I Answers to Odd-Numbered Exercises

CHAPTER 1

EXERCISES 1.1 ■ PAGE 19

1. Yes

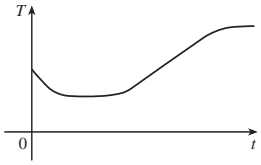
3. (a) 3 (b) -0.2 (c) 0, 3 (d) -0.8
(e) $[-2, 4], [-1, 3]$ (f) $[-2, 1]$

5. $[-85, 115]$ **7.** No

9. Yes, $[-3, 2], [-3, -2) \cup [-1, 3]$

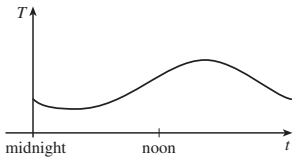
11. (a) 13.8°C (b) 1990 (c) 1910, 2005 (d) [13.5, 14.5]

13.



15. (a) 500 MW; 730 MW (b) 4 AM; noon; yes

17.



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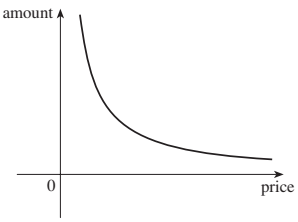

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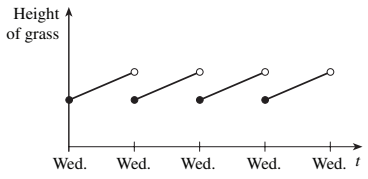
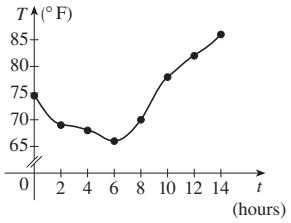


23. (a)



(b) 74°F

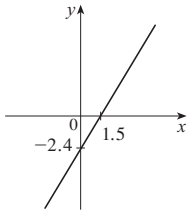
25. $12, 16, 3a^2 - a + 2, 3a^2 + a + 2, 3a^2 + 5a + 4,$
$6a^2 - 2a + 4, 12a^2 - 2a + 2, 3a^4 - a^2 + 2,$
$9a^4 - 6a^3 + 13a^2 - 4a + 4, 3a^2 + 6ah + 3h^2 - a - h + 2$

27. $-3 - h$ **29.** $-1/(ax)$

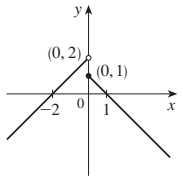
31. $(-\infty, -3) \cup (-3, 3) \cup (3, \infty)$ **33.** $(-\infty, \infty)$

35. $(-\infty, 0) \cup (5, \infty)$ **37.** $[0, 4]$

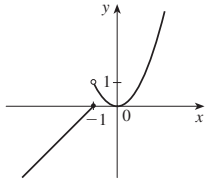
39. $(-\infty, \infty)$



41. $-1, 1, -1$



43. $-2, 0, 4$



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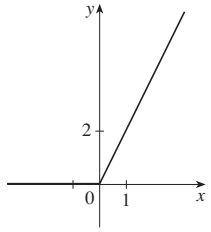

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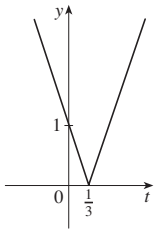
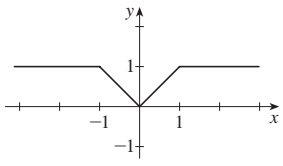


49.



51. $f(x) = \frac{5}{2}x - \frac{11}{2}, 1 \leqslant x \leqslant 5$ **53.** $f(x) = 1 - \sqrt{-x}$

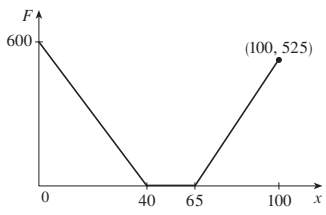
55. $f(x) = \begin{cases} -x + 3 & \text{if } 0 \leqslant x \leqslant 3 \\ 2x - 6 & \text{if } 3 < x \leqslant 5 \end{cases}$

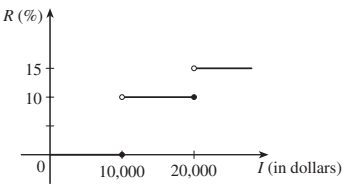
57. $A(L) = 10L - L^2, 0 < L < 10$

59. $A(x) = \sqrt{3}x^2/4, x > 0$ **61.** $S(x) = x^2 + (8/x), x > 0$

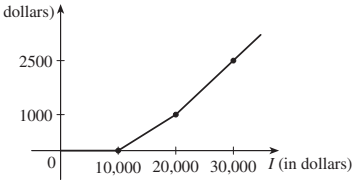
63. $V(x) = 4x^3 - 64x^2 + 240x, 0 < x < 6$

65. $F(x) = \begin{cases} 15(40 - x) & \text{if } 0 \leqslant x < 40 \\ 0 & \text{if } 40 \leqslant x \leqslant 65 \\ 15(x - 65) & \text{if } x > 65 \end{cases}$



67. (a) 

(b) \$400, \$1900

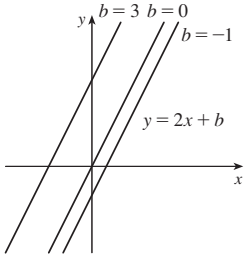
(c) 

69. f is odd, g is even **71.** (a) $(-5, 3)$ (b) $(-5, -3)$
73. Odd **75.** Neither **77.** Even
79. Even; odd; neither (unless $f = 0$ or $g = 0$)

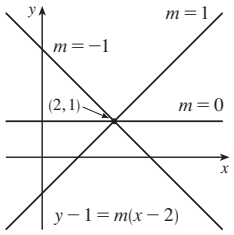
EXERCISES 1.2 ■ PAGE 33

1. (a) Logarithmic (b) Root (c) Rational
(d) Polynomial, degree 2 (e) Exponential (f) Trigonometric
3. (a) h (b) f (c) g
5. $\{x \mid x \neq \pi/2 + 2n\pi\}$, n an integer

7. (a) $y = 2x + b$,
where b is the y-intercept.

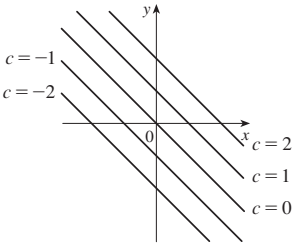


(b) $y = mx + 1 - 2m$,
where m is the slope.



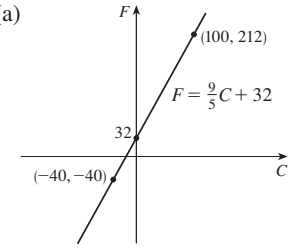
(c) $y = 2x - 3$

9. Their graphs have slope -1.



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

13. (a) 8.34, change in mg for every 1 year change
(b) 8.34 mg

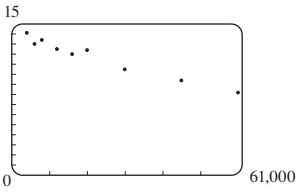
15. (a) 

(b) $\frac{9}{5}$, change in °F for every 1°C change; 32, Fahrenheit temperature corresponding to 0°C

17. (a) $T = \frac{1}{6}N + \frac{307}{6}$ (b) $\frac{1}{6}$, change in °F for every chirp per minute change (c) 76°F

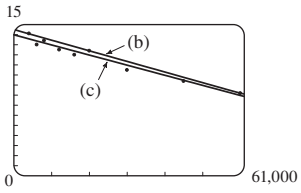
19. (a) $P = 0.434d + 15$ (b) 196 ft

21. (a) Cosine (b) Linear

23. (a) 

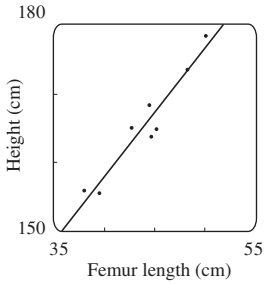
A linear model is appropriate.

(b) $y = -0.000105x + 14.521$



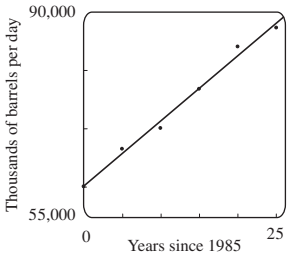
(c) $y = -0.00009979x + 13.951$
(d) About 11.5 per 100 population
(e) About 6% (f) No

25. (a) See graph in part (b).
(b) $y = 1.88074x + 82.64974$



(c) 182.3 cm

27. (a) A linear model is appropriate. See graph in part (b).
(b) $y = 1116.64x + 60{,}188.33$



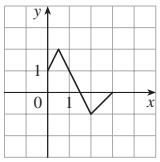
(c) In thousands of barrels per day: 79,171 and 90,338
29. Four times as bright
31. (a) $N = 3.1046A^{0.308}$ (b) 18

EXERCISES 1.3 ■ PAGE 42

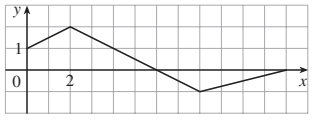
1. (a) $y = f(x) + 3$ (b) $y = f(x) - 3$ (c) $y = f(x - 3)$
(d) $y = f(x + 3)$ (e) $y = -f(x)$ (f) $y = f(-x)$
(g) $y = 3f(x)$ (h) $y = \frac{1}{3}f(x)$

3. (a) 3 (b) 1 (c) 4 (d) 5 (e) 2

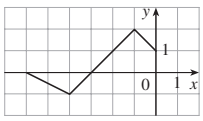
5. (a)



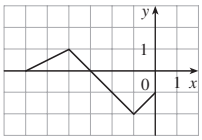
(b)



(c)

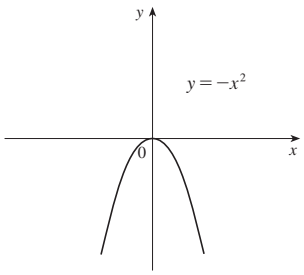


(d)



7. $y = -\sqrt{-x^2 - 5x - 4} - 1$

9.



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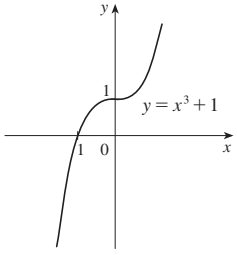
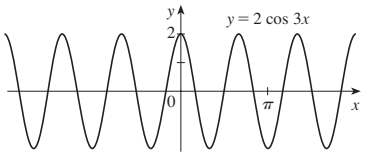


13.



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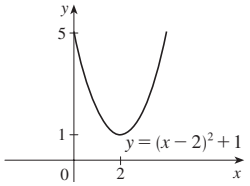

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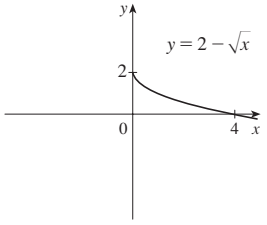

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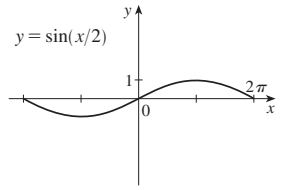

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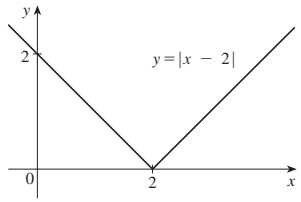

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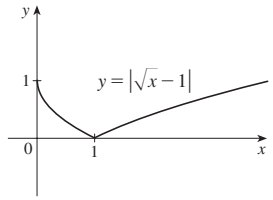
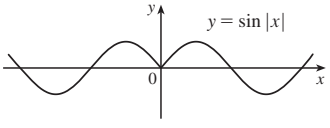


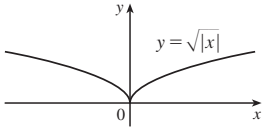
25. $L(t) = 12 + 2\sin\left[\dfrac{2\pi}{365}(t - 80)\right]$

27. $D(t) = 5\cos[(\pi/6)(t - 6.75)] + 7$

29. (a) The portion of the graph of $y = f(x)$ to the right of the y-axis is reflected about the y-axis.
(b)



(c)



31. (a) $(f+g)(x) = x^3 + 5x^2 - 1, (-\infty, \infty)$
(b) $(f-g)(x) = x^3 - x^2 + 1, (-\infty, \infty)$
(c) $(fg)(x) = 3x^5 + 6x^4 - x^3 - 2x^2, (-\infty, \infty)$
(d) $(f/g)(x) = \dfrac{x^3 + 2x^2}{3x^2 - 1}, \left\{x \mid x \neq \pm\dfrac{1}{\sqrt{3}}\right\}$

33. (a) $(f \circ g)(x) = 3x^2 + 3x + 5, (-\infty, \infty)$
(b) $(g \circ f)(x) = 9x^2 + 33x + 30, (-\infty, \infty)$
(c) $(f \circ f)(x) = 9x + 20, (-\infty, \infty)$
(d) $(g \circ g)(x) = x^4 + 2x^3 + 2x^2 + x, (-\infty, \infty)$

35. (a) $(f \circ g)(x) = \sqrt{4x - 2}, \left[\frac{1}{2}, \infty\right)$
(b) $(g \circ f)(x) = 4\sqrt{x+1} - 3, [-1, \infty)$
(c) $(f \circ f)(x) = \sqrt{\sqrt{x+1} + 1}, [-1, \infty)$
(d) $(g \circ g)(x) = 16x - 15, (-\infty, \infty)$

37. (a) $(f \circ g)(x) = \dfrac{2x^2 + 6x + 5}{(x+2)(x+1)}, \{x \mid x \neq -2, -1\}$

(b) $(g \circ f)(x) = \dfrac{x^2 + x + 1}{(x+1)^2}, \{x \mid x \neq -1, 0\}$

(c) $(f \circ f)(x) = \dfrac{x^4 + 3x^2 + 1}{x(x^2+1)}, \{x \mid x \neq 0\}$

(d) $(g \circ g)(x) = \dfrac{2x+3}{3x+5}, \left\{x \mid x \neq -2, -\frac{5}{3}\right\}$

39. $(f \circ g \circ h)(x) = 3\sin(x^2) - 2$

41. $(f \circ g \circ h)(x) = \sqrt{x^6 + 4x^3 + 1}$

43. $g(x) = 2x + x^2, f(x) = x^4$

45. $g(x) = \sqrt[3]{x}, f(x) = x/(1+x)$

47. $g(t) = t^2, f(t) = \sec t \tan t$

49. $h(x) = \sqrt{x}, g(x) = x - 1, f(x) = \sqrt{x}$

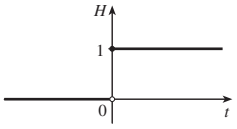
51. $h(t) = \cos t, g(t) = \sin t, f(t) = t^2$

53. (a) 4 (b) 3 (c) 0 (d) Does not exist; $f(6) = 6$ is not in the domain of g. (e) 4 (f) -2

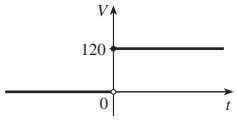
55. (a) $r(t) = 60t$ (b) $(A \circ r)(t) = 3600\pi t^2$; the area of the circle as a function of time

57. (a) $s = \sqrt{d^2 + 36}$ (b) $d = 30t$
(c) $(f \circ g)(t) = \sqrt{900t^2 + 36}$; the distance between the lighthouse and the ship as a function of the time elapsed since noon

59. (a)

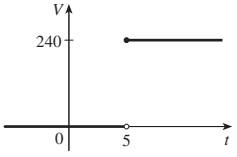


(b)



$V(t) = 120H(t)$

(c)



$V(t) = 240H(t-5)$

61. Yes; $m_1 m_2$

63. (a) $f(x) = x^2 + 6$ (b) $g(x) = x^2 + x - 1$

65. Yes

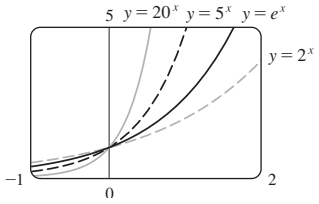
EXERCISES 1.4 ■ PAGE 53

1. (a) 4 (b) $x^{-4/3}$

3. (a) $16b^{12}$ (b) $648y^7$

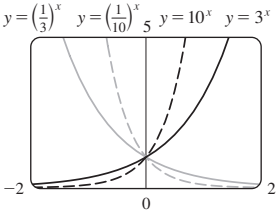
5. (a) $f(x) = b^x, b > 0$ (b) $\mathbb{R}$ (c) $(0, \infty)$
(d) See Figures 4(c), 4(b), and 4(a), respectively.

7.



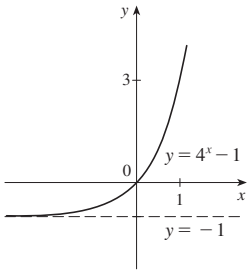
All approach 0 as $x \to -\infty$, all pass through (0, 1), and all are increasing. The larger the base, the faster the rate of increase.

9.

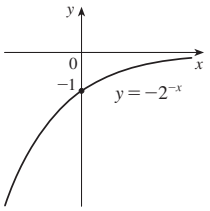


The functions with base greater than 1 are increasing and those with base less than 1 are decreasing. The latter are reflections of the former about the y-axis.

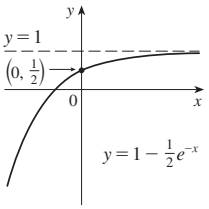
11.



13.



15.

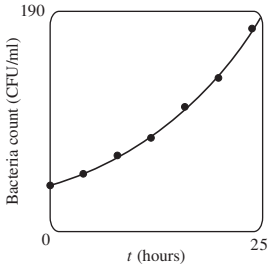


17. (a) $y = e^x - 2$ (b) $y = e^{x-2}$ (c) $y = -e^x$
(d) $y = e^{-x}$ (e) $y = -e^{-x}$

19. (a) $(-\infty, -1) \cup (-1, 1) \cup (1, \infty)$ (b) $(-\infty, \infty)$

21. $f(x) = 3 \cdot 2^x$ **27.** At $x \approx 35.8$

29. (a) See graph in part (c).
(b) $f(t) = 36.89301(1.06614)^t$
(c) About 10.87 h



31. (a) 25 mg (b) $200 \cdot 2^{-t/5}$ mg
(c) 10.9 mg (d) 38.2 days

33. 3.5 days

35. $P = 2614.086(1.01693)^t$; 5381 million; 8466 million

EXERCISES 1.5 ■ PAGE 66

1. (a) See Definition 1.
(b) It must pass the Horizontal Line Test.

3. No **5.** No **7.** Yes **9.** Yes **11.** No **13.** No

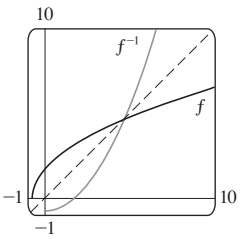
15. (a) 6 (b) 3 **17.** 0

19. $F = \frac{9}{5}C + 32$; the Fahrenheit temperature as a function of the Celsius temperature; $[-273.15, \infty)$

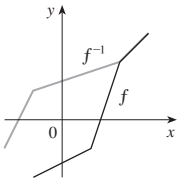
21. $f^{-1}(x) = \frac{1}{3}(x - 1)^2 - \frac{2}{3}, x \geqslant 1$

23. $f^{-1}(x) = \frac{1}{2}(1 + \ln x)$ **25.** $y = e^x - 3$

27. $f^{-1}(x) = \frac{1}{4}(x^2 - 3), x \geqslant 0$



29.



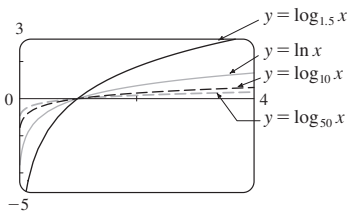
31. (a) $f^{-1}(x) = \sqrt{1 - x^2}, 0 \leqslant x \leqslant 1$; f^{-1} and f are the same function. (b) Quarter-circle in the first quadrant

33. (a) It's defined as the inverse of the exponential function with base b, that is, $\log_b x = y \iff b^y = x$.
(b) $(0, \infty)$ (c) $\mathbb{R}$ (d) See Figure 11.

35. (a) 5 (b) $\frac{1}{3}$ **37.** (a) 2 (b) $\frac{2}{3}$

39. $\ln 250$ **41.** $\ln \dfrac{\sqrt{x}}{x + 1}$

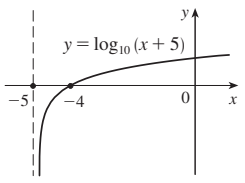
43.



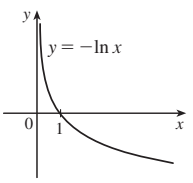
All graphs approach $-\infty$ as $x \to 0^+$, all pass through (1, 0), and all are increasing. The larger the base, the slower the rate of increase.

45. About 1,084,588 mi

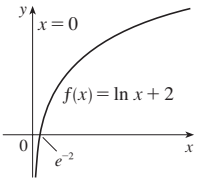
47. (a)



(b)



49. (a) $(0, \infty)$; $(-\infty, \infty)$ (b) e^{-2}
(c)



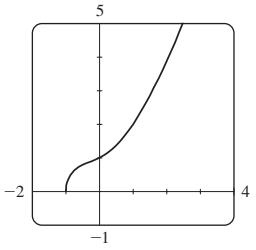
51. (a) $\frac{1}{4}(7 - \ln 6)$ (b) $\frac{1}{3}(e^2 + 10)$

53. (a) $5 + \log_2 3$ or $5 + (\ln 3)/\ln 2$ (b) $\frac{1}{2}\left(1 + \sqrt{1 + 4e}\right)$

55. (a) $0 < x < 1$ (b) $x > \ln 5$

57. (a) $(\ln 3, \infty)$ (b) $f^{-1}(x) = \ln(e^x + 3)$; $\mathbb{R}$

59. The graph passes the Horizontal Line Test.



$f^{-1}(x) = -\frac{1}{6}\sqrt[3]{4}\left(\sqrt[3]{D - 27x^2 + 20} - \sqrt[3]{D + 27x^2 - 20} + \sqrt[3]{2}\right)$, where $D = 3\sqrt{3}\sqrt{27x^4 - 40x^2 + 16}$; two of the expressions are complex.

61. (a) $f^{-1}(n) = (3/\ln 2)\ln(n/100)$; the time elapsed when there are n bacteria (b) After about 26.9 hours

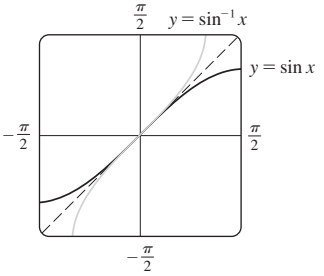
63. (a) π (b) $\pi/6$

65. (a) $\pi/4$ (b) $\pi/2$

67. (a) $5\pi/6$ (b) $\pi/3$

71. $x/\sqrt{1 + x^2}$

73.



The second graph is the reflection of the first graph about the line $y = x$

75. $\left[-\frac{2}{3}, 0\right]$, $[-\pi/2, \pi/2]$

77. (a) $g^{-1}(x) = f^{-1}(x) - c$ (b) $h^{-1}(x) = (1/c)f^{-1}(x)$

CHAPTER 1 REVIEW ■ PAGE 69

True-False Quiz

1. False **3.** False **5.** True **7.** False **9.** True

11. False **13.** False

Exercises

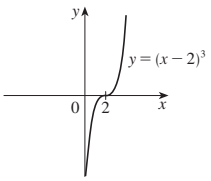
1. (a) 2.7 (b) 2.3, 5.6 (c) $[-6, 6]$ (d) $[-4, 4]$
(e) $[-4, 4]$ (f) No; it fails the Horizontal Line Test.
(g) Odd; its graph is symmetric about the origin.

3. $2a + h - 2$ **5.** $\left(-\infty, \frac{1}{3}\right) \cup \left(\frac{1}{3}, \infty\right)$, $(-\infty, 0) \cup (0, \infty)$

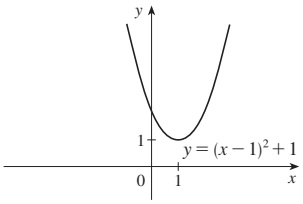
7. $(-6, \infty)$, $\mathbb{R}$

9. (a) Shift the graph 8 units upward.
(b) Shift the graph 8 units to the left.
(c) Stretch the graph vertically by a factor of 2, then shift it 1 unit upward.
(d) Shift the graph 2 units to the right and 2 units downward.
(e) Reflect the graph about the x-axis.
(f) Reflect the graph about the line $y = x$ (assuming f is one-to-one).

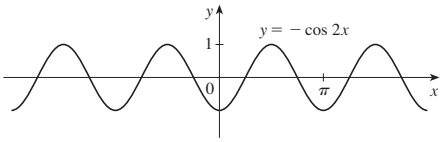
11.



13.



15.



17. (a) Neither (b) Odd (c) Even (d) Neither

19. (a) $(f \circ g)(x) = \ln(x^2 - 9)$, $(-\infty, -3) \cup (3, \infty)$
(b) $(g \circ f)(x) = (\ln x)^2 - 9$, $(0, \infty)$
(c) $(f \circ f)(x) = \ln \ln x$, $(1, \infty)$
(d) $(g \circ g)(x) = (x^2 - 9)^2 - 9$, $(-\infty, \infty)$

21. $y = 0.2493x - 423.4818$; about 77.6 years

23. 1 **25.** (a) 9 (b) 2 (c) $1/\sqrt{3}$ (d) $\frac{3}{5}$

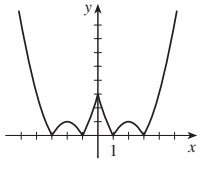
27. (a) $\frac{1}{16}$ g (b) $m(t) = 2^{-t/4}$
(c) $t(m) = -4 \log_2 m$; the time elapsed when there are m grams of ^{100}Pd
(d) About 26.6 days

PRINCIPLES OF PROBLEM SOLVING ■ PAGE 76

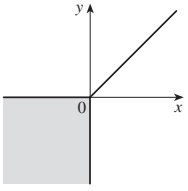
1. $a = 4\sqrt{h^2 - 16}/h$, where a is the length of the altitude and h is the length of the hypotenuse

3. $-\frac{7}{3}$, 9

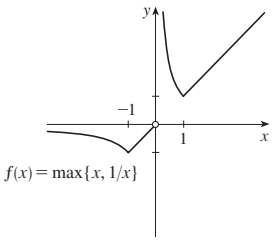
5.



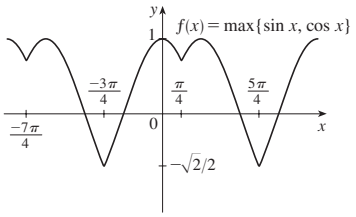
7.



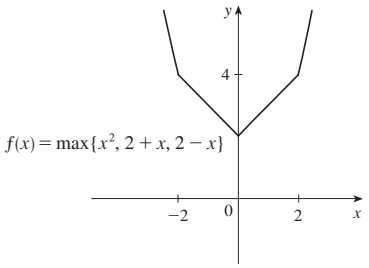
9. (a)



(b)



(c)



11. 5 **13.** $x \in \left[-1, 1 - \sqrt{3}\right) \cup \left(1 + \sqrt{3}, 3\right]$

15. 40 mi/h **19.** $f_n(x) = x^{2^{n+1}}$

CHAPTER 2

EXERCISES 2.1 ■ PAGE 82

1. (a) $-44.4, -38.8, -27.8, -22.2, -16.\overline{6}$
(b) -33.3 (c) $-33\frac{1}{3}$

3. (a) (i) 2 (ii) 1.111111 (iii) 1.010101 (iv) 1.001001
(v) 0.666667 (vi) 0.909091 (vii) 0.990099
(viii) 0.999001 (b) 1 (c) $y = x - 3$

5. (a) (i) -32 ft/s (ii) -25.6 ft/s (iii) -24.8 ft/s
(iv) -24.16 ft/s (b) -24 ft/s

7. (a) (i) 29.3 ft/s (ii) 32.7 ft/s (iii) 45.6 ft/s
(iv) 48.75 ft/s (b) 29.7 ft/s

9. (a) 0, 1.7321, -1.0847, -2.7433, 4.3301, -2.8173, 0, -2.1651, -2.6061, -5, 3.4202; no (c) -31.4

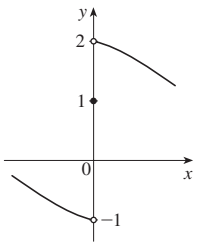
EXERCISES 2.2 ■ PAGE 92

1. Yes

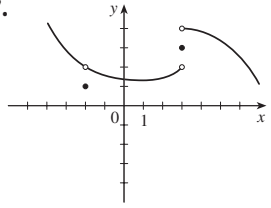
3. (a) $\lim_{x \to -3} f(x) = \infty$ means that the values of $f(x)$ can be made arbitrarily large (as large as we please) by taking x sufficiently close to -3 (but not equal to -3).
(b) $\lim_{x \to 4^+} f(x) = -\infty$ means that the values of $f(x)$ can be made arbitrarily large negative by taking x sufficiently close to 4 through values larger than 4.

5. (a) 2 (b) 1 (c) 4 (d) Does not exist (e) 3
7. (a) -1 (b) -2 (c) Does not exist (d) 2 (e) 0
(f) Does not exist (g) 1 (h) 3
9. (a) $-\infty$ (b) ∞ (c) ∞ (d) $-\infty$ (e) ∞
(f) $x = -7, x = -3, x = 0, x = 6$
11. $\lim_{x \to a} f(x)$ exists for all a except $a = -1$.
13. (a) 1 (b) 0 (c) Does not exist

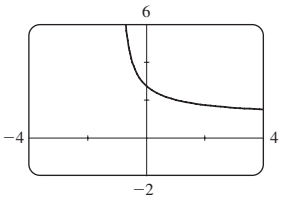
15.



17.



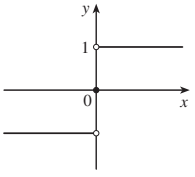
19. $\frac{1}{2}$ **21.** 5 **23.** 0.25 **25.** 1.5 **27.** 1
29. (a) -1.5 **31.** ∞ **33.** ∞ **35.** $-\infty$ **37.** $-\infty$
39. $-\infty$ **41.** ∞ **43.** $-\infty$ **45.** $-\infty$; ∞
47. (a) 2.71828 (b)



49. (a) 0.998000, 0.638259, 0.358484, 0.158680, 0.038851, 0.008928, 0.001465; 0
(b) 0.000572, -0.000614, -0.000907, -0.000978, -0.000993, -0.001000; -0.001
51. No matter how many times we zoom in toward the origin, the graph appears to consist of almost-vertical lines. This indicates more and more frequent oscillations as $x \to 0$.
53. $x \approx \pm 0.90, \pm 2.24$; $x = \pm \sin^{-1}(\pi/4), \pm(\pi - \sin^{-1}(\pi/4))$
55. (a) 6 (b) Within 0.0649 of 1

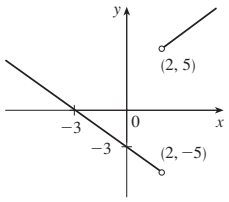
EXERCISES 2.3 ■ PAGE 102

1. (a) -6 (b) -8 (c) 2 (d) -6
(e) Does not exist (f) 0
3. 105 **5.** $\frac{7}{8}$ **7.** 390 **9.** $\frac{3}{2}$ **11.** 4
13. Does not exist **15.** $\frac{6}{5}$ **17.** -10 **19.** $\frac{1}{12}$
21. $\frac{1}{6}$ **23.** $-\frac{1}{9}$ **25.** 1 **27.** $\frac{1}{128}$ **29.** $-\frac{1}{2}$
31. $3x^2$ **33.** (a), (b) $\frac{2}{3}$ **37.** 7 **41.** 6 **43.** -4
45. Does not exist
47. (a)



(b) (i) 1
(ii) -1
(iii) Does not exist
(iv) 1

49. (a) (i) 5 (ii) -5 (b) Does not exist
(c)



51. 7
53. (a) (i) -2 (ii) Does not exist (iii) -3
(b) (i) $n - 1$ (ii) n (c) a is not an integer.
59. 8 **65.** 15; -1

EXERCISES 2.4 ■ PAGE 113

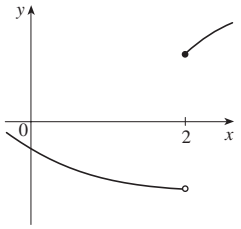
1. 0.1 (or any smaller positive number)
3. 1.44 (or any smaller positive number)
5. 0.0906 (or any smaller positive number)
7. 0.0219 (or any positive number);
0.011 (or any smaller positive number)
9. (a) 0.01 (or any smaller positive number)
(b) $\lim_{x \to 2^+} \dfrac{1}{\ln(x - 1)} = \infty$

11. (a) $\sqrt{1000/\pi}$ cm (b) Within approximately 0.0445 cm
(c) Radius; area; $\sqrt{1000/\pi}$; 1000; 5; ≈ 0.0445
13. (a) 0.025 (b) 0.0025
35. (a) 0.093 (b) $\delta = (B^{2/3} - 12)/(6B^{1/3}) - 1$, where $B = 216 + 108\varepsilon + 12\sqrt{336 + 324\varepsilon + 81\varepsilon^2}$
41. Within 0.1

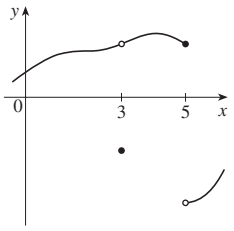
EXERCISES 2.5 ■ PAGE 124

1. $\lim_{x \to 4} f(x) = f(4)$
3. (a) $-4, -2, 2, 4$; $f(-4)$ is not defined and $\lim_{x \to a} f(x)$ does not exist for $a = -2, 2$, and 4
(b) -4, neither; -2, left; 2, right; 4, right

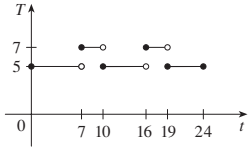
5.



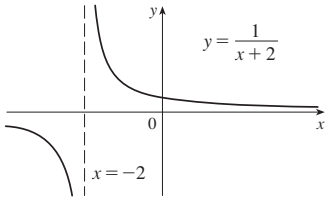
7.



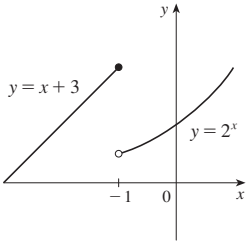
9. (a)



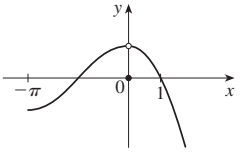
17. $f(-2)$ is undefined.



19. $\lim_{x\to -1} f(x)$ does not exist.



21. $\lim_{x\to 0} f(x) \neq f(0)$

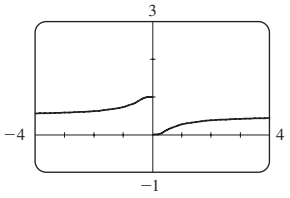


23. Define $f(2) = 3$. **25.** $(-\infty, \infty)$

27. $\left(-\infty, \sqrt[3]{2}\right) \cup \left(\sqrt[3]{2}, \infty\right)$ **29.** $[-1, 0]$

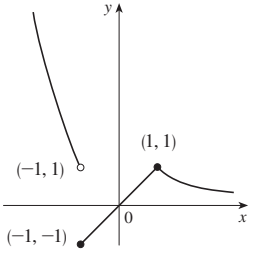
31. $(-\infty, -1] \cup (0, \infty)$

33. $x = 0$

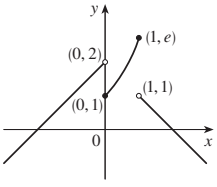


35. 8 **37.** ln 2

41. -1, right



43. 0, right; 1, left



45. $\frac{2}{3}$ **47.** 4

49. (a) $g(x) = x^3 + x^2 + x + 1$ (b) $g(x) = x^2 + x$

57. (b) (0.86, 0.87) **59.** (b) 70.347 **67.** None

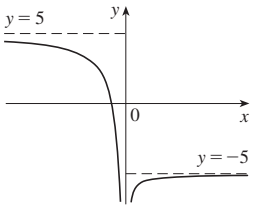
69. Yes

EXERCISES 2.6 ■ PAGE 137

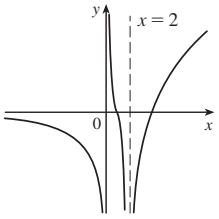
1. (a) As x becomes large, $f(x)$ approaches 5.
(b) As x becomes large negative, $f(x)$ approaches 3.

3. (a) -2 (b) 2 (c) ∞ (d) $-\infty$
(e) $x = 1, x = 3, y = -2, y = 2$

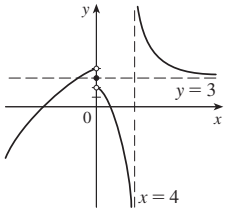
5.



7.



9.

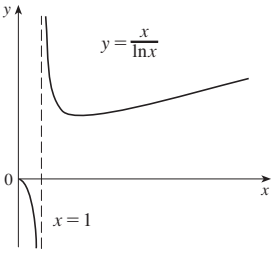


11. 0 **13.** $\frac{2}{5}$ **15.** $\frac{3}{2}$ **17.** 0 **19.** -1 **21.** 4

23. -2 **25.** $\frac{\sqrt{3}}{4}$ **27.** $\frac{1}{6}$ **29.** $\frac{1}{2}(a - b)$ **31.** ∞

33. $-\infty$ **35.** $\pi/2$ **37.** $-\frac{1}{2}$ **39.** 0 **41.** ∞

43. (a) (i) 0 (ii) $-\infty$ (iii) ∞ (b) ∞
(c)



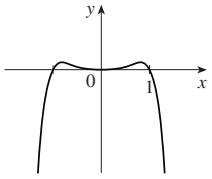
45. (a), (b) $-\frac{1}{2}$ **47.** $y = 4, x = -3$

49. $y = 2; x = -2, x = 1$ **51.** $x = 5$ **53.** $y = 3$

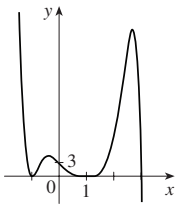
55. (a) 0 (b) $\pm\infty$

57. $f(x) = \dfrac{2 - x}{x^2(x - 3)}$ **59.** (a) $\frac{5}{4}$ (b) 5

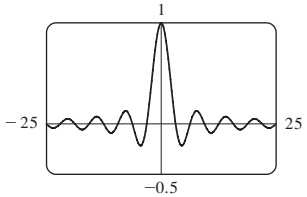
61. $-\infty, -\infty$



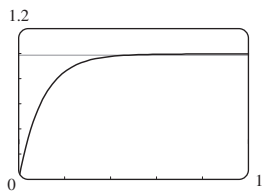
63. $-\infty, \infty$



65. (a) 0 (b) An infinite number of times



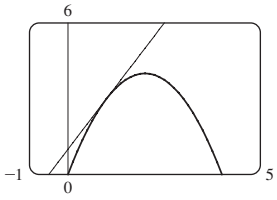
67. 5

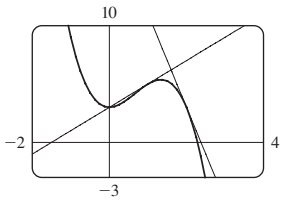
69. (a) v^* (b) 

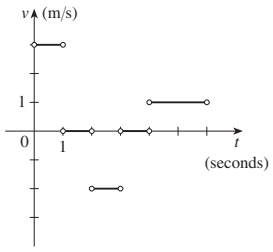
≈ 0.47 s

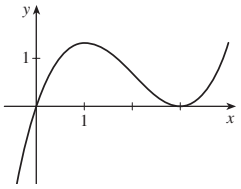
71. $N \geqslant 15$ **73.** $N \leqslant -9, N \leqslant -19$
75. (a) $x > 100$

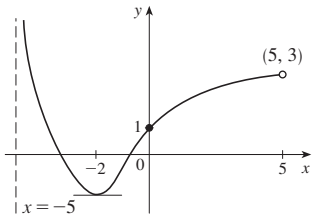
EXERCISES 2.7 ■ PAGE 148

1. (a) $\dfrac{f(x) - f(3)}{x - 3}$ (b) $\lim\limits_{x \to 3} \dfrac{f(x) - f(3)}{x - 3}$
3. (a) 2 (b) $y = 2x + 1$ (c) 

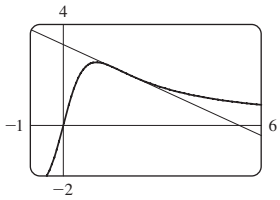
5. $y = -8x + 12$ **7.** $y = \frac{1}{2}x + \frac{1}{2}$
9. (a) $8a - 6a^2$ (b) $y = 2x + 3, y = -8x + 19$
(c) 

11. (a) Right: $0 < t < 1$ and $4 < t < 6$; left: $2 < t < 3$; standing still: $1 < t < 2$ and $3 < t < 4$
(b) 

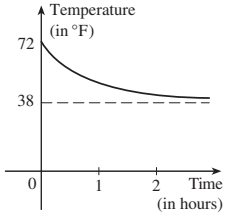
13. -24 ft/s
15. $-2/a^3$ m/s; -2 m/s; $-\frac{1}{4}$ m/s; $-\frac{2}{27}$ m/s
17. $g'(0), 0, g'(4), g'(2), g'(-2)$
19. (a) 26 (b) No (c) Yes
21. $f(2) = 3; f'(2) = 4$
23. 

25. 

27. $y = 3x - 1$

29. (a) $-\frac{3}{5}; y = -\frac{3}{5}x + \frac{16}{5}$ (b) 

31. $6a - 4$ **33.** $\dfrac{5}{(a + 3)^2}$ **35.** $-\dfrac{1}{\sqrt{1 - 2a}}$
37. $f(x) = \sqrt{x}, a = 9$ **39.** $f(x) = x^6, a = 2$
41. $f(x) = \cos x, a = \pi$ or $f(x) = \cos(\pi + x), a = 0$
43. 32 m/s; 32 m/s

45. 

Greater (in magnitude)

47. (a) In (mg/mL)/h: (i) -0.15 (ii) -0.12 (iii) -0.12 (iv) -0.11 (b) -0.12 (mg/mL)/h; After 2 hours, the BAC is decreasing at a rate of 0.12 (mg/mL)/h.

49. (a) 1169.6 thousands of barrels of oil per day per year; oil consumption rose by an average of 1169.6 thousands of barrels of oil per day each year from 1990 to 2005.
(b) 1397.8 thousands of barrels of oil per day per year

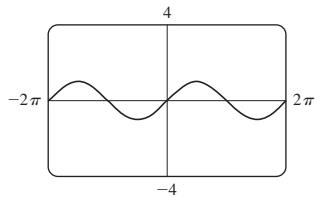
51. (a) (i) \$20.25/unit (ii) \$20.05/unit (b) \$20/unit

53. (a) The rate at which the cost is changing per ounce of gold produced; dollars per ounce
(b) When the 800th ounce of gold is produced, the cost of production is \$17/oz.
(c) Decrease in the short term; increase in the long term

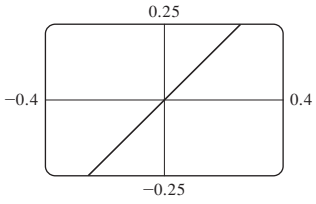
55. (a) The rate at which daily heating costs change with respect to temperature when the temperature is 58°F; dollars/°F
(b) Negative; If the outside temperature increases, the building should require less heating.

57. (a) The rate at which the oxygen solubility changes with respect to the water temperature; (mg/L)/°C
(b) $S'(16) \approx -0.25$; as the temperature increases past 16°C, the oxygen solubility is decreasing at a rate of 0.25 (mg/L)/°C.

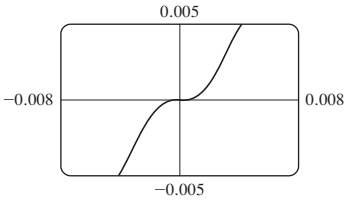
59. Does not exist

61. (a) 

Slope appears to be 1.

(b) 

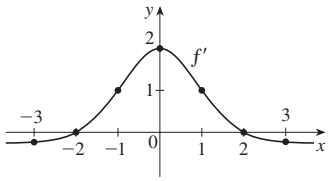
Yes

(c) 

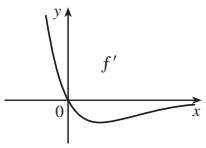
Yes; 0

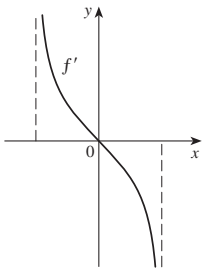
EXERCISES 2.8 ■ PAGE 160

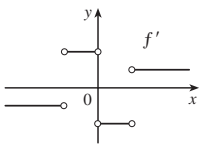
1. (a) −0.2 (b) 0 (c) 1 (d) 2
(e) 1 (f) 0 (g) −0.2

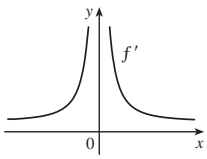


3. (a) II (b) IV (c) I (d) III

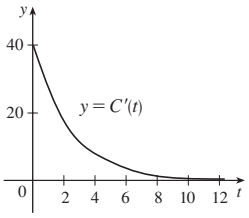
5. 

7. 

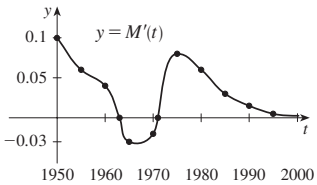
9. 

11. 

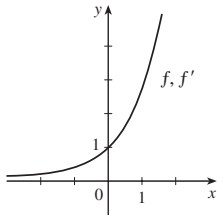
13. (a) The instantaneous rate of change of percentage of full capacity with respect to elapsed time in hours

(b) 

The rate of change of percentage of full capacity is decreasing and approaching 0.

15. 

1963 to 1971

17. 

$f'(x) = e^x$

19. (a) 0, 1, 2, 4 (b) −1, −2, −4 (c) $f'(x) = 2x$

21. $f'(x) = 3$, $\mathbb{R}$, $\mathbb{R}$ **23.** $f'(t) = 5t + 6$, $\mathbb{R}$, $\mathbb{R}$

25. $f'(x) = 2x - 6x^2$, $\mathbb{R}$, $\mathbb{R}$

27. $g'(x) = -\dfrac{1}{2\sqrt{9 - x}}$, $(-\infty, 9]$, $(-\infty, 9)$

29. $G'(t) = \dfrac{-7}{(3 + t)^2}$, $(-\infty, -3) \cup (-3, \infty)$, $(-\infty, -3) \cup (-3, \infty)$

31. $f'(x) = 4x^3$, $\mathbb{R}$, $\mathbb{R}$ **33.** (a) $f'(x) = 4x^3 + 2$

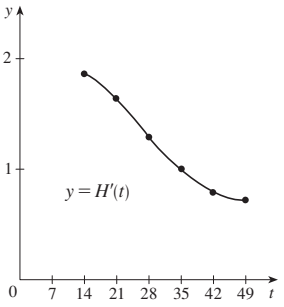
35. (a) The rate at which the unemployment rate is changing, in percent unemployed per year

(b)

t	$U'(t)$	t	$U'(t)$
2003	−0.50	2008	2.35
2004	−0.45	2009	1.90
2005	−0.45	2010	−0.20
2006	−0.25	2011	−0.75
2007	0.60	2012	−0.80

37.

t	14	21	28	35	42	49
$H'(t)$	$\frac{13}{7}$	$\frac{23}{14}$	$\frac{9}{7}$	1	$\frac{11}{14}$	$\frac{5}{7}$

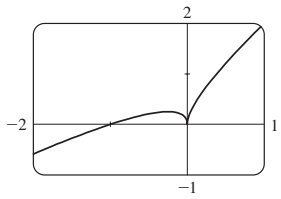


39. (a) The rate at which the percentage of electrical power produced by solar panels is changing, in percentage points per year. (b) On January 1, 2002, the percentage of electrical power produced by solar panels was increasing at a rate of 3.5 percentage points per year.

41. -4 (corner); 0 (discontinuity)

43. 1 (not defined); 5 (vertical tangent)

45.

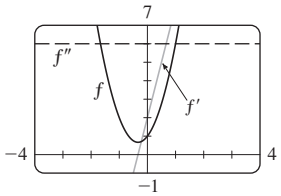


Differentiable at -1; not differentiable at 0

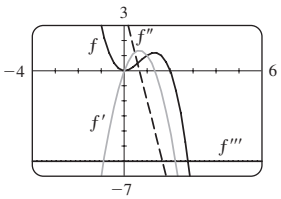
47. $f''(1)$ **49.** $a = f, b = f', c = f''$

51. a = acceleration, b = velocity, c = position

53. $6x + 2$; 6



55.

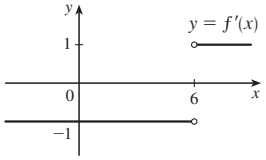


$f'(x) = 4x - 3x^2$,
$f''(x) = 4 - 6x$,
$f'''(x) = -6$,
$f^{(4)}(x) = 0$

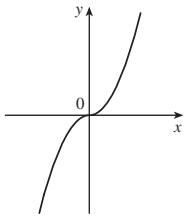
57. (a) $\frac{1}{3}a^{-2/3}$

59. $f'(x) = \begin{cases} -1 & \text{if } x < 6 \\ 1 & \text{if } x > 6 \end{cases}$

or $f'(x) = \dfrac{x-6}{|x-6|}$



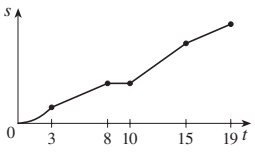
61. (a)



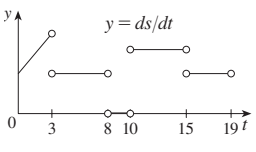
(b) All x

(c) $f'(x) = 2|x|$

65. (a)



(b)



67. 63°

CHAPTER 2 REVIEW ■ PAGE 166

True-False Quiz

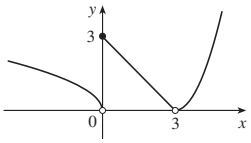
1. False **3.** True **5.** True **7.** False **9.** True
11. True **13.** True **15.** False **17.** True
19. True **21.** False **23.** False **25.** True

Exercises

1. (a) (i) 3 (ii) 0 (iii) Does not exist (iv) 2
(v) ∞ (vi) $-\infty$ (vii) 4 (viii) -1
(b) $y = 4, y = -1$ (c) $x = 0, x = 2$ (d) $-3, 0, 2, 4$

3. 1 **5.** $\frac{3}{2}$ **7.** 3 **9.** ∞ **11.** $\frac{4}{7}$ **13.** $\frac{1}{2}$
15. $-\infty$ **17.** 2 **19.** $\pi/2$ **21.** $x = 0, y = 0$ **23.** 1

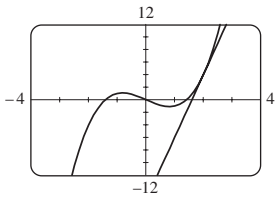
29. (a) (i) 3 (ii) 0 (iii) Does not exist
(iv) 0 (v) 0 (vi) 0
(b) At 0 and 3 (c)



31. $\mathbb{R}$ **35.** (a) -8 (b) $y = -8x + 17$

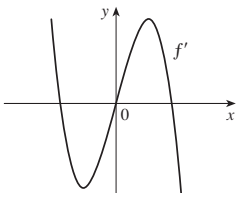
37. (a) (i) 3 m/s (ii) 2.75 m/s (iii) 2.625 m/s
(iv) 2.525 m/s (b) 2.5 m/s

39. (a) 10 (b) $y = 10x - 16$
(c)

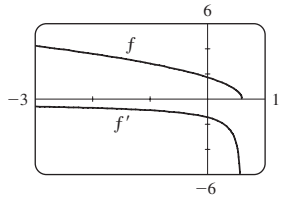


41. (a) The rate at which the cost changes with respect to the interest rate; dollars/(percent per year)
(b) As the interest rate increases past 10%, the cost is increasing at a rate of \$1200/(percent per year).
(c) Always positive

43.

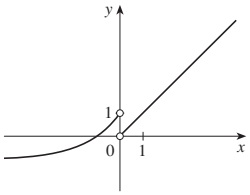


45. (a) $f'(x) = -\frac{5}{2}(3 - 5x)^{-1/2}$ (b) $\left(-\infty, \frac{3}{5}\right], \left(-\infty, \frac{3}{5}\right)$
(c)



47. -4 (discontinuity), -1 (corner), 2 (discontinuity), 5 (vertical tangent)

49.



51. The rate at which the number of US $20 bills in circulation is changing with respect to time; 0.156 billion bills per year

53. 0

PROBLEMS PLUS ■ PAGE 169

1. $\frac{2}{3}$ **3.** -4 **5.** (a) Does not exist (b) 1

7. $a = \frac{1}{2} \pm \frac{1}{2}\sqrt{5}$ **9.** $\frac{3}{4}$ **11.** (b) Yes (c) Yes; no

13. (a) 0 (b) 1 (c) $f'(x) = x^2 + 1$

CHAPTER 3

EXERCISES 3.1 ■ PAGE 180

1. (a) e is the number such that $\lim_{h \to 0} \dfrac{e^h - 1}{h} = 1$.

(b) 0.99, 1.03; $2.7 < e < 2.8$

3. $f'(x) = 0$ **5.** $f'(x) = 5.2$ **7.** $f'(t) = 6t^2 - 6t - 4$

9. $g'(x) = 2x - 6x^2$ **11.** $g'(t) = -\frac{3}{2}t^{-7/4}$

13. $F'(r) = -15/r^4$ **15.** $R'(a) = 18a + 6$

17. $S'(p) = \frac{1}{2}p^{-1/2} - 1$ **19.** $y' = 3e^x - \frac{4}{3}x^{-4/3}$

21. $h'(u) = 3Au^2 + 2Bu + C$

23. $y' = \frac{3}{2}\sqrt{x} + \dfrac{2}{\sqrt{x}} - \dfrac{3}{2x\sqrt{x}}$ **25.** $j'(x) = 2.4x^{1.4}$

27. $G'(q) = -2q^{-2} - 2q^{-3}$ **29.** $f'(v) = -\frac{2}{3}v^{-5/3} - 2e^v$

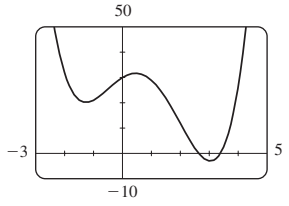
31. $z' = -10A/y^{11} + Be^y$ **33.** $y = 4x - 1$

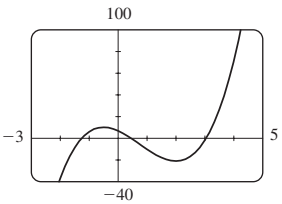
35. $y = \frac{1}{2}x + 2$

37. Tangent: $y = 2x + 2$; normal: $y = -\frac{1}{2}x + 2$

39. $y = 3x - 1$ **41.** $f'(x) = 4x^3 - 6x^2 + 2x$

43. (a) (c) $4x^3 - 9x^2 - 12x + 7$





45. $f'(x) = 0.005x^4 - 0.06x^2$, $f''(x) = 0.02x^3 - 0.12x$

47. $f'(x) = 2 - \frac{15}{4}x^{-1/4}$, $f''(x) = \frac{15}{16}x^{-5/4}$

49. (a) $v(t) = 3t^2 - 3$, $a(t) = 6t$ (b) 12 m/s^2

(c) $a(1) = 6$ m/s^2

51. 1.718; at 12 years, the length of the fish is increasing at a rate of 1.718 in/year

53. (a) $V = 5.3/P$

(b) -0.00212; instantaneous rate of change of the volume with respect to the pressure at 25°C; m^3/kPa

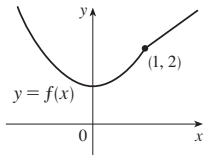
55. $(-2, 21)$, $(1, -6)$ **59.** $y = 3x - 3$, $y = 3x - 7$

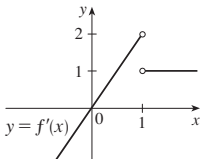
61. $y = -2x + 3$

63. $(\pm 2, 4)$ **67.** $P(x) = x^2 - x + 3$

69. $y = \frac{3}{16}x^3 - \frac{9}{4}x + 3$

71. No

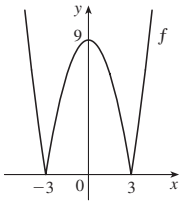


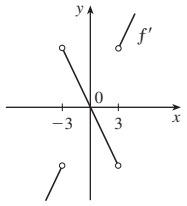


73. (a) Not differentiable at 3 or -3

$$f'(x) = \begin{cases} 2x & \text{if } |x| > 3 \\ -2x & \text{if } |x| < 3 \end{cases}$$

(b)





75. $y = 2x^2 - x$ **77.** $a = -\frac{1}{2}$, $b = 2$ **79.** $-\frac{1}{3}$

81. $m = 4$, $b = -4$ **83.** 1000 **85.** 3; 1

EXERCISES 3.2 ■ PAGE 188

1. $1 - 2x + 6x^2 - 8x^3$ **3.** $f'(x) = e^x(3x^2 + x - 5)$

5. $y' = \dfrac{1 - x}{e^x}$ **7.** $g'(x) = \dfrac{10}{(3 - 4x)^2}$ **9.** $H'(u) = 2u - 1$

11. $F'(y) = 5 + \dfrac{14}{y^2} + \dfrac{9}{y^4}$ **13.** $y' = \dfrac{x(-x^3 - 3x - 2)}{(x^3 - 1)^2}$

15. $y' = \dfrac{t^4 - 8t^3 + 6t^2 + 9}{(t^2 - 4t + 3)^2}$

17. $y' = e^p\left(1 + \frac{3}{2}\sqrt{p} + p + p\sqrt{p}\right)$ **19.** $y' = \dfrac{3 - 2\sqrt{s}}{2s^{5/2}}$

21. $f'(t) = \dfrac{-2t - 3}{3t^{2/3}(t - 3)^2}$ **23.** $f'(x) = \dfrac{xe^x(x^3 + 2e^x)}{(x^2 + e^x)^2}$

25. $f'(x) = \dfrac{2cx}{(x^2 + c)^2}$

27. $(x^3 + 3x^2 + 1)e^x$; $(x^3 + 6x^2 + 6x + 1)e^x$

29. $\dfrac{x(2 + 2e^x - xe^x)}{(1 + e^x)^2}$;

$$\frac{2 + 4e^x - 4xe^x - x^2e^x + 2e^{2x} - 4xe^{2x} + x^2e^{2x}}{(1 + e^x)^3}$$

31. $y = \frac{2}{3}x - \frac{2}{3}$ **33.** $y = 2x$; $y = -\frac{1}{2}x$

35. (a) $y = \frac{1}{2}x + 1$ (b)