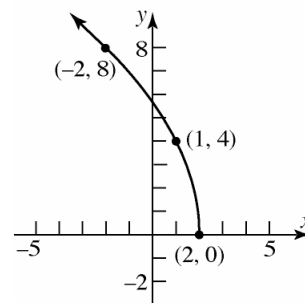
61.  $g(x) = 2|1-x| = 2|-(1+x)| = 2|x-1|$

Using the graph of  $y = |x|$ , horizontally shift to the right 1 unit, and vertically stretch by a factor of 2.



62.  $g(x) = 4\sqrt{2-x} = 4\sqrt{-(x-2)}$

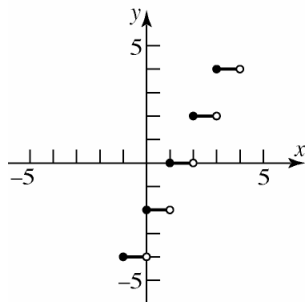
Reflect the graph of  $y = \sqrt{x}$  about the  $y$ -axis, horizontally shift to the right 2 units, and vertically stretch by a factor of 4.



## Chapter 1: Functions and Their Graphs

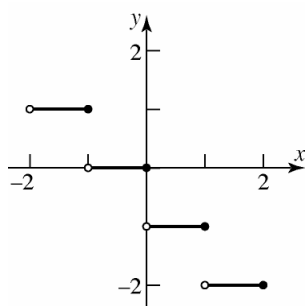
63.  $h(x) = 2 \operatorname{int}(x-1)$

Using the graph of  $y = \operatorname{int}(x)$ , horizontally shift to the right 1 unit, and vertically stretch by a factor of 2.



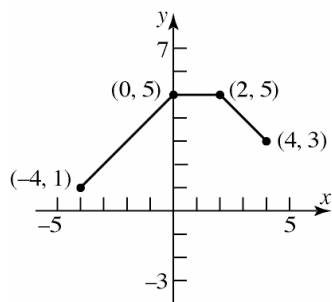
64.  $h(x) = \operatorname{int}(-x)$

Reflect the graph of  $y = \operatorname{int}(x)$  about the y-axis.



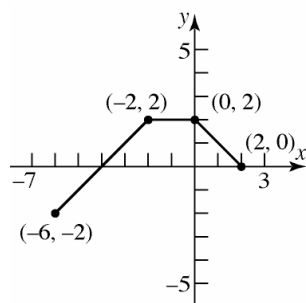
65. a.  $F(x) = f(x) + 3$

Shift up 3 units.



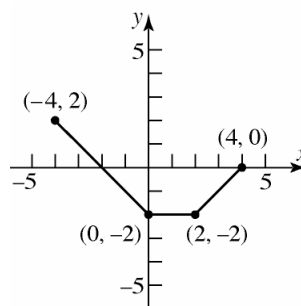
b.  $G(x) = f(x+2)$

Shift left 2 units.



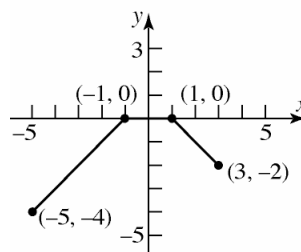
c.  $P(x) = -f(x)$

Reflect about the x-axis.



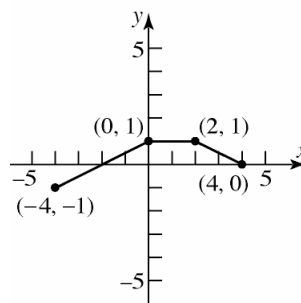
d.  $H(x) = f(x+1) - 2$

Shift left 1 unit and shift down 2 units.



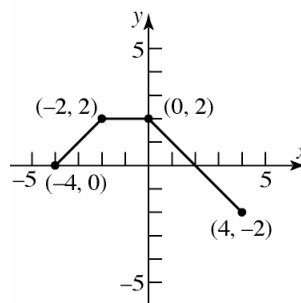
e.  $Q(x) = \frac{1}{2}f(x)$

Compress vertically by a factor of  $\frac{1}{2}$ .



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

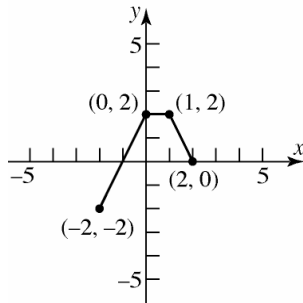
Reflect about the y-axis.



## Section 1.5: Graphing Techniques: Transformations

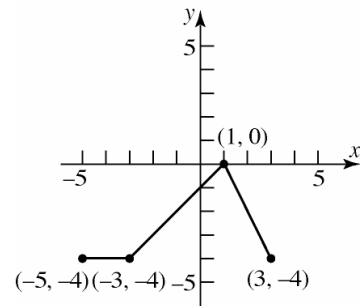
g.  $h(x) = f(2x)$

Compress horizontally by a factor of  $\frac{1}{2}$ .



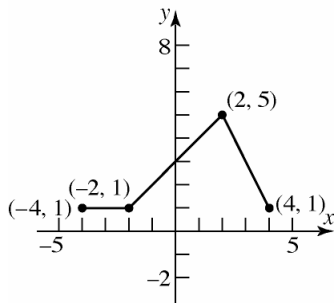
d.  $H(x) = f(x+1) - 2$

Shift left 1 unit and shift down 2 units.



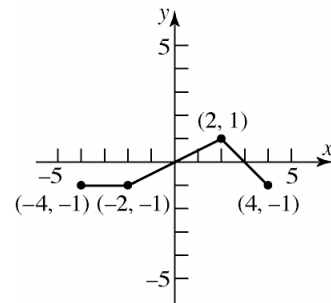
66. a.  $F(x) = f(x) + 3$

Shift up 3 units.



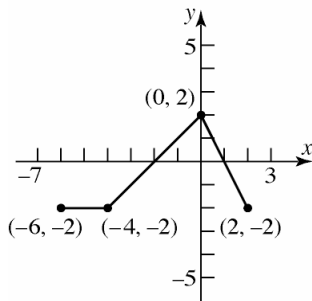
e.  $Q(x) = \frac{1}{2}f(x)$

Compress vertically by a factor of  $\frac{1}{2}$ .



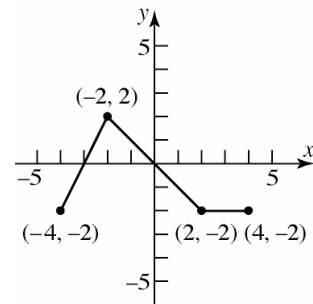
b.  $G(x) = f(x+2)$

Shift left 2 units.



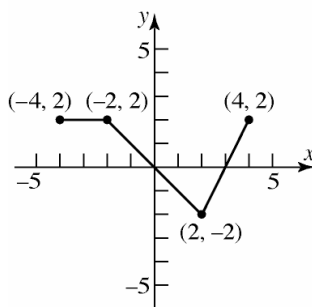
f.  $g(x) = f(-x)$

Reflect about the y-axis.



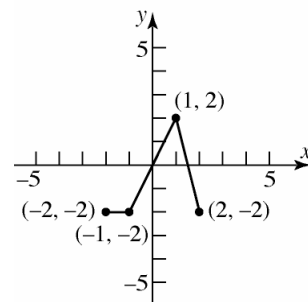
c.  $P(x) = -f(x)$

Reflect about the x-axis.



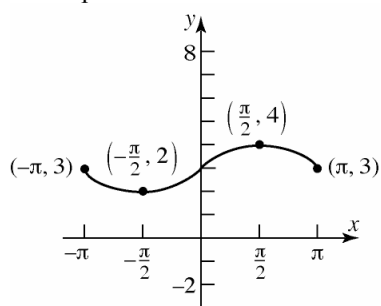
g.  $h(x) = f(2x)$

Compress horizontally by a factor of  $\frac{1}{2}$ .

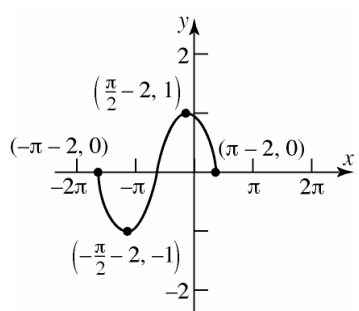


## Chapter 1: Functions and Their Graphs

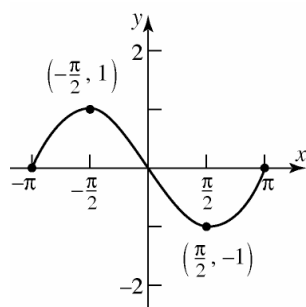
67. a.  $F(x) = f(x) + 3$   
Shift up 3 units.



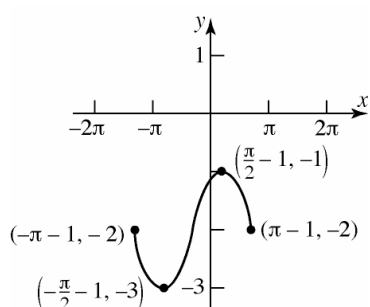
- b.  $G(x) = f(x + 2)$   
Shift left 2 units.



- c.  $P(x) = -f(x)$   
Reflect about the  $x$ -axis.

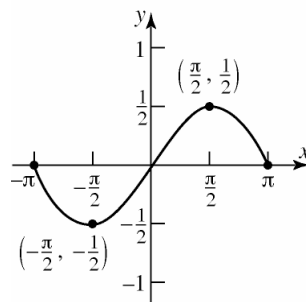


- d.  $H(x) = f(x + 1) - 2$   
Shift left 1 unit and shift down 2 units.

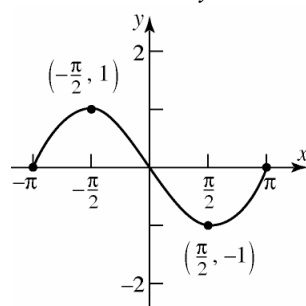


- e.  $Q(x) = \frac{1}{2}f(x)$

Compress vertically by a factor of  $\frac{1}{2}$ .

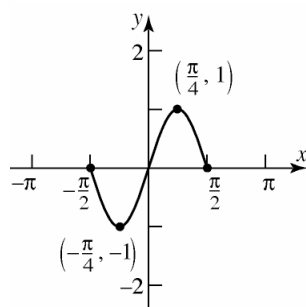


- f.  $g(x) = f(-x)$   
Reflect about the  $y$ -axis.

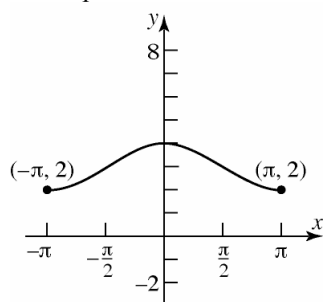


- g.  $h(x) = f(2x)$

Compress horizontally by a factor of  $\frac{1}{2}$ .



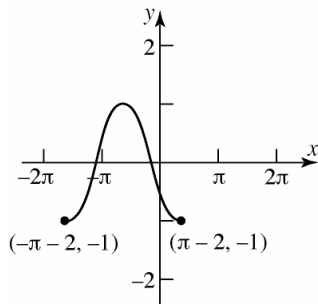
68. a.  $F(x) = f(x) + 3$   
Shift up 3 units.



## Section 1.5: Graphing Techniques: Transformations

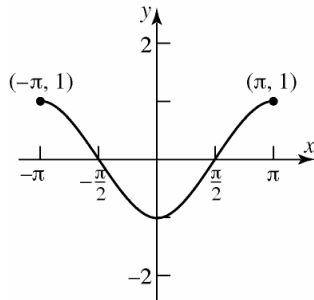
b.  $G(x) = f(x+2)$

Shift left 2 units.



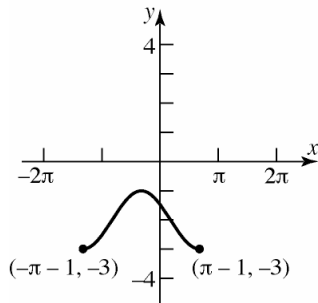
c.  $P(x) = -f(x)$

Reflect about the  $x$ -axis.



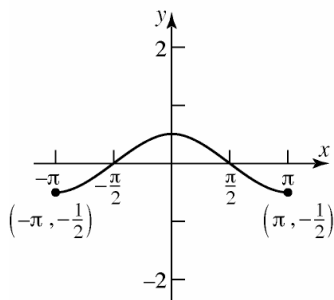
d.  $H(x) = f(x+1) - 2$

Shift left 1 unit and shift down 2 units.



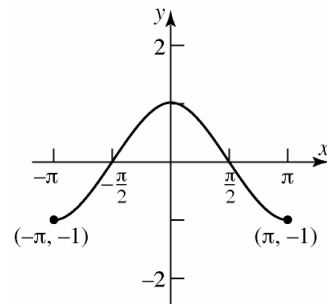
e.  $Q(x) = \frac{1}{2}f(x)$

Compress vertically by a factor of  $\frac{1}{2}$ .



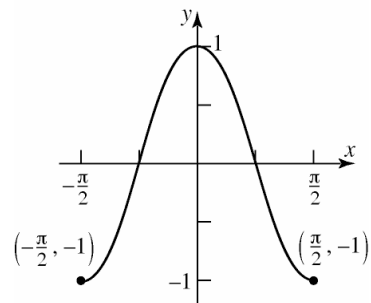
f.  $g(x) = f(-x)$

Reflect about the  $y$ -axis.



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

Compress horizontally by a factor of  $\frac{1}{2}$ .



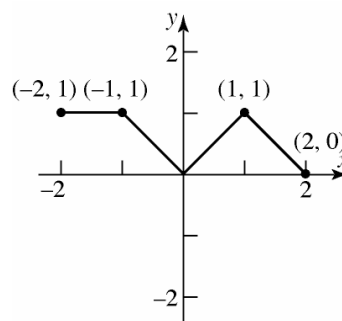
69. a. The graph of  $y = f(x+2)$  is the same as the graph of  $y = f(x)$ , but shifted 2 units to the left. Therefore, the  $x$ -intercepts are  $-7$  and  $1$ .
- b. The graph of  $y = f(x-2)$  is the same as the graph of  $y = f(x)$ , but shifted 2 units to the right. Therefore, the  $x$ -intercepts are  $-3$  and  $5$ .
- c. The graph of  $y = 4f(x)$  is the same as the graph of  $y = f(x)$ , but stretched vertically by a factor of 4. Therefore, the  $x$ -intercepts are still  $-5$  and  $3$  since the  $y$ -coordinate of each is 0.
- d. The graph of  $y = f(-x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $y$ -axis. Therefore, the  $x$ -intercepts are  $5$  and  $-3$ .

## Chapter 1: Functions and Their Graphs

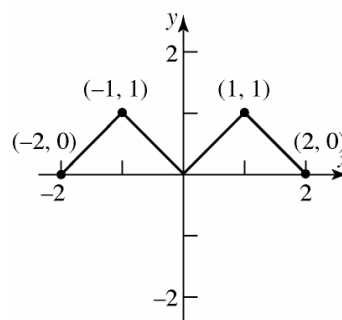
70. a. The graph of  $y = f(x+4)$  is the same as the graph of  $y = f(x)$ , but shifted 4 units to the left. Therefore, the  $x$ -intercepts are  $-12$  and  $-3$ .
- b. The graph of  $y = f(x-3)$  is the same as the graph of  $y = f(x)$ , but shifted 3 units to the right. Therefore, the  $x$ -intercepts are  $-5$  and  $4$ .
- c. The graph of  $y = 2f(x)$  is the same as the graph of  $y = f(x)$ , but stretched vertically by a factor of 2. Therefore, the  $x$ -intercepts are still  $-8$  and  $1$  since the  $y$ -coordinate of each is 0.
- d. The graph of  $y = f(-x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $y$ -axis. Therefore, the  $x$ -intercepts are  $8$  and  $-1$ .
71. a. The graph of  $y = f(x+2)$  is the same as the graph of  $y = f(x)$ , but shifted 2 units to the left. Therefore, the graph of  $f(x+2)$  is increasing on the interval  $(-3, 3)$ .
- b. The graph of  $y = f(x-5)$  is the same as the graph of  $y = f(x)$ , but shifted 5 units to the right. Therefore, the graph of  $f(x-5)$  is increasing on the interval  $(4, 10)$ .
- c. The graph of  $y = -f(x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $x$ -axis. Therefore, we can say that the graph of  $y = -f(x)$  must be *decreasing* on the interval  $(-1, 5)$ .
- d. The graph of  $y = f(-x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $y$ -axis. Therefore, we can say that the graph of  $y = f(-x)$  must be *decreasing* on the interval  $(-5, 1)$ .

72. a. The graph of  $y = f(x+2)$  is the same as the graph of  $y = f(x)$ , but shifted 2 units to the left. Therefore, the graph of  $f(x+2)$  is decreasing on the interval  $(-4, 5)$ .
- b. The graph of  $y = f(x-5)$  is the same as the graph of  $y = f(x)$ , but shifted 5 units to the right. Therefore, the graph of  $f(x-5)$  is decreasing on the interval  $(3, 12)$ .
- c. The graph of  $y = -f(x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $x$ -axis. Therefore, we can say that the graph of  $y = -f(x)$  must be *increasing* on the interval  $(-2, 7)$ .
- d. The graph of  $y = f(-x)$  is the same as the graph of  $y = f(x)$ , but reflected about the  $y$ -axis. Therefore, we can say that the graph of  $y = f(-x)$  must be *increasing* on the interval  $(-7, 2)$ .

73. a.  $y = |f(x)|$

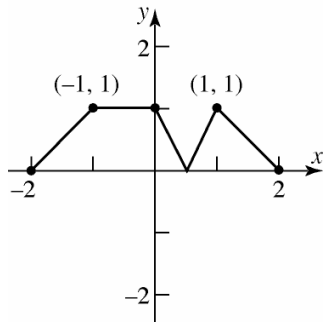


b.  $y = f(|x|)$

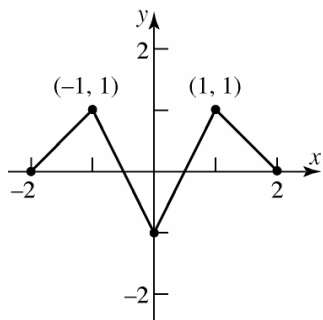


# Section 1.5: Graphing Techniques: Transformations

74. a.  $y = |f(x)|$



b.  $y = f(|x|)$

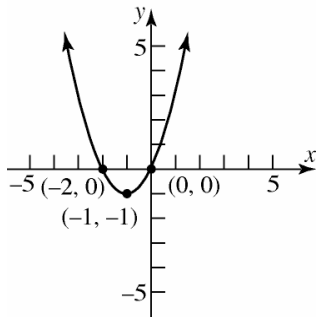


75.  $f(x) = x^2 + 2x$

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

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

Using  $f(x) = x^2$ , shift left 1 unit and shift down 1 unit.

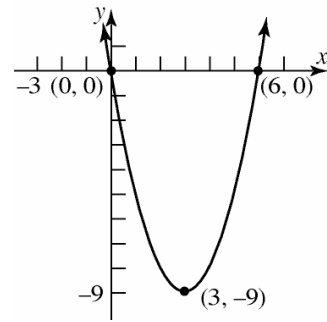


76.  $f(x) = x^2 - 6x$

$$f(x) = (x^2 - 6x + 9) - 9$$

$$f(x) = (x-3)^2 - 9$$

Using  $f(x) = x^2$ , shift right 3 units and shift down 9 units.

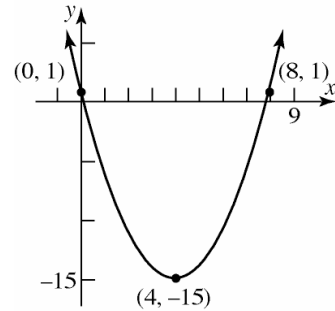


77.  $f(x) = x^2 - 8x + 1$

$$f(x) = (x^2 - 8x + 16) + 1 - 16$$

$$f(x) = (x-4)^2 - 15$$

Using  $f(x) = x^2$ , shift right 4 units and shift down 15 units.

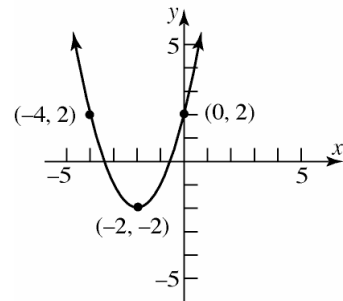


78.  $f(x) = x^2 + 4x + 2$

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

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

Using  $f(x) = x^2$ , shift left 2 units and shift down 2 units.



## Chapter 1: Functions and Their Graphs

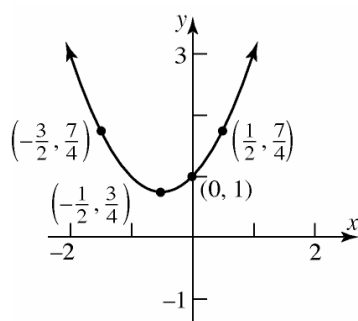
79.  $f(x) = x^2 + x + 1$

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

$$f(x) = \left(x + \frac{1}{2}\right)^2 + \frac{3}{4}$$

Using  $f(x) = x^2$ , shift left  $\frac{1}{2}$  unit and shift up

$\frac{3}{4}$  unit.



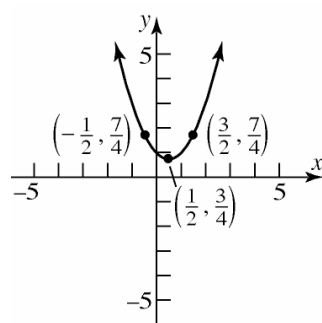
80.  $f(x) = x^2 - x + 1$

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

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

Using  $f(x) = x^2$ , shift right  $\frac{1}{2}$  unit and shift up

$\frac{3}{4}$  unit.



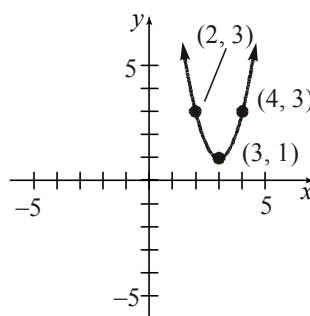
81.  $f(x) = 2x^2 - 12x + 19$

$$= 2(x^2 - 6x) + 19$$

$$= 2(x^2 - 6x + 9) + 19 - 18$$

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

Using  $f(x) = x^2$ , shift right 3 units, vertically stretch by a factor of 2, and then shift up 1 unit.



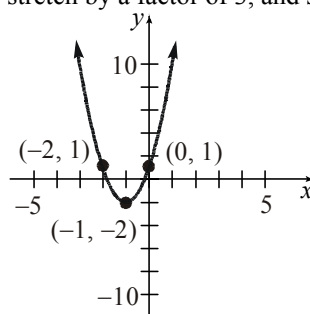
82.  $f(x) = 3x^2 + 6x + 1$

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

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

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

Using  $f(x) = x^2$ , shift left 1 unit, vertically stretch by a factor of 3, and shift down 2 units.



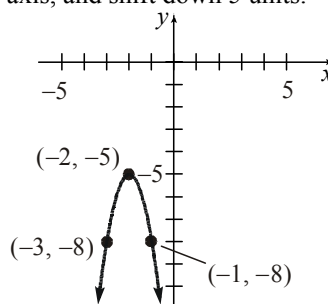
83.  $f(x) = -3x^2 - 12x - 17$

$$= -3(x^2 + 4x) - 17$$

$$= -3(x^2 + 4x + 4) - 17 + 12$$

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

Using  $f(x) = x^2$ , shift left 2 units, stretch vertically by a factor of 3, reflect about the  $x$ -axis, and shift down 5 units.

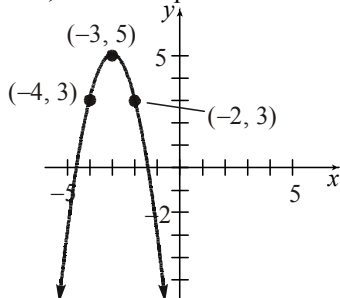




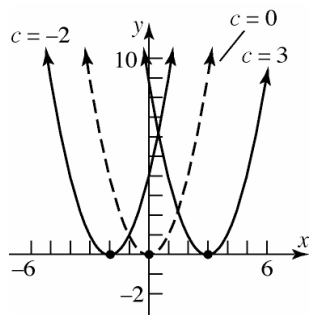
# Section 1.5: Graphing Techniques: Transformations

$$\begin{aligned}
 84. \quad f(x) &= -2x^2 - 12x - 13 \\
 &= -2(x^2 + 6x) - 13 \\
 &= -2(x^2 + 6x + 9) - 13 + 18 \\
 &= -2(x + 3)^2 + 5
 \end{aligned}$$

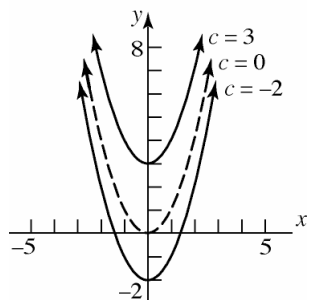
Using  $f(x) = x^2$ , shift left 3 units, stretch vertically by a factor of 2, reflect about the  $x$ -axis, and shift up 5 units.



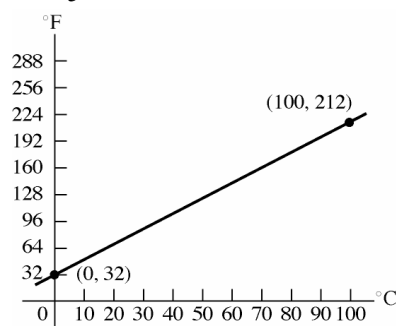
$$\begin{aligned}
 85. \quad y &= (x - c)^2 \\
 \text{If } c &= 0, y = x^2. \\
 \text{If } c &= 3, y = (x - 3)^2; \text{ shift right 3 units.} \\
 \text{If } c &= -2, y = (x + 2)^2; \text{ shift left 2 units.}
 \end{aligned}$$



$$\begin{aligned}
 86. \quad y &= x^2 + c \\
 \text{If } c &= 0, y = x^2. \\
 \text{If } c &= 3, y = x^2 + 3; \text{ shift up 3 units.} \\
 \text{If } c &= -2, y = x^2 - 2; \text{ shift down 2 units.}
 \end{aligned}$$

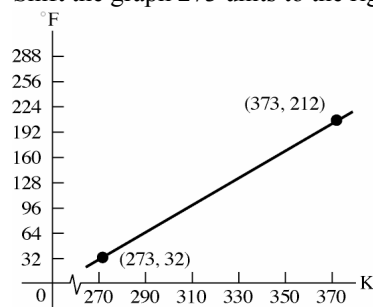


$$87. \quad F = \frac{9}{5}C + 32$$

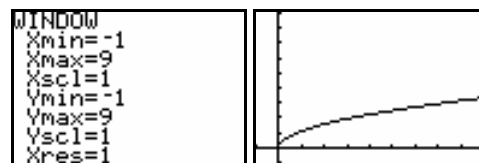


$$F = \frac{9}{5}(K - 273) + 32$$

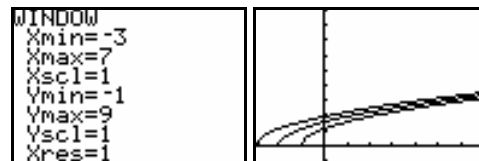
Shift the graph 273 units to the right.



$$88. \quad a. \quad T = 2\pi\sqrt{\frac{l}{g}}$$



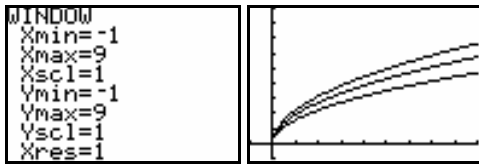
$$\begin{aligned}
 b. \quad T_1 &= 2\pi\sqrt{\frac{l+1}{g}}; \quad T_2 = 2\pi\sqrt{\frac{l+2}{g}}; \\
 T_3 &= 2\pi\sqrt{\frac{l+3}{g}}
 \end{aligned}$$



c. As the length of the pendulum increases, the period increases.

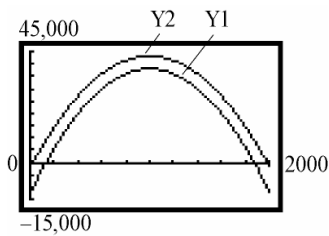
## Chapter 1: Functions and Their Graphs

d.  $T_1 = 2\pi\sqrt{\frac{2l}{g}}$ ;  $T_2 = 2\pi\sqrt{\frac{3l}{g}}$ ;  $T_3 = 2\pi\sqrt{\frac{4l}{g}}$

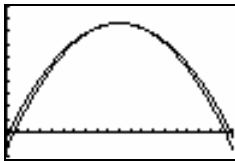


- e. If the length of the pendulum is multiplied by  $k$ , the period is multiplied by  $\sqrt{k}$ .

89. a.  $p(x) = -0.05x^2 + 100x - 2000$



- b. Select the 10% tax since the profits are higher.
- c. The graph of Y1 is obtained by shifting the graph of  $p(x)$  vertically down 10,000 units. The graph of Y2 is obtained by multiplying the  $y$ -coordinate of the graph of  $p(x)$  by 0.9. Thus, Y2 is the graph of  $p(x)$  vertically compressed by a factor of 0.9.
- d. Select the 10% tax since the graph of  $Y1 = 0.9p(x) \geq Y2 = -0.05x^2 + 100x - 6800$  for all  $x$  in the domain.



90. The graph of  $y = 4f(x)$  is a vertical stretch of the graph of  $f$  by a factor of 4, while the graph of  $y = f(4x)$  is a horizontal compression of the graph of  $f$  by a factor of  $\frac{1}{4}$ .

## Section 1.6

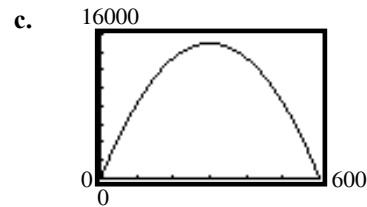
1.  $V = \pi r^2 h$ ,  $h = 2r \Rightarrow V(r) = \pi r^2 \cdot (2r) = 2\pi r^3$

2.  $V = \frac{1}{3}\pi r^2 h$ ,  $h = 2r$

$$V(r) = \frac{1}{3}\pi \cdot r^2 \cdot (2r) = \frac{2}{3}\pi r^3$$

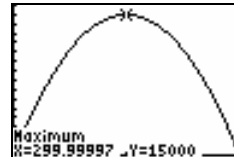
3. a.  $R(x) = x\left(-\frac{1}{6}x + 100\right) = -\frac{1}{6}x^2 + 100x$

b.  $R(200) = -\frac{1}{6}(200)^2 + 100(200)$   
 $= \frac{-20,000}{3} + 20,000$   
 $= \frac{40,000}{3} \approx \$13,333.33$



d.  $x = 300$  maximizes revenue  
 $R(300) = -\frac{1}{6}(300)^2 + 100(300)$   
 $= -15,000 + 30,000$   
 $= \$15,000$

The maximum revenue is \$15,000.

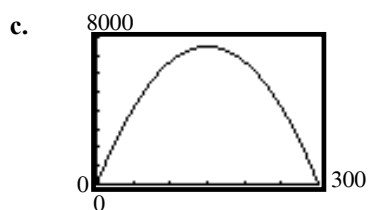


e.  $p = -\frac{1}{6}(300) + 100 = -50 + 100 = \$50$   
maximizes revenue

## Section 1.6: Mathematical Models: Constructing Functions

4. a.  $R(x) = x\left(-\frac{1}{3}x + 100\right)$   
 $= -\frac{1}{3}x^2 + 100x$

b.  $R(100) = -\frac{1}{3}(100)^2 + 100(100)$   
 $= \frac{-10,000}{3} + 10,000$   
 $= \frac{20,000}{3} \approx \$6666.67$



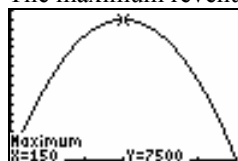
d.  $x = 150$  maximizes revenue

$$R(150) = -\frac{1}{3}(150)^2 + 100(150)$$

$$= -7500 + 15,000$$

$$= \$7500$$

The maximum revenue is \$7500.

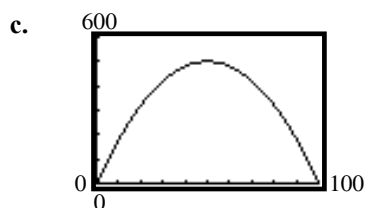


e.  $p = -\frac{1}{3}(150) + 100 = -50 + 100 = \$50$   
maximizes revenue

5. a. If  $x = -5p + 100$ , then  $p = \frac{100 - x}{5}$ .

$$R(x) = x\left(\frac{100 - x}{5}\right) = -\frac{1}{5}x^2 + 20x$$

b.  $R(15) = -\frac{1}{5}(15)^2 + 20(15)$   
 $= -45 + 300 = \$255$

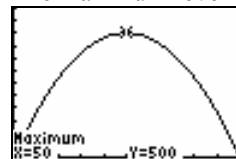


d.  $x = 50$  maximizes revenue

$$R(50) = -\frac{1}{5}(50)^2 + 20(50)$$

$$= -500 + 1000 = \$500$$

The maximum revenue is \$500.

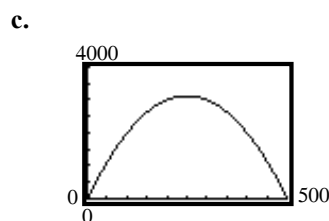


e.  $p = \frac{100 - 50}{5} = \frac{50}{5} = \$10$   
maximizes revenue.

6. a. If  $x = -20p + 500$ , then  $p = \frac{500 - x}{20}$ .

$$R(x) = x\left(\frac{500 - x}{20}\right) = -\frac{1}{20}x^2 + 25x$$

b.  $R(20) = -\frac{1}{20}(20)^2 + 25(20)$   
 $= -20 + 500 = \$480$

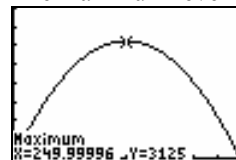


d.  $x = 250$  maximizes revenue

$$R(250) = -\frac{1}{20}(250)^2 + 25(250)$$

$$= -3125 + 6250 = \$3125$$

The maximum revenue is \$3125.



e.  $p = \frac{500 - 250}{20} = \frac{250}{20} = \$12.50$   
maximizes revenue.

## Chapter 1: Functions and Their Graphs

7. a. Let  $x$  = width and  $y$  = length of the rectangular area.

$$P = 2x + 2y = 400$$

$$y = \frac{400 - 2x}{2} = 200 - x$$

Then

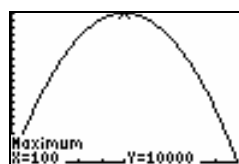
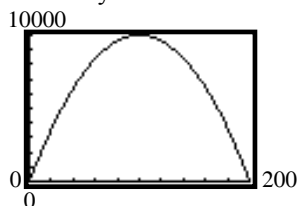
$$A(x) = (200 - x)x$$

$$= 200x - x^2$$

$$= -x^2 + 200x$$

- b. We need  $x > 0$  and  $y > 0$ . This means  $200 - x > 0 \Rightarrow 200 > x$ .  
Thus, the domain of  $A$  is  $\{x | 0 < x < 200\}$ .

- c.  $x = 100$  yards maximizes area



8. a. Let  $x$  = length and  $y$  = width of the rectangular field.

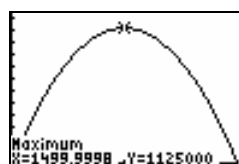
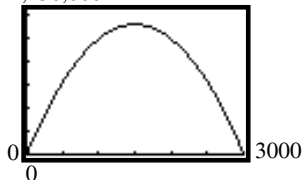
$$P = x + 2y = 3000$$

$$y = \frac{3000 - x}{2} = 1500 - \frac{1}{2}x$$

Then,

$$A(x) = \left(1500 - \frac{1}{2}x\right)x = 1500x - \frac{1}{2}x^2$$

- b.  $x = 1500$  feet maximizes area



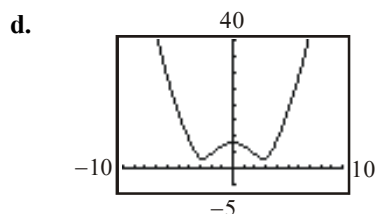
9. a. The distance  $d$  from  $P$  to the origin is

$d = \sqrt{x^2 + y^2}$ . Since  $P$  is a point on the graph of  $y = x^2 - 8$ , we have:

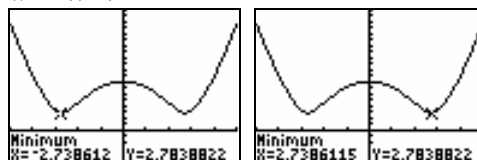
$$d(x) = \sqrt{x^2 + (x^2 - 8)^2} = \sqrt{x^4 - 15x^2 + 64}$$

b.  $d(0) = \sqrt{0^4 - 15(0)^2 + 64} = \sqrt{64} = 8$

c.  $d(1) = \sqrt{(1)^4 - 15(1)^2 + 64} = \sqrt{1 - 15 + 64} = \sqrt{50} = 5\sqrt{2} \approx 7.07$



- e.  $d$  is smallest when  $x \approx -2.74$  and when  $x \approx 2.74$ .



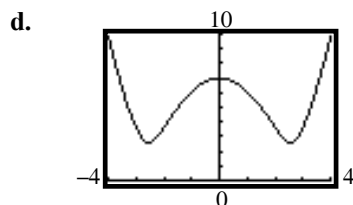
10. a. The distance  $d$  from  $P$  to  $(0, -1)$  is

$d = \sqrt{x^2 + (y+1)^2}$ . Since  $P$  is a point on the graph of  $y = x^2 - 8$ , we have:

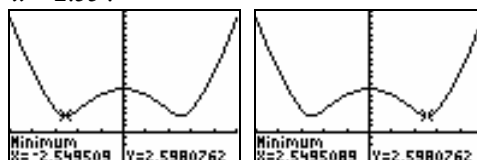
$$d(x) = \sqrt{x^2 + (x^2 - 8 + 1)^2} = \sqrt{x^2 + (x^2 - 7)^2} = \sqrt{x^4 - 13x^2 + 49}$$

b.  $d(0) = \sqrt{0^4 - 13(0)^2 + 49} = \sqrt{49} = 7$

c.  $d(-1) = \sqrt{(-1)^4 - 13(-1)^2 + 49} = \sqrt{37} \approx 6.08$



- e.  $d$  is smallest when  $x \approx -2.55$  and when  $x \approx 2.55$ .

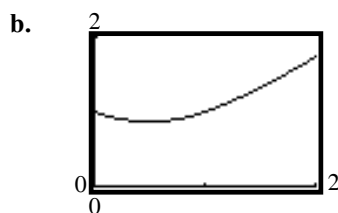


## Section 1.6: Mathematical Models: Constructing Functions

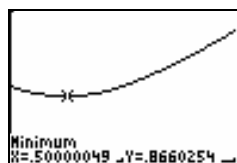
11. a. The distance  $d$  from  $P$  to the point  $(1, 0)$  is  $d = \sqrt{(x-1)^2 + y^2}$ . Since  $P$  is a point on the graph of  $y = \sqrt{x}$ , we have:

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

where  $x \geq 0$ .

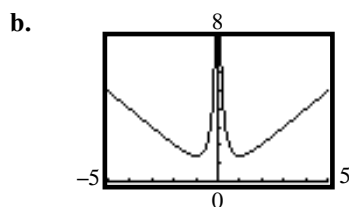


- c.  $d$  is smallest when  $x = \frac{1}{2}$ .

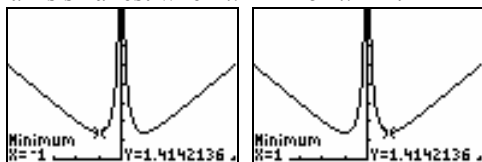


12. a. The distance  $d$  from  $P$  to the origin is  $d = \sqrt{x^2 + y^2}$ . Since  $P$  is a point on the graph of  $y = \frac{1}{x}$ , we have:

$$d(x) = \sqrt{x^2 + \left(\frac{1}{x}\right)^2} = \sqrt{x^2 + \frac{1}{x^2}} = \sqrt{\frac{x^4 + 1}{x^2}}$$



- c.  $d$  is smallest when  $x = -1$  or  $x = 1$ .



13. By definition, a triangle has area

$$A = \frac{1}{2}bh, \quad b = \text{base}, \quad h = \text{height}.$$

From the figure, we know that  $b = x$  and  $h = y$ . Expressing the area of the triangle as a function of  $x$ , we have:

$$A(x) = \frac{1}{2}xy = \frac{1}{2}x(x^3) = \frac{1}{2}x^4.$$

14. By definition, a triangle has area

$$A = \frac{1}{2}bh, \quad b = \text{base}, \quad h = \text{height}.$$

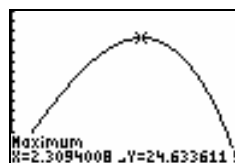
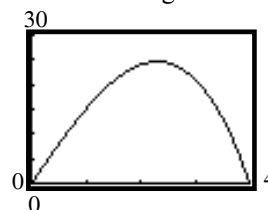
Because one vertex of the triangle is at the origin and the other is on the  $x$ -axis, we know that  $b = x$  and  $h = y$ . Expressing the area of the triangle as a function of  $x$ , we have:

$$A(x) = \frac{1}{2}xy = \frac{1}{2}x(9 - x^2) = \frac{9}{2}x - \frac{1}{2}x^3.$$

15. a.  $A(x) = xy = x(16 - x^2) = -x^3 + 16x$

- b. Domain:  $\{x \mid 0 < x < 4\}$

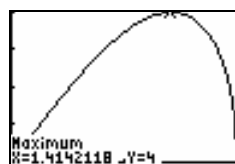
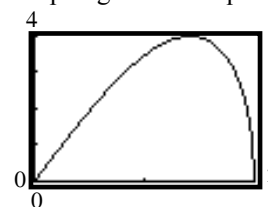
- c. The area is largest when  $x \approx 2.31$ .



16. a.  $A(x) = 2xy = 2x\sqrt{4 - x^2}$

- b.  $p(x) = 2(2x) + 2(y) = 4x + 2\sqrt{4 - x^2}$

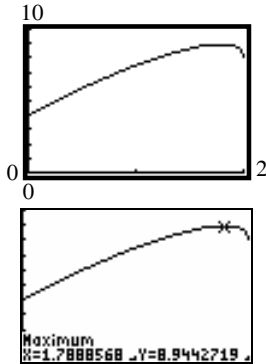
- c. Graphing the area equation:



The area is largest when  $x \approx 1.41$ .

## Chapter 1: Functions and Their Graphs

- d. Graphing the perimeter equation:



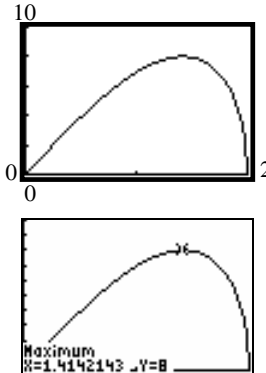
The perimeter is largest when  $x \approx 1.79$ .

17. a. In Quadrant I,  $x^2 + y^2 = 4 \rightarrow y = \sqrt{4 - x^2}$

$$A(x) = (2x)(2y) = 4x\sqrt{4 - x^2}$$

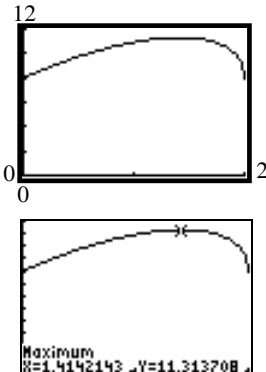
- b.  $p(x) = 2(2x) + 2(2y) = 4x + 4\sqrt{4 - x^2}$

- c. Graphing the area equation:



The area is largest when  $x \approx 1.41$ .

- d. Graphing the perimeter equation:



The perimeter is largest when  $x \approx 1.41$ .

18. a.  $A(r) = (2r)(2r) = 4r^2$

- b.  $p(r) = 4(2r) = 8r$

19. a.  $C$  = circumference,  $A$  = total area,  
 $r$  = radius,  $x$  = side of square

$$C = 2\pi r = 10 - 4x \Rightarrow r = \frac{5 - 2x}{\pi}$$

$$\text{Total Area} = \text{area}_{\text{square}} + \text{area}_{\text{circle}} = x^2 + \pi r^2$$

$$A(x) = x^2 + \pi \left( \frac{5 - 2x}{\pi} \right)^2 = x^2 + \frac{25 - 20x + 4x^2}{\pi}$$

- b. Since the lengths must be positive, we have:

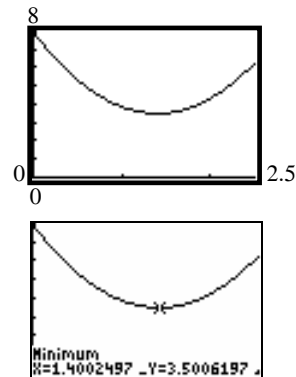
$$10 - 4x > 0 \quad \text{and} \quad x > 0$$

$$-4x > -10 \quad \text{and} \quad x > 0$$

$$x < 2.5 \quad \text{and} \quad x > 0$$

$$\text{Domain: } \{x \mid 0 < x < 2.5\}$$

- c. The total area is smallest when  $x \approx 1.40$  meters.



20. a.  $C$  = circumference,  $A$  = total area,  
 $r$  = radius,  $x$  = side of equilateral triangle

$$C = 2\pi r = 10 - 3x \Rightarrow r = \frac{10 - 3x}{2\pi}$$

$$\text{The height of the equilateral triangle is } \frac{\sqrt{3}}{2}x.$$

$$\text{Total Area} = \text{area}_{\text{triangle}} + \text{area}_{\text{circle}}$$

$$= \frac{1}{2}x \left( \frac{\sqrt{3}}{2}x \right) + \pi r^2$$

$$A(x) = \frac{\sqrt{3}}{4}x^2 + \pi \left( \frac{10 - 3x}{2\pi} \right)^2$$

$$= \frac{\sqrt{3}}{4}x^2 + \frac{100 - 60x + 9x^2}{4\pi}$$

## Section 1.6: Mathematical Models: Constructing Functions

- b. Since the lengths must be positive, we have:

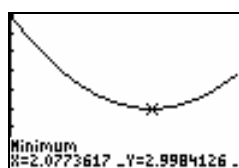
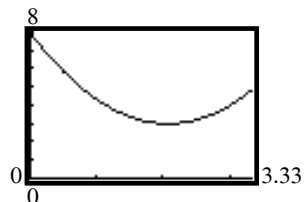
$$10 - 3x > 0 \quad \text{and} \quad x > 0$$

$$-3x > -10 \quad \text{and} \quad x > 0$$

$$x < \frac{10}{3} \quad \text{and} \quad x > 0$$

$$\text{Domain: } \left\{ x \mid 0 < x < \frac{10}{3} \right\}$$

- c. The area is smallest when  $x \approx 2.08$  meters.



21. a. Since the wire of length  $x$  is bent into a circle, the circumference is  $x$ . Therefore,  $C(x) = x$ .

- b. Since  $C = x = 2\pi r$ ,  $r = \frac{x}{2\pi}$ .

$$A(x) = \pi r^2 = \pi \left( \frac{x}{2\pi} \right)^2 = \frac{x^2}{4\pi}.$$

22. a. Since the wire of length  $x$  is bent into a square, the perimeter is  $x$ . Therefore,  $P(x) = x$ .

- b. Since  $P = x = 4s$ ,  $s = \frac{1}{4}x$ , we have

$$A(x) = s^2 = \left( \frac{1}{4}x \right)^2 = \frac{1}{16}x^2.$$

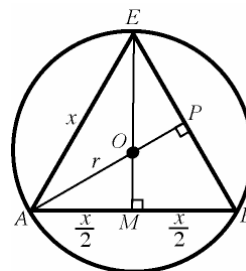
23. a.  $A$  = area,  $r$  = radius; diameter =  $2r$

$$A(r) = (2r)(r) = 2r^2$$

- b.  $p$  = perimeter

$$p(r) = 2(2r) + 2r = 6r$$

24.  $C$  = circumference,  $r$  = radius;  
 $x$  = length of a side of the triangle



$$\text{Since } \triangle ABC \text{ is equilateral, } EM = \frac{\sqrt{3}x}{2}.$$

$$\text{Therefore, } OM = \frac{\sqrt{3}x}{2} - OE = \frac{\sqrt{3}x}{2} - r$$

$$\text{In } \triangle OAM, r^2 = \left( \frac{x}{2} \right)^2 + \left( \frac{\sqrt{3}x}{2} - r \right)^2$$

$$r^2 = \frac{x^2}{4} + \frac{3}{4}x^2 - \sqrt{3}rx + r^2$$

$$\sqrt{3}rx = x^2$$

$$r = \frac{x}{\sqrt{3}}$$

Therefore, the circumference of the circle is

$$C(x) = 2\pi r = 2\pi \left( \frac{x}{\sqrt{3}} \right) = \frac{2\pi\sqrt{3}}{3}x$$

25. Area of the equilateral triangle

$$A = \frac{1}{2}x \cdot \frac{\sqrt{3}}{2}x = \frac{\sqrt{3}}{4}x^2$$

$$\text{From problem 24, we have } r^2 = \frac{x^2}{3}.$$

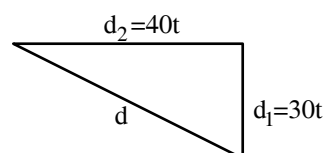
Area inside the circle, but outside the triangle:

$$\begin{aligned} A(x) &= \pi r^2 - \frac{\sqrt{3}}{4}x^2 \\ &= \pi \frac{x^2}{3} - \frac{\sqrt{3}}{4}x^2 = \left( \frac{\pi}{3} - \frac{\sqrt{3}}{4} \right) x^2 \end{aligned}$$

26.  $d^2 = d_1^2 + d_2^2$

$$d^2 = (30t)^2 + (40t)^2$$

$$d(t) = \sqrt{900t^2 + 1600t^2} = \sqrt{2500t^2} = 50t$$



## Chapter 1: Functions and Their Graphs

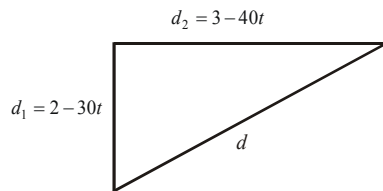
27. a.  $d^2 = d_1^2 + d_2^2$

$$d^2 = (2 - 30t)^2 + (3 - 40t)^2$$

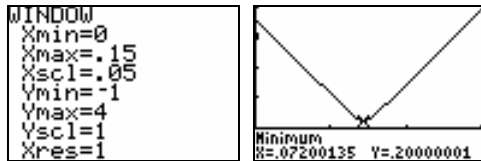
$$d(t) = \sqrt{(2 - 30t)^2 + (3 - 40t)^2}$$

$$= \sqrt{4 - 120t + 900t^2 + 9 - 240t + 1600t^2}$$

$$= \sqrt{2500t^2 - 360t + 13}$$



b. The distance is smallest at  $t \approx 0.07$  hours.



28.  $r$  = radius of cylinder,  $h$  = height of cylinder,  
 $V$  = volume of cylinder

$$r^2 + \left(\frac{h}{2}\right)^2 = R^2 \Rightarrow r^2 + \frac{h^2}{4} = R^2 \Rightarrow r^2 = R^2 - \frac{h^2}{4}$$

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

$$V(h) = \pi \left( R^2 - \frac{h^2}{4} \right) h = \pi h \left( R^2 - \frac{h^2}{4} \right)$$

29.  $r$  = radius of cylinder,  $h$  = height of cylinder,  
 $V$  = volume of cylinder

By similar triangles:  $\frac{H}{R} = \frac{H-h}{r}$

$$Hr = R(H-h)$$

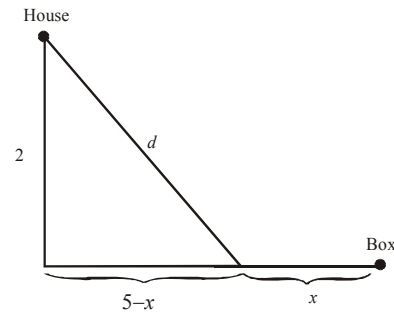
$$Hr = RH - Rh$$

$$Rh = RH - Hr$$

$$h = \frac{RH - Hr}{R} = \frac{H(R-r)}{R}$$

$$V = \pi r^2 h = \pi r^2 \left( \frac{H(R-r)}{R} \right) = \frac{\pi H(R-r)r^2}{R}$$

30. a. The total cost of installing the cable along the road is  $10x$ . If cable is installed  $x$  miles along the road, there are  $5-x$  miles between the road to the house and where the cable ends along the road.



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

$$= \sqrt{25 - 10x + x^2 + 4} = \sqrt{x^2 - 10x + 29}$$

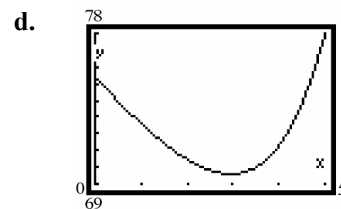
The total cost of installing the cable is:

$$C(x) = 10x + 14\sqrt{x^2 - 10x + 29}$$

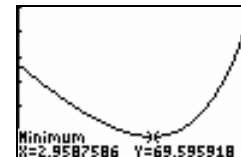
$$\text{Domain: } \{x \mid 0 \leq x \leq 5\}$$

b.  $C(1) = 10(1) + 14\sqrt{1^2 - 10(1) + 29}$   
 $= 10 + 14\sqrt{20} \approx \$72.61$

c.  $C(3) = 10(3) + 14\sqrt{3^2 - 10(3) + 29}$   
 $= 30 + 14\sqrt{8} \approx \$69.60$



e. Using MINIMUM, the graph indicates that  $x \approx 2.96$  miles results in the least cost.

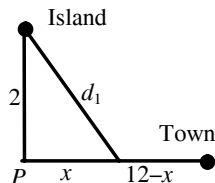




## Chapter 1 Review Exercises

31. a. The time on the boat is given by  $\frac{d_1}{3}$ . The

time on land is given by  $\frac{12-x}{5}$ .



$$d_1 = \sqrt{x^2 + 2^2} = \sqrt{x^2 + 4}$$

The total time for the trip is:

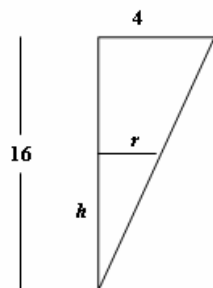
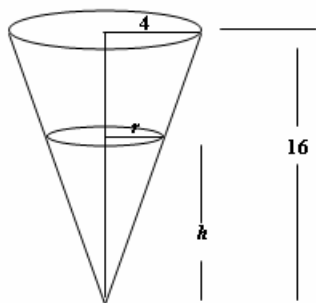
$$T(x) = \frac{12-x}{5} + \frac{d_1}{3} = \frac{12-x}{5} + \frac{\sqrt{x^2 + 4}}{3}$$

- b. Domain:  $\{x \mid 0 \leq x \leq 12\}$

$$\begin{aligned} \text{c. } T(4) &= \frac{12-4}{5} + \frac{\sqrt{4^2 + 4}}{3} \\ &= \frac{8}{5} + \frac{\sqrt{20}}{3} \approx 3.09 \text{ hours} \end{aligned}$$

$$\begin{aligned} \text{d. } T(8) &= \frac{12-8}{5} + \frac{\sqrt{8^2 + 4}}{3} \\ &= \frac{4}{5} + \frac{\sqrt{68}}{3} \approx 3.55 \text{ hours} \end{aligned}$$

32. Consider the diagrams shown below.



There is a pair of similar triangles in the diagram. Since the smaller triangle is similar to the larger triangle, we have the proportion

$$\frac{r}{h} = \frac{4}{16} \Rightarrow \frac{r}{h} = \frac{1}{4} \Rightarrow r = \frac{1}{4}h$$

Substituting into the volume formula for the conical portion of water gives

$$V(h) = \frac{1}{3} \pi r^2 h = \frac{1}{3} \pi \left( \frac{1}{4}h \right)^2 h = \frac{1}{48} \pi h^3.$$

## Chapter 1 Review Exercises

- This relation represents a function.  
Domain =  $\{-1, 2, 4\}$ ; Range =  $\{0, 3\}$ .
- This relation does not represent a function, since 4 is paired with two different values.

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

$$\text{a. } f(2) = \frac{3(2)}{(2)^2 - 1} = \frac{6}{4-1} = \frac{6}{3} = 2$$

$$\text{b. } f(-2) = \frac{3(-2)}{(-2)^2 - 1} = \frac{-6}{4-1} = \frac{-6}{3} = -2$$

$$\text{c. } f(-x) = \frac{3(-x)}{(-x)^2 - 1} = \frac{-3x}{x^2 - 1}$$

$$\text{d. } -f(x) = -\left( \frac{3x}{x^2 - 1} \right) = \frac{-3x}{x^2 - 1}$$

$$\begin{aligned} \text{e. } f(x-2) &= \frac{3(x-2)}{(x-2)^2 - 1} \\ &= \frac{3x-6}{x^2-4x+4-1} = \frac{3(x-2)}{x^2-4x+3} \end{aligned}$$

$$\text{f. } f(2x) = \frac{3(2x)}{(2x)^2 - 1} = \frac{6x}{4x^2 - 1}$$

$$4. \quad f(x) = \frac{x^2}{x+1}$$

$$\text{a. } f(2) = \frac{2^2}{2+1} = \frac{4}{3}$$

$$\text{b. } f(-2) = \frac{(-2)^2}{-2+1} = \frac{4}{-1} = -4$$

$$\text{c. } f(-x) = \frac{(-x)^2}{-x+1} = \frac{x^2}{-x+1}$$

## Chapter 1: Functions and Their Graphs

- d.  $-f(x) = -\frac{x^2}{x+1} = \frac{-x^2}{x+1}$
- e.  $f(x-2) = \frac{(x-2)^2}{(x-2)+1} = \frac{(x-2)^2}{x-1}$
- f.  $f(2x) = \frac{(2x)^2}{(2x)+1} = \frac{4x^2}{2x+1}$
5.  $f(x) = \sqrt{x^2 - 4}$
- a.  $f(2) = \sqrt{2^2 - 4} = \sqrt{4 - 4} = \sqrt{0} = 0$
- b.  $f(-2) = \sqrt{(-2)^2 - 4} = \sqrt{4 - 4} = \sqrt{0} = 0$
- c.  $f(-x) = \sqrt{(-x)^2 - 4} = \sqrt{x^2 - 4}$
- d.  $-f(x) = -\sqrt{x^2 - 4}$
- e.  $f(x-2) = \sqrt{(x-2)^2 - 4}$   
 $= \sqrt{x^2 - 4x + 4 - 4}$   
 $= \sqrt{x^2 - 4x}$
- f.  $f(2x) = \sqrt{(2x)^2 - 4} = \sqrt{4x^2 - 4}$   
 $= \sqrt{4(x^2 - 1)} = 2\sqrt{x^2 - 1}$
6.  $f(x) = |x^2 - 4|$
- a.  $f(2) = |2^2 - 4| = |4 - 4| = |0| = 0$
- b.  $f(-2) = |(-2)^2 - 4| = |4 - 4| = |0| = 0$
- c.  $f(-x) = |(-x)^2 - 4| = |x^2 - 4|$
- d.  $-f(x) = -|x^2 - 4|$
- e.  $f(x-2) = |(x-2)^2 - 4|$   
 $= |x^2 - 4x + 4 - 4|$   
 $= |x^2 - 4x|$
- f.  $f(2x) = |(2x)^2 - 4| = |4x^2 - 4|$   
 $= |4(x^2 - 1)| = 4|x^2 - 1|$
7.  $f(x) = \frac{x^2 - 4}{x^2}$
- a.  $f(2) = \frac{2^2 - 4}{2^2} = \frac{4 - 4}{4} = \frac{0}{4} = 0$
- b.  $f(-2) = \frac{(-2)^2 - 4}{(-2)^2} = \frac{4 - 4}{4} = \frac{0}{4} = 0$
- c.  $f(-x) = \frac{(-x)^2 - 4}{(-x)^2} = \frac{x^2 - 4}{x^2}$
- d.  $-f(x) = -\left(\frac{x^2 - 4}{x^2}\right) = \frac{4 - x^2}{x^2} = -\frac{x^2 - 4}{x^2}$
- e.  $f(x-2) = \frac{(x-2)^2 - 4}{(x-2)^2} = \frac{x^2 - 4x + 4 - 4}{(x-2)^2}$   
 $= \frac{x^2 - 4x}{(x-2)^2} = \frac{x(x-4)}{(x-2)^2}$
- f.  $f(2x) = \frac{(2x)^2 - 4}{(2x)^2} = \frac{4x^2 - 4}{4x^2}$   
 $= \frac{4(x^2 - 1)}{4x^2} = \frac{x^2 - 1}{x^2}$
8.  $f(x) = \frac{x^3}{x^2 - 9}$
- a.  $f(2) = \frac{2^3}{2^2 - 9} = \frac{8}{4 - 9} = \frac{8}{-5} = -\frac{8}{5}$
- b.  $f(-2) = \frac{(-2)^3}{(-2)^2 - 9} = \frac{-8}{4 - 9} = \frac{-8}{-5} = \frac{8}{5}$
- c.  $f(-x) = \frac{(-x)^3}{(-x)^2 - 9} = \frac{-x^3}{x^2 - 9}$
- d.  $-f(x) = -\frac{x^3}{x^2 - 9} = \frac{-x^3}{x^2 - 9}$
- e.  $f(x-2) = \frac{(x-2)^3}{(x-2)^2 - 9}$   
 $= \frac{(x-2)^3}{x^2 - 4x + 4 - 9}$   
 $= \frac{(x-2)^3}{x^2 - 4x - 5}$
- f.  $f(2x) = \frac{(2x)^3}{(2x)^2 - 9} = \frac{8x^3}{4x^2 - 9}$

9.  $f(x) = \frac{x}{x^2 - 9}$

The denominator cannot be zero:

$$x^2 - 9 \neq 0$$

$$(x+3)(x-3) \neq 0$$

$$x \neq -3 \text{ or } 3$$

$$\text{Domain: } \{x \mid x \neq -3, x \neq 3\}$$

10.  $f(x) = \frac{3x^2}{x-2}$

The denominator cannot be zero:

$$x - 2 \neq 0$$

$$x \neq 2$$

$$\text{Domain: } \{x \mid x \neq 2\}$$

11.  $f(x) = \sqrt{2-x}$

The radicand must be non-negative:

$$2 - x \geq 0$$

$$x \leq 2$$

$$\text{Domain: } \{x \mid x \leq 2\} \text{ or } (-\infty, 2]$$

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

The radicand must be non-negative:

$$x + 2 \geq 0$$

$$x \geq -2$$

$$\text{Domain: } \{x \mid x \geq -2\} \text{ or } [-2, \infty)$$

13.  $f(x) = \frac{\sqrt{x}}{|x|}$

The radicand must be non-negative and the denominator cannot be zero:  $x > 0$

$$\text{Domain: } \{x \mid x > 0\} \text{ or } (0, \infty)$$

14.  $g(x) = \frac{|x|}{x}$

The denominator cannot be zero:

$$x \neq 0$$

$$\text{Domain: } \{x \mid x \neq 0\}$$

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

The denominator cannot be zero:

$$x^2 + 2x - 3 \neq 0$$

$$(x+3)(x-1) \neq 0$$

$$x \neq -3 \text{ or } 1$$

$$\text{Domain: } \{x \mid x \neq -3, x \neq 1\}$$

16.  $F(x) = \frac{1}{x^2 - 3x - 4}$

The denominator cannot be zero:

$$x^2 - 3x - 4 \neq 0$$

$$(x+1)(x-4) \neq 0$$

$$x \neq -1 \text{ or } 4$$

$$\text{Domain: } \{x \mid x \neq -1, x \neq 4\}$$

17.  $f(x) = 2 - x$     $g(x) = 3x + 1$

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

$$= 2 - x + 3x + 1 = 2x + 3$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

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

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

$$= 2 - x - 3x - 1$$

$$= -4x + 1$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$(f \cdot g)(x) = f(x) \cdot g(x)$$

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

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

$$= -3x^2 + 5x + 2$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{2-x}{3x+1}$$

$$3x + 1 \neq 0$$

$$3x \neq -1 \Rightarrow x \neq -\frac{1}{3}$$

$$\text{Domain: } \left\{x \mid x \neq -\frac{1}{3}\right\}$$

18.  $f(x) = 2x - 1$     $g(x) = 2x + 1$

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

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

$$= 4x$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

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

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

$$= 2x - 1 - 2x - 1$$

$$= -2$$

$$\text{Domain: } \{x \mid x \text{ is any real number}\}$$

## Chapter 1: Functions and Their Graphs

$$\begin{aligned}(f \cdot g)(x) &= f(x) \cdot g(x) \\ &= (2x-1)(2x+1) \\ &= 4x^2 - 1\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{2x-1}{2x+1}$$

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

Domain:  $\{x \mid x \neq -\frac{1}{2}\}$

19.  $f(x) = 3x^2 + x + 1 \quad g(x) = 3x$

$$\begin{aligned}(f+g)(x) &= f(x) + g(x) \\ &= 3x^2 + x + 1 + 3x \\ &= 3x^2 + 4x + 1\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\begin{aligned}(f-g)(x) &= f(x) - g(x) \\ &= 3x^2 + x + 1 - 3x \\ &= 3x^2 - 2x + 1\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\begin{aligned}(f \cdot g)(x) &= f(x) \cdot g(x) \\ &= (3x^2 + x + 1)(3x) \\ &= 9x^3 + 3x^2 + 3x\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{3x^2 + x + 1}{3x}$$

$$3x \neq 0 \Rightarrow x \neq 0$$

Domain:  $\{x \mid x \neq 0\}$

20.  $f(x) = 3x \quad g(x) = 1 + x + x^2$

$$\begin{aligned}(f+g)(x) &= f(x) + g(x) \\ &= 3x + 1 + x + x^2 \\ &= x^2 + 4x + 1\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\begin{aligned}(f-g)(x) &= f(x) - g(x) \\ &= 3x - (1 + x + x^2) \\ &= -x^2 + 2x - 1\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\begin{aligned}(f \cdot g)(x) &= f(x) \cdot g(x) \\ &= (3x)(1 + x + x^2) \\ &= 3x + 3x^2 + 3x^3\end{aligned}$$

Domain:  $\{x \mid x \text{ is any real number}\}$

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{3x}{1 + x + x^2}$$

$$1 + x + x^2 \neq 0$$

$$x^2 + x + 1 \neq 0$$

Since the discriminant is  $1^2 - 4(1)(1) = -3 < 0$ ,

$x^2 + x + 1$  will never equal 0.

Domain:  $\{x \mid x \text{ is any real number}\}$

21.  $f(x) = \frac{x+1}{x-1} \quad g(x) = \frac{1}{x}$

$$\begin{aligned}(f+g)(x) &= f(x) + g(x) \\ &= \frac{x+1}{x-1} + \frac{1}{x} = \frac{x(x+1) + 1(x-1)}{x(x-1)} \\ &= \frac{x^2 + x + x - 1}{x(x-1)} = \frac{x^2 + 2x - 1}{x(x-1)}\end{aligned}$$

Domain:  $\{x \mid x \neq 0, x \neq 1\}$

$$\begin{aligned}(f-g)(x) &= f(x) - g(x) \\ &= \frac{x+1}{x-1} - \frac{1}{x} = \frac{x(x+1) - 1(x-1)}{x(x-1)} \\ &= \frac{x^2 + x - x + 1}{x(x-1)} = \frac{x^2 + 1}{x(x-1)}\end{aligned}$$

Domain:  $\{x \mid x \neq 0, x \neq 1\}$

$$(f \cdot g)(x) = f(x) \cdot g(x) = \left(\frac{x+1}{x-1}\right)\left(\frac{1}{x}\right) = \frac{x+1}{x(x-1)}$$

Domain:  $\{x \mid x \neq 0, x \neq 1\}$

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} = \frac{\frac{x+1}{x-1}}{\frac{1}{x}} = \left(\frac{x+1}{x-1}\right)\left(\frac{x}{1}\right) = \frac{x(x+1)}{x-1}$$

Domain:  $\{x \mid x \neq 0, x \neq 1\}$

$$22. f(x) = \frac{1}{x-3} \quad g(x) = \frac{3}{x}$$

$$\begin{aligned}(f+g)(x) &= f(x) + g(x) \\ &= \frac{1}{x-3} + \frac{3}{x} = \frac{x+3(x-3)}{x(x-3)} \\ &= \frac{x+3x-9}{x(x-3)} = \frac{4x-9}{x(x-3)}\end{aligned}$$

$$\text{Domain: } \{x \mid x \neq 0, x \neq 3\}$$

$$\begin{aligned}(f-g)(x) &= f(x) - g(x) = \frac{1}{x-3} - \frac{3}{x} \\ &= \frac{x-3(x-3)}{x(x-3)} = \frac{x-3x+9}{x(x-3)} \\ &= \frac{-2x+9}{x(x-3)}\end{aligned}$$

$$\text{Domain: } \{x \mid x \neq 0, x \neq 3\}$$

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

$$\text{Domain: } \{x \mid x \neq 0, x \neq 3\}$$

$$\begin{aligned}\left(\frac{f}{g}\right)(x) &= \frac{f(x)}{g(x)} = \frac{\frac{1}{x-3}}{\frac{3}{x}} \\ &= \left(\frac{1}{x-3}\right)\left(\frac{x}{3}\right) \\ &= \frac{x}{3(x-3)}\end{aligned}$$

$$\text{Domain: } \{x \mid x \neq 0, x \neq 3\}$$

$$23. f(x) = -2x^2 + x + 1$$

$$\begin{aligned}\frac{f(x+h)-f(x)}{h} &= \frac{-2(x+h)^2 + (x+h) + 1 - (-2x^2 + x + 1)}{h} \\ &= \frac{-2(x^2 + 2xh + h^2) + x + h + 1 + 2x^2 - x - 1}{h} \\ &= \frac{-2x^2 - 4xh - 2h^2 + x + h + 1 + 2x^2 - x - 1}{h} \\ &= \frac{-4xh - 2h^2 + h}{h} = \frac{h(-4x - 2h + 1)}{h} \\ &= -4x - 2h + 1\end{aligned}$$

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

$$\begin{aligned}\frac{f(x+h)-f(x)}{h} &= \frac{3(x+h)^2 - 2(x+h) + 4 - (3x^2 - 2x + 4)}{h} \\ &= \frac{3(x^2 + 2xh + h^2) - 2x - 2h + 4 - 3x^2 + 2x - 4}{h} \\ &= \frac{3x^2 + 6xh + 3h^2 - 2x - 2h + 4 - 3x^2 + 2x - 4}{h} \\ &= \frac{6xh + 3h^2 - 2h}{h} = \frac{h(6x + 3h - 2)}{h} \\ &= 6x + 3h - 2\end{aligned}$$

$$25. \text{ a. Domain: } \{x \mid -4 \leq x \leq 3\}; [-4, 3]$$

$$\text{Range: } \{y \mid -3 \leq y \leq 3\}; [-3, 3]$$

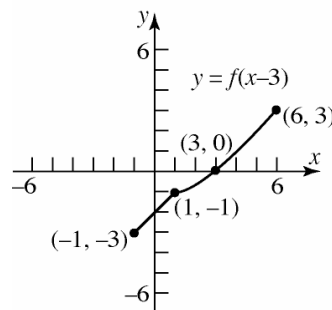
$$\text{ b. } x\text{-intercept: } (0, 0); y\text{-intercept: } (0, 0)$$

$$\text{ c. } f(-2) = -1$$

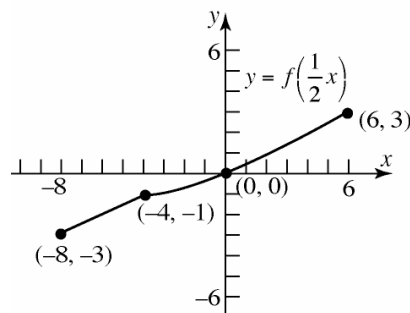
$$\text{ d. } f(x) = -3 \text{ when } x = -4$$

$$\text{ e. } f(x) > 0 \text{ when } 0 < x \leq 3$$

f. To graph  $y = f(x-3)$ , shift the graph of  $f$  horizontally 3 units to the right.

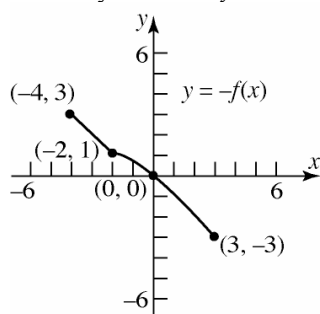


g. To graph  $y = f\left(\frac{1}{2}x\right)$ , stretch the graph of  $f$  horizontally by a factor of 2.

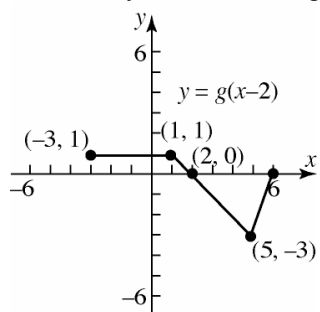


## Chapter 1: Functions and Their Graphs

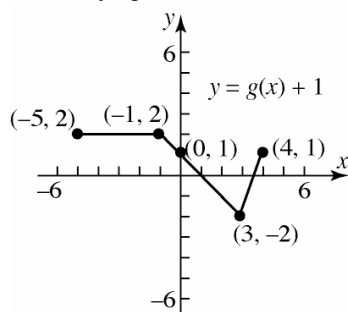
- h. To graph  $y = -f(x)$ , reflect the graph of  $f$  vertically about the  $y$ -axis.



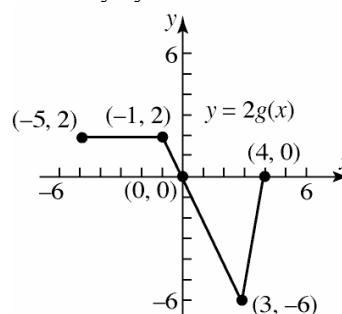
26. a. Domain:  $\{x \mid -5 \leq x \leq 4\}$ ;  $[-5, 4]$   
 Range:  $\{y \mid -3 \leq y \leq 1\}$ ;  $[-3, 1]$
- b.  $g(-1) = 1$
- c.  $x$ -intercepts:  $(0, 0)$ ,  $(4, 0)$ ;  
 $y$ -intercept:  $(0, 0)$
- d.  $g(x) = -3$  when  $x = 3$
- e.  $g(x) > 0$  when  $-5 \leq x < 0$
- f. To graph  $y = g(x-2)$ , shift the graph of  $g$  horizontally 2 units to the right.



- g. To graph  $y = g(x) + 1$ , shift the graph of  $g$  vertically up 1 unit.



- h. To graph  $y = 2g(x)$ , stretch the graph of  $g$  vertically by a factor of 2.



27. a. Domain:  $\{x \mid -4 \leq x \leq 4\}$ ;  $[-4, 4]$   
 Range:  $\{y \mid -3 \leq y \leq 1\}$ ;  $[-3, 1]$
- b. Increasing:  $(-4, -1)$  and  $(3, 4)$ ;  
 Decreasing:  $(-1, 3)$
- c. Local minimum is  $-3$  when  $x = 3$ ;  
 Local maximum is  $1$  when  $x = -1$ .  
 Note that  $x = 4$  and  $x = -4$  do not yield local extrema because there is no open interval that contains either value.
- d. The graph is not symmetric with respect to the  $x$ -axis, the  $y$ -axis or the origin.
- e. The function is neither even nor odd.
- f.  $x$ -intercepts:  $(-2, 0)$ ,  $(0, 0)$ ,  $(4, 0)$ ,  
 $y$ -intercept:  $(0, 0)$
- g. The zeros are  $x = -2$ ,  $x = 0$  and  $x = 4$ .
28. a. Domain:  $\{x \mid x \text{ is any real number}\}$   
 Range:  $\{y \mid y \text{ is any real number}\}$
- b. Increasing:  $(-\infty, -2)$  and  $(2, \infty)$ ;  
 Decreasing:  $(-2, 2)$
- c. Local minimum is  $-1$  at  $x = 2$ ;  
 Local maximum is  $1$  at  $x = -2$
- d. The graph is symmetric with respect to the origin.
- e. The function is odd.
- f.  $x$ -intercepts:  $(-3, 0)$ ,  $(0, 0)$ ,  $(3, 0)$ ;  
 $y$ -intercept:  $(0, 0)$
- g. The zeros are  $x = -3$ ,  $x = 0$ , and  $x = 3$ .

## Chapter 1 Review Exercises

29.  $f(x) = x^3 - 4x$

$$f(-x) = (-x)^3 - 4(-x) = -x^3 + 4x \\ = -(x^3 - 4x) = -f(x)$$

$f$  is odd.

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

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

$g$  is even.

31.  $h(x) = \frac{1}{x^4} + \frac{1}{x^2} + 1$

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

$h$  is even.

32.  $F(x) = \sqrt{1-x^3}$

$$F(-x) = \sqrt{1-(-x)^3} = \sqrt{1+x^3} \neq F(x) \text{ or } -F(x)$$

$F$  is neither even nor odd.

33.  $G(x) = 1 - x + x^3$

$$G(-x) = 1 - (-x) + (-x)^3 \\ = 1 + x - x^3 \neq -G(x) \text{ or } G(x)$$

$G$  is neither even nor odd.

34.  $H(x) = 1 + x + x^2$

$$H(-x) = 1 + (-x) + (-x)^2 \\ = 1 - x + x^2 \neq -H(x) \text{ or } H(x)$$

$H$  is neither even nor odd.

35.  $f(x) = \frac{x}{1+x^2}$

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

$f$  is odd.

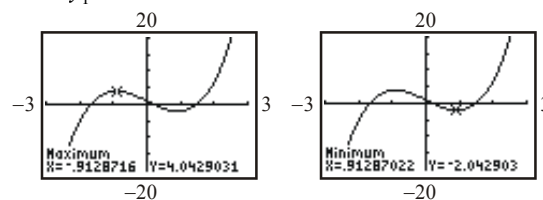
36.  $g(x) = \frac{1+x^2}{x^3}$

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

$g$  is odd.

37.  $f(x) = 2x^3 - 5x + 1$  on the interval  $(-3, 3)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = 2x^3 - 5x + 1$ .



local maximum at:  $(-0.91, 4.04)$ ;

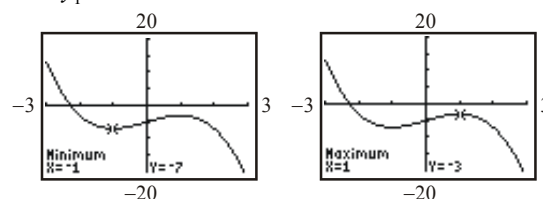
local minimum at:  $(0.91, -2.04)$ ;

$f$  is increasing on:  $(-3, -0.91)$  and  $(0.91, 3)$ ;

$f$  is decreasing on:  $(-0.91, 0.91)$ .

38.  $f(x) = -x^3 + 3x - 5$  on the interval  $(-3, 3)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = -x^3 + 3x - 5$ .



local maximum at:  $(1, -3)$ ;

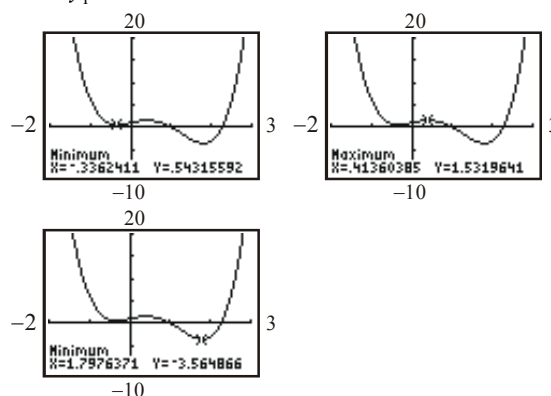
local minimum at:  $(-1, -7)$ ;

$f$  is increasing on:  $(-1, 1)$ ;

$f$  is decreasing on:  $(-3, -1)$  and  $(1, 3)$ .

39.  $f(x) = 2x^4 - 5x^3 + 2x + 1$  on the interval  $(-2, 3)$

Use MAXIMUM and MINIMUM on the graph of  $y_1 = 2x^4 - 5x^3 + 2x + 1$ .



local maximum at:  $(0.41, 1.53)$ ;

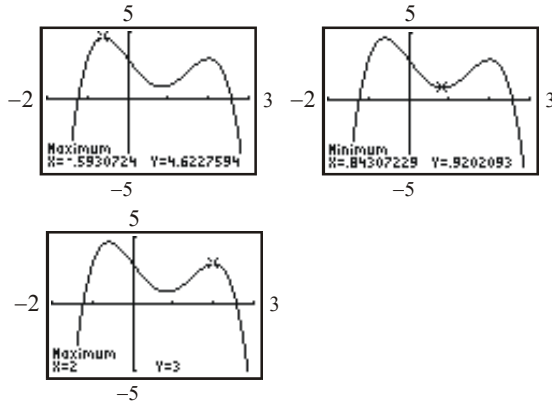
local minima at:  $(-0.34, 0.54)$  and  $(1.80, -3.56)$ ;

$f$  is increasing on:  $(-0.34, 0.41)$  and  $(1.80, 3)$ ;

$f$  is decreasing on:  $(-2, -0.34)$  and  $(0.41, 1.80)$ .

## Chapter 1: Functions and Their Graphs

40.  $f(x) = -x^4 + 3x^3 - 4x + 3$  on the interval  $(-2, 3)$   
Use MAXIMUM and MINIMUM on the graph of  $y_1 = -x^4 + 3x^3 - 4x + 3$ .



local maxima at:  $(-0.59, 4.62)$  and  $(2, 3)$ ;

local minimum at:  $(0.84, 0.92)$ ;

$f$  is increasing on:  $(-2, -0.59)$  and  $(0.84, 2)$ ;

$f$  is decreasing on:  $(-0.59, 0.84)$  and  $(2, 3)$ .

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

a. 
$$\frac{f(2) - f(1)}{2 - 1} = \frac{8(2)^2 - 2 - [8(1)^2 - 1]}{1} = 32 - 2 - (7) = 23$$

b. 
$$\frac{f(1) - f(0)}{1 - 0} = \frac{8(1)^2 - 1 - [8(0)^2 - 0]}{1} = 8 - 1 - (0) = 7$$

c. 
$$\frac{f(4) - f(2)}{4 - 2} = \frac{8(4)^2 - 4 - [8(2)^2 - 2]}{2} = \frac{128 - 4 - (30)}{2} = \frac{94}{2} = 47$$

42.  $f(x) = 2x^3 + x$

a. 
$$\frac{f(2) - f(1)}{2 - 1} = \frac{2(2)^3 + 2 - (2(1)^3 + 1)}{1} = 16 + 2 - (3) = 15$$

b. 
$$\frac{f(1) - f(0)}{1 - 0} = \frac{2(1)^3 + 1 - (2(0)^3 + 0)}{1} = 2 + 1 - (0) = 3$$

c. 
$$\frac{f(4) - f(2)}{4 - 2} = \frac{2(4)^3 + 4 - (2(2)^3 + 2)}{2} = \frac{128 + 4 - (18)}{2} = \frac{114}{2} = 57$$

43.  $f(x) = 2 - 5x$

$$\begin{aligned} \frac{f(x) - f(2)}{x - 2} &= \frac{2 - 5x - (-8)}{x - 2} \\ &= \frac{-5x + 10}{x - 2} = \frac{-5(x - 2)}{x - 2} = -5 \end{aligned}$$

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

$$\begin{aligned} \frac{f(x) - f(2)}{x - 2} &= \frac{2x^2 + 7 - 15}{x - 2} = \frac{2x^2 - 8}{x - 2} \\ &= \frac{2(x - 2)(x + 2)}{x - 2} \\ &= 2(x + 2) \text{ or } 2x + 4 \end{aligned}$$

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

$$\begin{aligned} \frac{f(x) - f(2)}{x - 2} &= \frac{3x - 4x^2 - (-10)}{x - 2} \\ &= \frac{-4x^2 + 3x + 10}{x - 2} \\ &= \frac{-(4x^2 - 3x - 10)}{x - 2} \\ &= \frac{-(4x + 5)(x - 2)}{x - 2} \\ &= -4x - 5 \end{aligned}$$

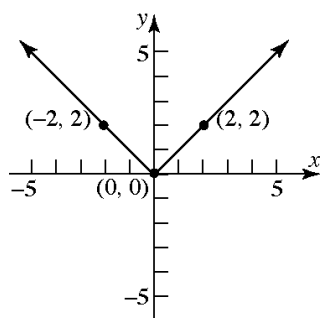
46.  $f(x) = x^2 - 3x + 2$

$$\begin{aligned} \frac{f(x) - f(2)}{x - 2} &= \frac{x^2 - 3x + 2 - 0}{x - 2} \\ &= \frac{x^2 - 3x + 2}{x - 2} \\ &= \frac{(x - 2)(x - 1)}{x - 2} \\ &= x - 1 \end{aligned}$$

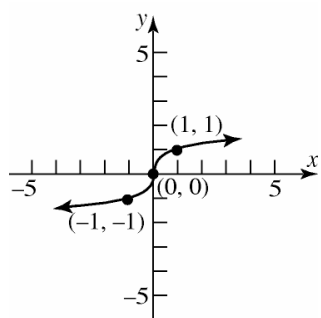
47. The graph does not pass the Vertical Line Test and is therefore not a function.
48. The graph passes the Vertical Line Test and is therefore a function.
49. The graph passes the Vertical Line Test and is therefore a function.
50. The graph passes the Vertical Line Test and is therefore a function.



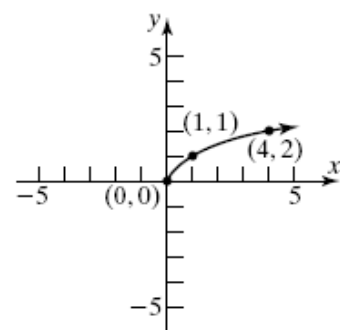
51.  $f(x) = |x|$



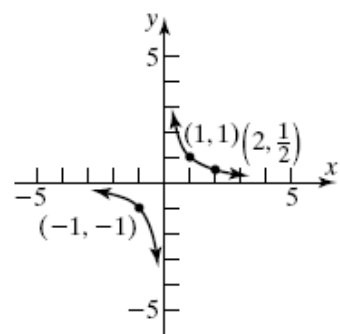
52.  $f(x) = \sqrt[3]{x}$



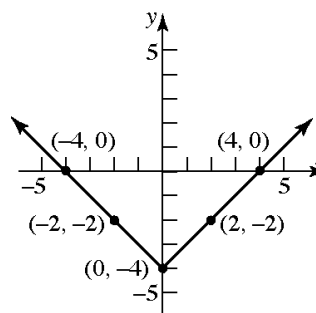
53.  $f(x) = \sqrt{x}$



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



55.  $F(x) = |x| - 4$ . Using the graph of  $y = |x|$ , vertically shift the graph downward 4 units.

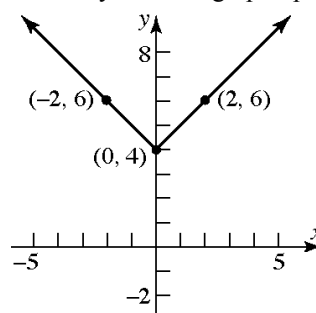


Intercepts:  $(-4, 0), (4, 0), (0, -4)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq -4\}$  or  $[-4, \infty)$

56.  $f(x) = |x| + 4$ . Using the graph of  $y = |x|$ , vertically shift the graph upward 4 units.

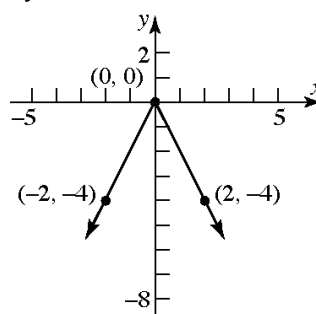


Intercepts:  $(0, 4)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq 4\}$  or  $[4, \infty)$

57.  $g(x) = -2|x|$ . Reflect the graph of  $y = |x|$  about the  $x$ -axis and vertically stretch the graph by a factor of 2.



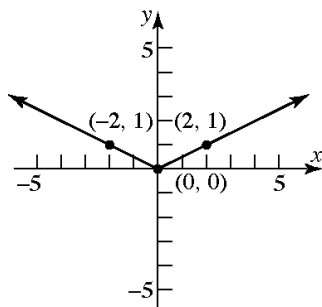
Intercepts:  $(0, 0)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \leq 0\}$  or  $(-\infty, 0]$

## Chapter 1: Functions and Their Graphs

58.  $g(x) = \frac{1}{2}|x|$ . Using the graph of  $y = |x|$ , vertically shrink the graph by a factor of  $\frac{1}{2}$ .

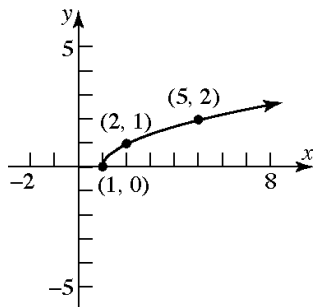


Intercepts:  $(0, 0)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq 0\}$  or  $[0, \infty)$

59.  $h(x) = \sqrt{x-1}$ . Using the graph of  $y = \sqrt{x}$ , horizontally shift the graph to the right 1 unit.

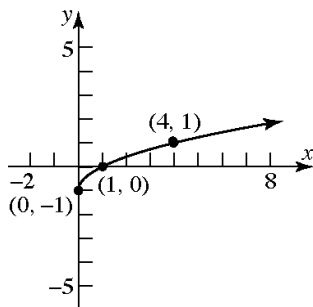


Intercept:  $(1, 0)$

Domain:  $\{x \mid x \geq 1\}$  or  $[1, \infty)$

Range:  $\{y \mid y \geq 0\}$  or  $[0, \infty)$

60.  $h(x) = \sqrt{x} - 1$ . Using the graph of  $y = \sqrt{x}$ , vertically shift the graph downward 1 unit.

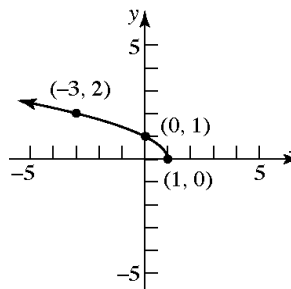


Intercepts:  $(1, 0), (0, -1)$

Domain:  $\{x \mid x \geq 0\}$  or  $[0, \infty)$

Range:  $\{y \mid y \geq -1\}$  or  $[-1, \infty)$

61.  $f(x) = \sqrt{1-x} = \sqrt{-1(x-1)}$ . Reflect the graph of  $y = \sqrt{x}$  about the  $y$ -axis and horizontally shift the graph to the right 1 unit.

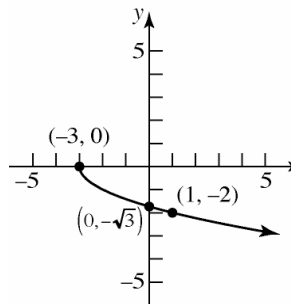


Intercepts:  $(1, 0), (0, 1)$

Domain:  $\{x \mid x \leq 1\}$  or  $(-\infty, 1]$

Range:  $\{y \mid y \geq 0\}$  or  $[0, \infty)$

62.  $f(x) = -\sqrt{x+3}$ . Using the graph of  $y = \sqrt{x}$ , horizontally shift the graph to the left 3 units, and reflect on the  $x$ -axis.

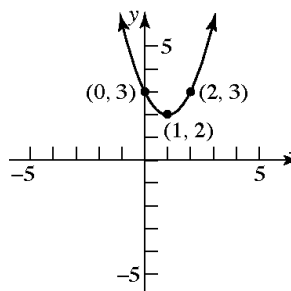


Intercepts:  $(-3, 0), (0, -\sqrt{3})$

Domain:  $\{x \mid x \geq -3\}$  or  $[-3, \infty)$

Range:  $\{y \mid y \leq 0\}$  or  $(-\infty, 0]$

63.  $h(x) = (x-1)^2 + 2$ . Using the graph of  $y = x^2$ , horizontally shift the graph to the right 1 unit and vertically shift the graph up 2 units.

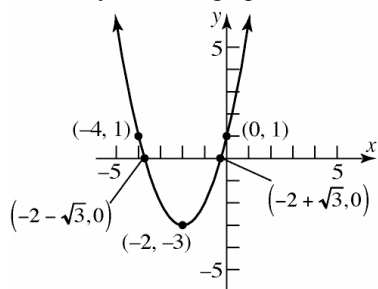


Intercepts:  $(0, 3)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq 2\}$  or  $[2, \infty)$

64.  $h(x) = (x+2)^2 - 3$ . Using the graph of  $y = x^2$ , horizontally shift the graph to the left 2 units and vertically shift the graph down 3 units.

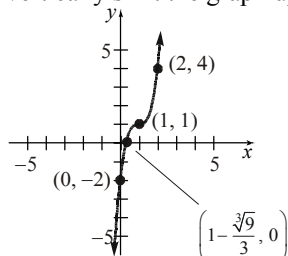


Intercepts:  $(0, 1)$ ,  $(-2 + \sqrt{3}, 0)$ ,  $(-2 - \sqrt{3}, 0)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq -3\}$  or  $[-3, \infty)$

65.  $g(x) = 3(x-1)^3 + 1$ . Using the graph of  $y = x^3$ , horizontally shift the graph to the right 1 unit vertically stretch the graph by a factor of 3, and vertically shift the graph up 1 unit.



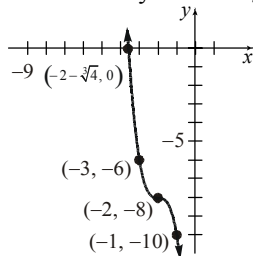
Intercepts:  $(0, -2)$ ,  $\left(1 - \frac{\sqrt[3]{9}}{3}, 0\right) \approx (0.3, 0)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \text{ is any real number}\}$

66.  $g(x) = -2(x+2)^3 - 8$

Using the graph of  $y = x^3$ , horizontally shift the graph to the left 2 units, vertically stretch the graph by a factor of 2, reflect about the  $x$ -axis, and vertically shift the graph down 8 units.



Intercepts:  $(0, -24)$ ,  $(-2 - \sqrt[3]{4}, 0) \approx (-3.6, 0)$

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \text{ is any real number}\}$

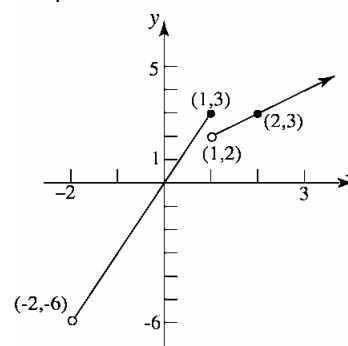
67.  $f(x) = \begin{cases} 3x & \text{if } -2 < x \leq 1 \\ x+1 & \text{if } x > 1 \end{cases}$

a. Domain:  $\{x \mid x > -2\}$  or  $(-2, \infty)$

b.  $x$ -intercept:  $(0, 0)$

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

c. Graph:



d. Range:  $\{y \mid y > -6\}$  or  $(-6, \infty)$

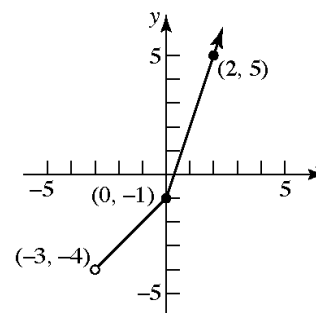
68.  $f(x) = \begin{cases} x-1 & \text{if } -3 < x < 0 \\ 3x-1 & \text{if } x \geq 0 \end{cases}$

a. Domain:  $\{x \mid x > -3\}$  or  $(-3, \infty)$

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

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

c. Graph:



d. Range:  $\{y \mid y > -4\}$  or  $(-4, \infty)$

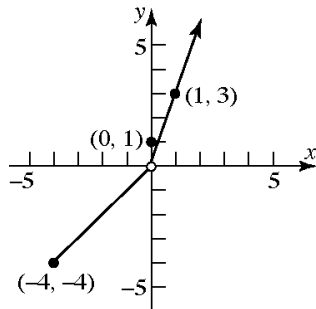
## Chapter 1: Functions and Their Graphs

69.  $f(x) = \begin{cases} x & \text{if } -4 \leq x < 0 \\ 1 & \text{if } x = 0 \\ 3x & \text{if } x > 0 \end{cases}$

a. Domain:  $\{x \mid x \geq -4\}$  or  $[-4, \infty)$

b.  $x$ -intercept: none  
 $y$ -intercept:  $(0, 1)$

c. Graph:



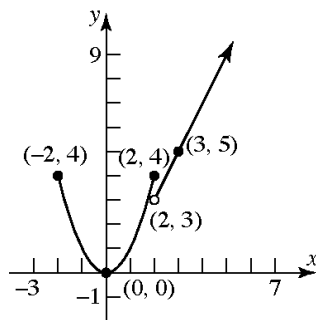
d. Range:  $\{y \mid y \geq -4, y \neq 0\}$

70.  $f(x) = \begin{cases} x^2 & \text{if } -2 \leq x \leq 2 \\ 2x - 1 & \text{if } x > 2 \end{cases}$

a. Domain:  $\{x \mid x \geq -2\}$  or  $[-2, \infty)$

b.  $x$ -intercept:  $(0, 0)$   
 $y$ -intercept:  $(0, 0)$

c. Graph:



d. Range:  $\{y \mid y \geq 0\}$  or  $[0, \infty)$

71.  $f(x) = \frac{Ax + 5}{6x - 2}$  and  $f(1) = 4$

$$\frac{A(1) + 5}{6(1) - 2} = 4$$

$$\frac{A + 5}{4} = 4$$

$$A + 5 = 16$$

$$A = 11$$

72.  $g(x) = \frac{A}{x} + \frac{8}{x^2}$  and  $g(-1) = 0$

$$\frac{A}{-1} + \frac{8}{(-1)^2} = 0$$

$$-A + 8 = 0$$

$$A = 8$$

73.  $S = 4\pi r^2$ ;  $V = \frac{4}{3}\pi r^3$

Let  $R = 2r$ ,  $S_2$  = new surface area, and

$V_2$  = new volume.

$$S_2 = 4\pi R^2$$

$$= 4\pi (2r)^2 = 4\pi (4r^2) = 4(4\pi r^2) = 4S$$

$$V_2 = \frac{4}{3}\pi R^3$$

$$= \frac{4}{3}\pi (2r)^3 = \frac{4}{3}\pi (8r^3) = 8\left(\frac{4}{3}\pi r^3\right) = 8V$$

Thus, if the radius of the sphere doubles, the surface area is 4 times as large and the volume is 8 times as large as for the original sphere.

74. a. The printed region is a rectangle. Its area is given by

$$A = (\text{length})(\text{width}) = (11 - 2x)(8.5 - 2x)$$

$$A(x) = (11 - 2x)(8.5 - 2x)$$

b. For the domain of  $A(x) = (11 - 2x)(8.5 - 2x)$  recall that the dimensions of a rectangle must be non-negative.

$$x \geq 0 \text{ and } 11 - 2x > 0 \text{ and } 8.5 - 2x > 0$$

$$-2x > -11 \quad -2x > 8.5$$

$$x < 5.5 \quad x < 4.25$$

The domain is given by  $0 \leq x < 4.25$ .

The range of  $A(x) = (11 - 2x)(8.5 - 2x)$  is given by  $A(4.25) < A \leq A(0) \Rightarrow$

$$0 < A \leq 93.5.$$

c.  $A(1) = (11 - 2(1))(8.5 - 2(1))$

$$= 9 \cdot 6.5 = 58.5 \text{ in}^2$$

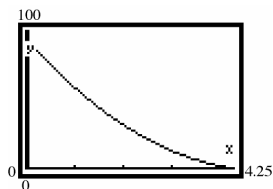
$$A(1.2) = (11 - 2(1.2))(8.5 - 2(1.2))$$

$$= 8.6 \cdot 6.1 = 52.46 \text{ in}^2$$

$$A(1.5) = (11 - 2(1.5))(8.5 - 2(1.5))$$

$$= 8 \cdot 5.5 = 44 \text{ in}^2$$

d.  $y_1 = (11 - 2x)(8.5 - 2x)$



e. Using TRACE,

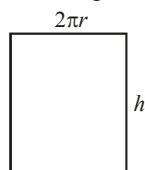
$$A \approx 70 \text{ when } x \approx 0.643 \text{ inches}$$

$$A = 50 \text{ when } x \approx 1.28 \text{ inches}$$

75. a. We are given that the volume is 100 cubic feet, so we have

$$V = \pi r^2 h = 100 \Rightarrow h = \frac{100}{\pi r^2}$$

The amount of material needed to construct the drum is the surface area of the barrel. The cylindrical body of the barrel can be viewed as a rectangle whose dimensions are given by



$$A = \text{area}_{\text{top}} + \text{area}_{\text{bottom}} + \text{area}_{\text{body}}$$

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

$$A(r) = 2\pi r^2 + 2\pi r \left( \frac{100}{\pi r^2} \right) = 2\pi r^2 + \frac{200}{r}$$

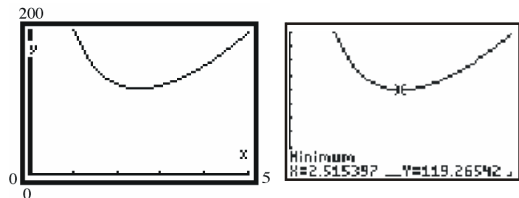
b.  $A(3) = 2\pi(3)^2 + \frac{200}{3}$

$$= 18\pi + \frac{200}{3} \approx 123.22 \text{ ft}^2$$

c.  $A(4) = 2\pi(4)^2 + \frac{200}{4} = 32\pi + 50 \approx 150.53 \text{ ft}^2$

d.  $A(5) = 2\pi(5)^2 + \frac{200}{5} = 50\pi + 40 \approx 197.08 \text{ ft}^2$

e. Graphing:

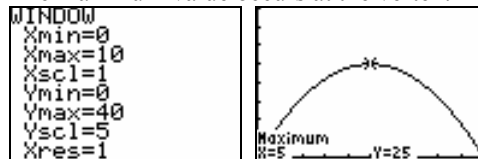


The surface area is smallest when  $r \approx 2.52$  ft.

76. a. The area function is:

$$A(x) = x(10 - x) = -x^2 + 10x$$

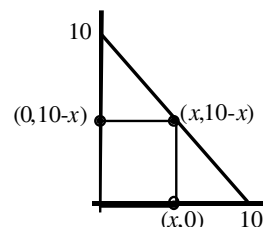
- b. The maximum value occurs at the vertex:



The maximum area is:

$$A(5) = -(5)^2 + 10(5)$$

$$= -25 + 50 = 25 \text{ square units}$$

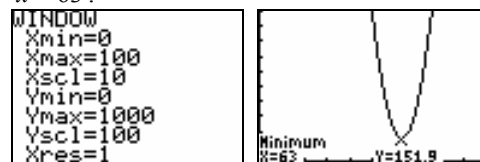


77.  $C(x) = 4.9x^2 - 617.40x + 19,600$ ;

$$a = 4.9, b = -617.40, c = 19,600.$$

Since  $a = 4.9 > 0$ , the graph opens up, so the vertex is a minimum point.

- a. The minimum marginal cost occurs at  $x = 63$ .



- b. The minimum marginal cost is

$$C\left(\frac{-b}{2a}\right) = C(63)$$

$$= 4.9(63)^2 - (617.40)(63) + 19600$$

$$= \$151.90$$

78. Let  $P = (3,1)$  and  $Q = (x,y) = (x,x)$ .

$$d(P, Q) = \sqrt{(x-3)^2 + (x-1)^2}$$

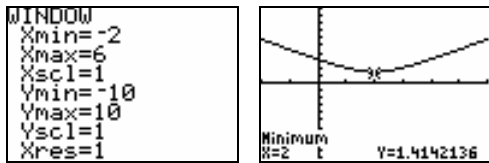
$$d^2(x) = (x-3)^2 + (x-1)^2$$

$$= x^2 - 6x + 9 + x^2 - 2x + 1$$

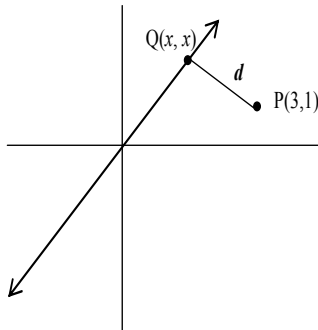
$$d^2(x) = 2x^2 - 8x + 10$$

Since  $d^2(x) = 2x^2 - 8x + 10$  is a quadratic function with  $a = 2 > 0$ , the vertex corresponds to the minimum value for the function.

## Chapter 1: Functions and Their Graphs



The vertex occurs at  $x = 2$ . Therefore the point  $Q$  on the line  $y = x$  will be closest to the point  $P = (3, 1)$  when  $Q = (2, 2)$ .



79. Let  $P = (4, 1)$  and  $Q = (x, y) = (x, x + 1)$ .

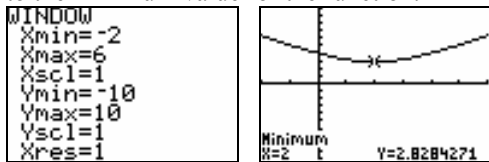
$$d(P, Q) = \sqrt{(x - 4)^2 + (x + 1 - 1)^2}$$

$$\rightarrow d^2(x) = (x - 4)^2 + x^2$$

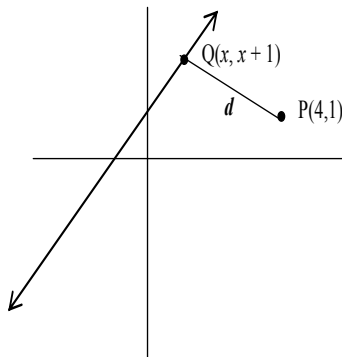
$$= x^2 - 8x + 16 + x^2$$

$$\therefore d^2(x) = 2x^2 - 8x + 16$$

Since  $d^2(x) = 2x^2 - 8x + 16$  is a quadratic function with  $a = 2 > 0$ , the vertex corresponds to the minimum value for the function.



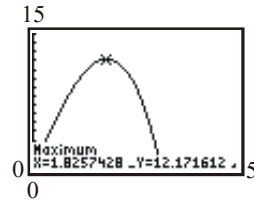
The vertex occurs at  $x = 2$ . Therefore the point  $Q$  on the line  $y = x + 1$  will be closest to the point  $P = (4, 1)$  when  $Q = (2, 3)$ .



80. The area function is:

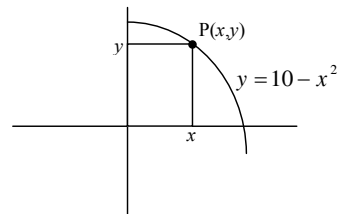
$$A(x) = x(10 - x^2) = -x^3 + 10x$$

$$y_1 = -x^3 + 10x$$



The maximum area is:

$$A(1.83) = -(1.83)^3 + 10(1.83) \approx 12.17 \text{ sq. units.}$$



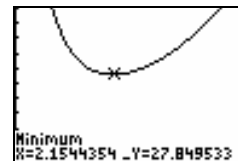
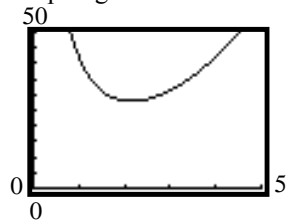
81. a.  $x^2 h = 10 \Rightarrow h = \frac{10}{x^2}$

$$\begin{aligned} A(x) &= 2x^2 + 4xh \\ &= 2x^2 + 4x\left(\frac{10}{x^2}\right) \\ &= 2x^2 + \frac{40}{x} \end{aligned}$$

b.  $A(1) = 2 \cdot 1^2 + \frac{40}{1} = 2 + 40 = 42 \text{ ft}^2$

c.  $A(2) = 2 \cdot 2^2 + \frac{40}{2} = 8 + 20 = 28 \text{ ft}^2$

- d. Graphing:



The area is smallest when  $x \approx 2.15$  feet.

82. a. We are given that the volume is 500 centimeters, so we have

$$V = \pi r^2 h = 500 \Rightarrow h = \frac{500}{\pi r^2}$$

$$\text{Total Cost} = \text{cost}_{\text{top}} + \text{cost}_{\text{bottom}} + \text{cost}_{\text{body}}$$

$$= 2(\text{cost}_{\text{top}}) + \text{cost}_{\text{body}}$$

$$= 2(\text{area}_{\text{top}})(\text{cost per area}_{\text{top}})$$

$$+ (\text{area}_{\text{body}})(\text{cost per area}_{\text{body}})$$

$$= 2(\pi r^2)(0.06) + (2\pi rh)(0.04)$$

$$= 0.12\pi r^2 + 0.08\pi rh$$

$$= 0.12\pi r^2 + 0.08\pi r \left( \frac{500}{\pi r^2} \right)$$

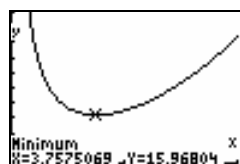
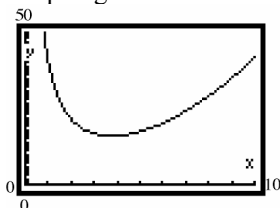
$$= 0.12\pi r^2 + \frac{40}{r}$$

$$C(r) = 0.12\pi r^2 + \frac{40}{r}$$

b.  $C(4) = 0.12\pi(4)^2 + \frac{40}{4}$   
 $= 1.92\pi + 10 \approx \$16.03$

c.  $C(8) = 0.12\pi(8)^2 + \frac{40}{8}$   
 $= 7.68\pi + 5 \approx \$29.13$

- d. Graphing:



The minimum cost occurs when  $r \approx 3.76$  centimeters.

## Chapter 1 Test

1. a.  $\{(2, 5), (4, 6), (6, 7), (8, 8)\}$

This relation is a function because there are no ordered pairs that have the same first element and different second elements.

Domain:  $\{2, 4, 6, 8\}$

Range:  $\{5, 6, 7, 8\}$

b.  $\{(1, 3), (4, -2), (-3, 5), (1, 7)\}$

This relation is not a function because there are two ordered pairs that have the same first element but different second elements.

- c. This relation is not a function because the graph fails the vertical line test.

- d. This relation is a function because it passes the vertical line test.

Domain:  $\{x \mid x \text{ is any real number}\}$

Range:  $\{y \mid y \geq 2\}$  or  $[2, \infty)$

2.  $f(x) = \sqrt{4 - 5x}$

The function tells us to take the square root of  $4 - 5x$ . Only nonnegative numbers have real square roots so we need  $4 - 5x \geq 0$ .

$$4 - 5x \geq 0$$

$$4 - 5x - 4 \geq 0 - 4$$

$$-5x \geq -4$$

$$\frac{-5x}{-5} \leq \frac{-4}{-5}$$

$$x \leq \frac{4}{5}$$

$$\text{Domain: } \left\{x \mid x \leq \frac{4}{5}\right\} \text{ or } \left(-\infty, \frac{4}{5}\right]$$

$$f(-1) = \sqrt{4 - 5(-1)} = \sqrt{4 + 5} = \sqrt{9} = 3$$

3.  $g(x) = \frac{x+2}{|x+2|}$

The function tells us to divide  $x+2$  by  $|x+2|$ .

Division by 0 is undefined, so the denominator can never equal 0. This means that  $x \neq -2$ .

Domain:  $\{x \mid x \neq -2\}$

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

## Chapter 1: Functions and Their Graphs

4.  $h(x) = \frac{x-4}{x^2+5x-36}$

The function tells us to divide  $x-4$  by  $x^2+5x-36$ . Since division by 0 is not defined, we need to exclude any values which make the denominator 0.

$$x^2+5x-36=0$$

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

$$x=-9 \text{ or } x=4$$

$$\text{Domain: } \{x \mid x \neq -9, x \neq 4\}$$

(note: there is a common factor of  $x-4$  but we must determine the domain prior to simplifying)

$$h(-1) = \frac{(-1)-4}{(-1)^2+5(-1)-36} = \frac{-5}{-40} = \frac{1}{8}$$

5. a. To find the domain, note that all the points on the graph will have an  $x$ -coordinate between  $-5$  and  $5$ , inclusive. To find the range, note that all the points on the graph will have a  $y$ -coordinate between  $-3$  and  $3$ , inclusive.

$$\text{Domain: } \{x \mid -5 \leq x \leq 5\} \text{ or } [-5, 5]$$

$$\text{Range: } \{y \mid -3 \leq y \leq 3\} \text{ or } [-3, 3]$$

- b. The intercepts are  $(0, 2)$ ,  $(-2, 0)$ , and  $(2, 0)$ .  
 $x$ -intercepts:  $-2, 2$   
 $y$ -intercept:  $2$

- c.  $f(1)$  is the value of the function when  $x = 1$ . According to the graph,  $f(1) = 3$ .

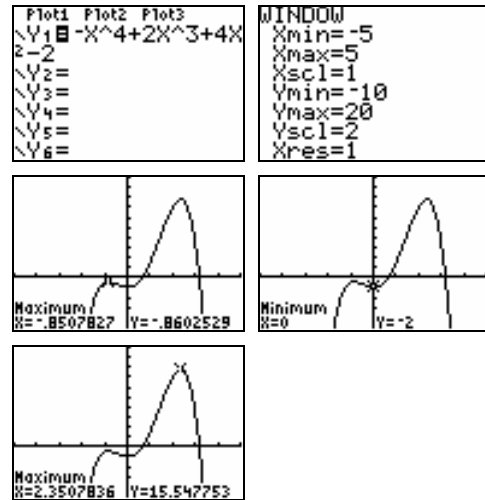
- d. Since  $(-5, -3)$  and  $(3, -3)$  are the only points on the graph for which  $y = f(x) = -3$ , we have  $f(x) = -3$  when  $x = -5$  and  $x = 3$ .

- e. To solve  $f(x) < 0$ , we want to find  $x$ -values such that the graph is below the  $x$ -axis. The graph is below the  $x$ -axis for values in the domain that are less than  $-2$  and greater than  $2$ . Therefore, the solution set is  $\{x \mid -5 \leq x < -2 \text{ or } 2 < x \leq 5\}$ . In interval notation we would write the solution set as  $[-5, -2) \cup (2, 5]$ .

- f. The zeros are at  $x = -2$  and  $x = 2$ .

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

We set  $X_{\min} = -5$  and  $X_{\max} = 5$ . The standard  $Y_{\min}$  and  $Y_{\max}$  will not be good enough to see the whole picture so some adjustment must be made.



We see that the graph has a local maximum of  $-0.86$  (rounded to two places) when  $x = -0.85$  and another local maximum of  $15.55$  when  $x = 2.35$ . There is a local minimum of  $-2$  when  $x = 0$ . Thus, we have

$$\text{Local maxima: } f(-0.85) \approx -0.86$$

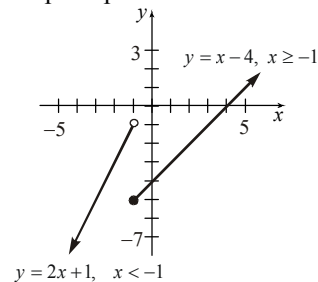
$$f(2.35) \approx 15.55$$

$$\text{Local minima: } f(0) = -2$$

The function is increasing on the intervals  $(-5, -0.85)$  and  $(0, 2.35)$  and decreasing on the intervals  $(-0.85, 0)$  and  $(2.35, 5)$ .

7. a.  $f(x) = \begin{cases} 2x+1 & x < -1 \\ x-4 & x \geq -1 \end{cases}$

To graph the function, we graph each "piece". First we graph the line  $y = 2x+1$  but only keep the part for which  $x < -1$ . Then we plot the line  $y = x-4$  but only keep the part for which  $x \geq -1$ .





- b. To find the intercepts, notice that the only piece that hits either axis is  $y = x - 4$ .

$$\begin{array}{ll} y = x - 4 & y = x - 4 \\ y = 0 - 4 & 0 = x - 4 \\ y = -4 & 4 = x \end{array}$$

The intercepts are  $(0, -4)$  and  $(4, 0)$ .

- c. To find  $g(-5)$  we first note that  $x = -5$  so we must use the first “piece” because  $-5 < -1$ .  
 $g(-5) = 2(-5) + 1 = -10 + 1 = -9$

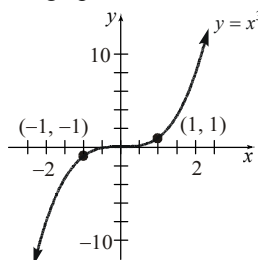
- d. To find  $g(2)$  we first note that  $x = 2$  so we must use the second “piece” because  $2 \geq -1$ .  
 $g(2) = 2 - 4 = -2$

8. The average rate of change from 3 to  $x$  is given by

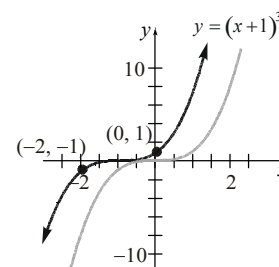
$$\begin{aligned} \frac{\Delta y}{\Delta x} &= \frac{f(x) - f(3)}{x - 3} \quad x \neq 3 \\ &= \frac{(3x^2 - 2x + 4) - (3(3)^2 - 2(3) + 4)}{x - 3} \\ &= \frac{3x^2 - 2x + 4 - 25}{x - 3} = \frac{3x^2 - 2x - 21}{x - 3} \\ &= \frac{(x - 3)(3x + 7)}{x - 3} = 3x + 7, \quad x \neq 3 \end{aligned}$$

9. a.  $f - g = (2x^2 + 1) - (3x - 2)$   
 $= 2x^2 + 1 - 3x + 2 = 2x^2 - 3x + 3$
- b.  $f \cdot g = (2x^2 + 1)(3x - 2) = 6x^3 - 4x^2 + 3x - 2$
- c.  $f(x + h) - f(x)$   
 $= (2(x + h)^2 + 1) - (2x^2 + 1)$   
 $= (2(x^2 + 2xh + h^2) + 1) - (2x^2 + 1)$   
 $= 2x^2 + 4xh + 2h^2 + 1 - 2x^2 - 1$   
 $= 4xh + 2h^2$

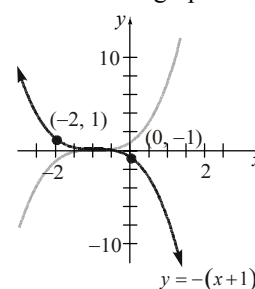
10. a. The basic function is  $y = x^3$  so we start with the graph of this function.



Next we shift this graph 1 unit to the left to obtain the graph of  $y = (x + 1)^3$ .

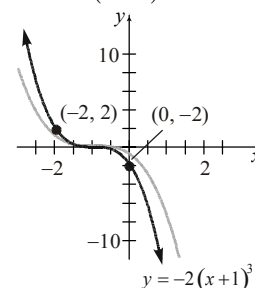


Next we reflect this graph about the  $x$ -axis to obtain the graph of  $y = -(x + 1)^3$ .

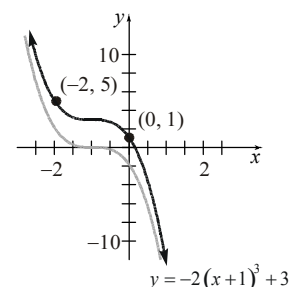


Next we stretch this graph vertically by a factor of 2 to obtain the graph of

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

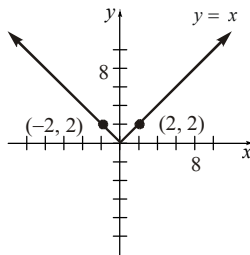


The last step is to shift this graph up 3 units to obtain the graph of  $y = -2(x + 1)^3 + 3$ .

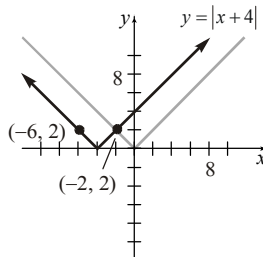


## Chapter 1: Functions and Their Graphs

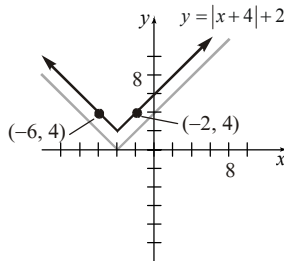
- b. The basic function is  $y = |x|$  so we start with the graph of this function.



Next we shift this graph 4 units to the left to obtain the graph of  $y = |x + 4|$ .

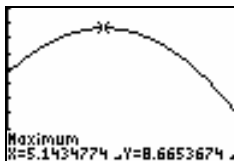
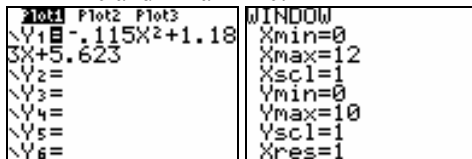


Next we shift this graph up 2 units to obtain the graph of  $y = |x + 4| + 2$ .



11. a.  $r(x) = -0.115x^2 + 1.183x + 5.623$

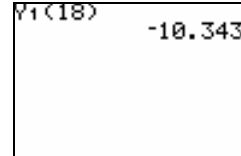
For the years 1992 to 2004, we have values of  $x$  between 0 and 12. Therefore, we can let  $Xmin = 0$  and  $Xmax = 12$ . Since  $r$  is the interest rate as a percent, we can try letting  $Ymin = 0$  and  $Ymax = 10$ .



The highest rate during this period appears to be 8.67%, occurring in 1997 ( $x \approx 5$ ).

- b. For 2010, we have  $x = 2010 - 1992 = 18$ .

$$r(18) = -0.115(18)^2 + 1.183(18) + 5.623 = -10.343$$



The model predicts that the interest rate will be  $-10.343\%$ . This is not a reasonable value since it implies that the bank would be paying interest to the borrower.

12. a. Let  $x$  = width of the rink in feet. Then the length of the rectangular portion is given by  $2x - 20$ . The radius of the semicircular portions is half the width, or  $r = \frac{x}{2}$ .

To find the volume, we first find the area of the surface and multiply by the thickness of the ice. The two semicircles can be combined to form a complete circle, so the area is given by

$$\begin{aligned} A &= l \cdot w + \pi r^2 \\ &= (2x - 20)(x) + \pi \left(\frac{x}{2}\right)^2 \\ &= 2x^2 - 20x + \frac{\pi x^2}{4} \end{aligned}$$

We have expressed our measures in feet so we need to convert the thickness to feet as well.

$$0.75 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} = \frac{0.75}{12} \text{ ft} = \frac{1}{16} \text{ ft}$$

Now we multiply this by the area to obtain the volume. That is,

$$\begin{aligned} V(x) &= \frac{1}{16} \left( 2x^2 - 20x + \frac{\pi x^2}{4} \right) \\ V(x) &= \frac{x^2}{8} - \frac{5x}{4} + \frac{\pi x^2}{64} \end{aligned}$$

- b. If the rink is 90 feet wide, then we have  $x = 90$ .

$$V(90) = \frac{90^2}{8} - \frac{5(90)}{4} + \frac{\pi(90)^2}{64} \approx 1297.61$$

The volume of ice is roughly  $1297.61 \text{ ft}^3$ .

## Chapter 1 Projects

## Project 1

- a. Plan A1: Total cost =  $\$49.99 \times 24 = \$1199.76$   
 Plan A2: Total cost =  $\$59.99 \times 24 = \$1439.76$   
 Plan B1: Total cost =  $\$39.99 \times 24 = \$959.76$   
 Plan B2: Total cost =  $\$49.99 \times 24 = \$1199.76$   
 Plan C1: Total cost =  $\$45.00 \times 24 = \$1080.00$   
 Plan C2: Total cost =  $\$60.00 \times 24 = \$1440.00$

- b. All plans allow for 2500 night and weekend minutes free, so the only minutes that will be considered here are 600:

A1: \$49.99

A2: \$59.99

B1:  $\$39.99 + 0.45(150) = \$107.49$

B2: \$49.99

C1:  $\$45.00 + 0.40(300) = \$165.00$

C2: \$60.00

The best plan here is either plan A1 or B2 at \$49.99.

The only plan that changes price from above when the night and weekend minutes increase to 3500 is B1. It only has 3000 free night and weekend minutes.

B1:  $\$39.99 + 0.45(150) + 0.45(500) = \$332.49$

The best plan is still either A1 or B2.

- c. For 425 minutes, all of them have a fixed price except C1:  $\$45.00 + 0.40(125) = \$95$ .  
 The best priced plan is B1 at \$39.99.

For 750 minutes:

A1:  $\$49.99 + 0.45(150) = \$117.49$

A2: \$59.99

B1:  $\$39.99 + 0.45(300) = \$174.99$

B2:  $\$49.99 + 0.40(150) = \$109.99$

C1:  $\$45.00 + 0.40(450) = \$247.50$

C2:  $\$60.00 + 0.40(50) = \$80.00$

- d. Monthly cost =  $\frac{\text{Base Price}}{\text{Price}} + \left( \frac{\text{charge per minute}}{\text{minute}} \right) \left( \frac{\# \text{ of min. over those included}}{\text{those included}} \right)$

A1:  $C(x) = 49.99 + 0.45(x - 600)$

$$C(x) = \begin{cases} 49.99 & 0 \leq x \leq 600 \\ 0.45x - 220.01 & x > 600 \end{cases}$$

A2:  $C(x) = 59.99 + 0.35(x - 900)$

$$C(x) = \begin{cases} 59.99 & 0 \leq x \leq 900 \\ 0.35x - 255.01 & x > 900 \end{cases}$$

B1:  $C(x) = 39.99 + 0.45(x - 450)$

$$C(x) = \begin{cases} 39.99 & 0 \leq x \leq 450 \\ 0.45x - 162.01 & x > 450 \end{cases}$$

B2:  $C(x) = 49.99 + 0.40(x - 600)$

$$C(x) = \begin{cases} 49.99 & 0 \leq x \leq 600 \\ 0.40x - 190.01 & x > 600 \end{cases}$$

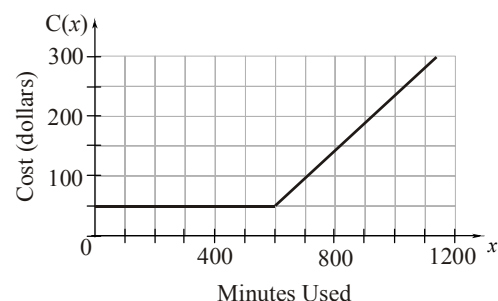
C1:  $C(x) = 45.00 + 0.40(x - 300)$

$$C(x) = \begin{cases} 45.00 & 0 \leq x \leq 300 \\ 0.40x - 75 & x > 300 \end{cases}$$

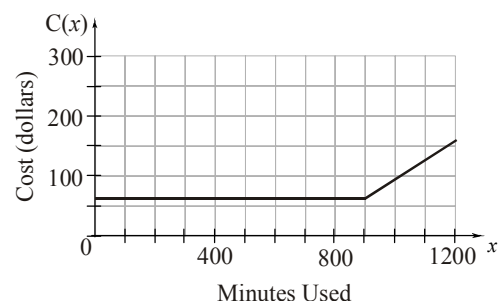
C2:  $C(x) = 60.00 + 0.40(x - 700)$

$$C(x) = \begin{cases} 60.00 & 0 \leq x \leq 700 \\ 0.40x - 220 & x > 700 \end{cases}$$

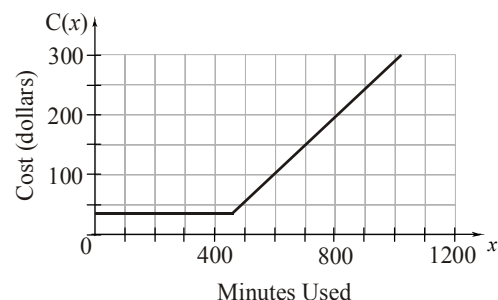
- e. Graph for plan A1:



- Graph for plan A2:

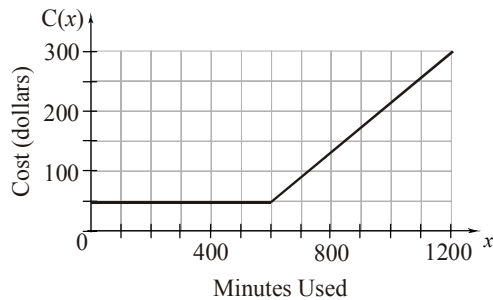


- Graph for plan B1:

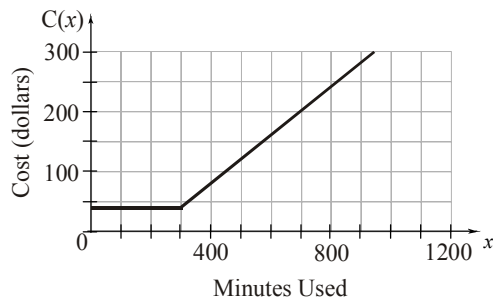


## Chapter 1: Functions and Their Graphs

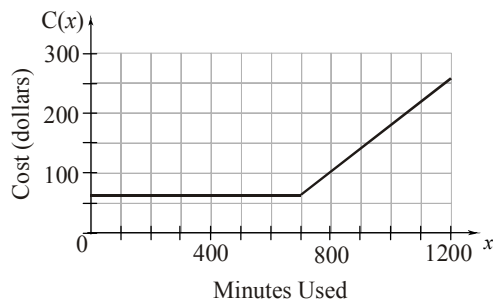
Graph for plan B2:



Graph for plan C1:



Graph for plan C2:



- f. A1:  $\frac{\$49.99}{600 \text{ min}} = \$0.083 / \text{min}$   
 A2:  $\frac{\$59.99}{900 \text{ min}} = \$0.067 / \text{min}$   
 A2 is the better plan.
- B1:  $\frac{\$39.99}{450 \text{ min}} = \$0.089 / \text{min}$   
 B2:  $\frac{\$49.99}{600 \text{ min}} = \$0.083 / \text{min}$   
 B2 is the better plan.
- C1:  $\frac{\$45.00}{300 \text{ min}} = \$0.15 / \text{min}$   
 C2:  $\frac{\$60.00}{700 \text{ min}} = \$0.086 / \text{min}$   
 C2 is the better plan.

g. Out of A2, B2, and C2, the best plan to choose is A2 since its \$/min rate is best.

h. Answers will vary.

### Project 2 (IRC)

a. Silver:  $C(x) = 20 + 0.16(x - 200) = 0.16x - 12$

$$C(x) = \begin{cases} 20 & 0 \leq x \leq 200 \\ 0.16x - 12 & x > 200 \end{cases}$$

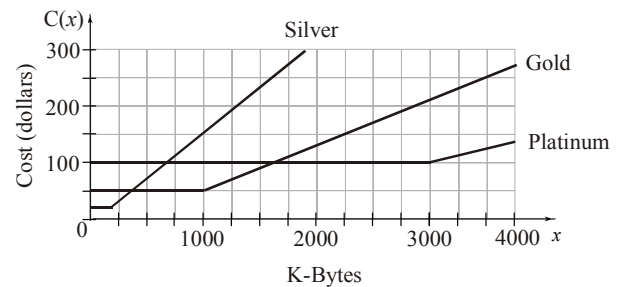
Gold:  $C(x) = 50 + 0.08(x - 1000) = 0.08x - 30$

$$C(x) = \begin{cases} 50.00 & 0 \leq x \leq 1000 \\ 0.08x - 30 & x > 1000 \end{cases}$$

Platinum:  $C(x) = 100 + 0.04(x - 3000)$

$$= 0.04x - 20$$

$$C(x) = \begin{cases} 100.00 & 0 \leq x \leq 3000 \\ 0.04x - 20 & x > 3000 \end{cases}$$



c. Let  $y = \#K\text{-bytes}$  of service over the plan minimum.

Silver:  $20 + 0.16y \leq 50$

$$0.16y \leq 30$$

$$y \leq 187.5$$

Silver is the best up to  $187.5 + 200 = 387.5$  K-bytes of service.

Gold:  $50 + 0.08y \leq 100$

$$0.08y \leq 50$$

$$y \leq 625$$

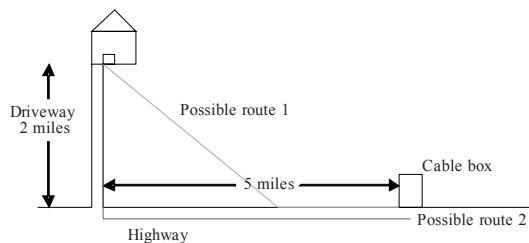
Gold is the best from 387.5 K-bytes to  $625 + 1000 = 1625$  K-bytes of service.

Platinum: Platinum will be the best if more than 1625 K-bytes is needed.

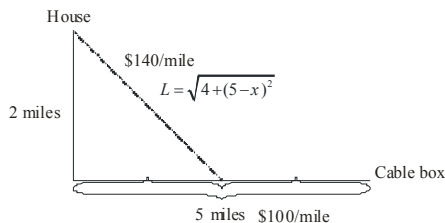
d. Answers will vary.

**Project 3 (IRC)**

a.



b.



$$C(x) = 100x + 140L$$

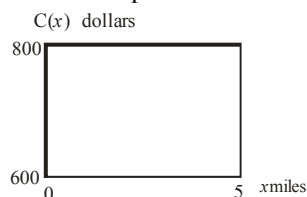
$$C(x) = 100x + 140\sqrt{4 + (5-x)^2}$$

c.

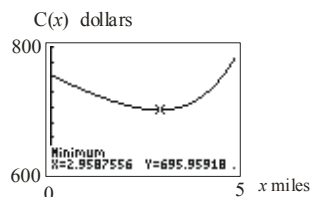
$x$	$C(x)$
0	$100(0) + 140\sqrt{4 + 25} \approx \$753.92$
1	$100(1) + 140\sqrt{4 + 16} \approx \$726.10$
2	$100(2) + 140\sqrt{4 + 9} \approx \$704.78$
3	$100(3) + 140\sqrt{4 + 4} \approx \$695.98$
4	$100(4) + 140\sqrt{4 + 1} \approx \$713.05$
5	$100(5) + 140\sqrt{4 + 0} = \$780.00$

The choice where the cable goes 3 miles down the road then cutting up to the house seems to yield the lowest cost.

- d. Since all of the costs are less than \$800, there would be a profit made with any of the plans.



Using the MINIMUM function on a graphing calculator, the minimum occurs at  $x \approx 2.96$ .



The minimum cost occurs when the cable runs for 2.96 mile along the road.

$$\begin{aligned} f. \quad C(4.5) &= 100(4.5) + 140\sqrt{4 + (5-4.5)^2} \\ &\approx \$738.62 \end{aligned}$$

The cost for the Steven's cable would be \$738.62.

- g.  $5000(738.62) = \$3,693,100$  State legislated  
 $5000(695.96) = \$3,479,800$  cheapest cost  
 It will cost the company \$213,300 more.

**Project 4 (IRC)**

$$a. \quad A = \pi r^2$$

$$b. \quad r = 2.2t$$

$$\begin{aligned} c. \quad r &= 2.2(2) = 4.4 \text{ ft} \\ r &= 2.2(2.5) = 5.5 \text{ ft} \end{aligned}$$

$$\begin{aligned} d. \quad A &= \pi(4.4)^2 = 60.82 \text{ ft}^2 \\ A &= \pi(5.5)^2 = 95.03 \text{ ft}^2 \end{aligned}$$

$$e. \quad A = \pi(2.2t)^2 = 4.84\pi t^2$$

$$\begin{aligned} f. \quad A &= 4.84\pi(2)^2 = 60.82 \text{ ft}^2 \\ A &= 4.84\pi(2.5)^2 = 95.03 \text{ ft}^2 \end{aligned}$$

$$g. \quad \frac{A(2.5) - A(2)}{2.5 - 2} = \frac{95.03 - 60.82}{0.5} = 68.42 \text{ ft/hr}$$

$$h. \quad \frac{A(3.5) - A(3)}{3.5 - 3} = \frac{186.27 - 136.85}{0.5} = 98.84 \text{ ft/hr}$$

i. The average rate of change is increasing.

$$\begin{aligned} j. \quad 150 \text{ yds} &= 450 \text{ ft} \\ r &= 2.2t \\ t &= \frac{450}{2.2} = 204.5 \text{ hours} \end{aligned}$$

$$\begin{aligned} k. \quad 6 \text{ miles} &= 31680 \text{ ft} \\ \text{Therefore, we need a radius of } 15,840 \text{ ft.} \\ t &= \frac{15,840}{2.2} = 7200 \text{ hours} \end{aligned}$$