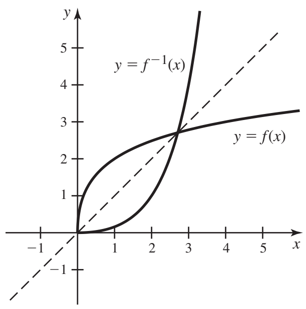
45. $t = \frac{e^4 - 4}{5}$ **47.** $\theta = \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4}$ **49.** $\theta = \pm\frac{\pi}{12}, \pm\frac{5\pi}{12}$

51. Approx. 35 years **53.** $(-\infty, 0]$, $[0, 2]$, and $[2, \infty)$

55. $f^{-1}(x) = -\frac{1}{4}x + \frac{3}{2}$ **57.** $f^{-1}(x) = 2 + \sqrt{x-1}$

59. $f^{-1}(x) = -\sqrt{\frac{x-1}{3}}$ **61.** $f^{-1}(x) = \sqrt{\ln x - 1}$

63. $f^{-1}(x) = \frac{4x^2}{(6-x)^2}$, for $0 \le x < 6$



65. a. $f(t) = -2\cos\frac{\pi t}{3}$ **b.** $f(t) = 5\sin\frac{\pi t}{12} + 15$

67. a. F **b.** E **c.** D **d.** B **e.** C **f.** A

69. $(7\pi/6, -1/2)$; $(11\pi/6, -1/2)$ **71.** $-\frac{\sqrt{2+\sqrt{2}}}{2}$

73. $\pi/6$ **75.** $-\pi/2$ **77.** x, provided $-1 \le x \le 1$

79. $\cos\theta = \frac{5}{13}$; $\tan\theta = \frac{12}{5}$; $\cot\theta = \frac{5}{12}$; $\sec\theta = \frac{13}{5}$; $\csc\theta = \frac{13}{12}$

81. $\frac{\sqrt{16 - x^2}}{4}$ **83.** $\pi/2 - \theta$ **85.** 0

87. $\tan 2\theta = \frac{\sin 2\theta}{\cos 2\theta} = \frac{2\sin\theta\cos\theta}{\cos^2\theta - \sin^2\theta}$
$= \frac{2\sin\theta\cos\theta/\cos^2\theta}{(\cos^2\theta - \sin^2\theta)/\cos^2\theta} = \frac{2\tan\theta}{1 - \tan^2\theta}$

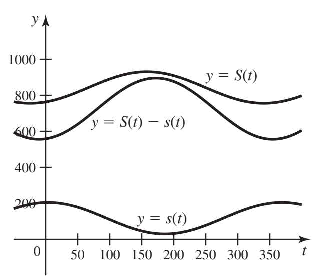
89. a.

n	1	2	3	4	5	6	7	8	9	10
$T(n)$	1	5	14	30	55	91	140	204	285	385

b. $D = \{n: n \text{ is a positive integer}\}$ **c.** 14

91. $s(t) = 117.5 - 87.5\sin\left(\frac{\pi}{182.5}(t - 95)\right)$

$S(t) = 844.5 + 87.5\sin\left(\frac{\pi}{182.5}(t - 67)\right)$



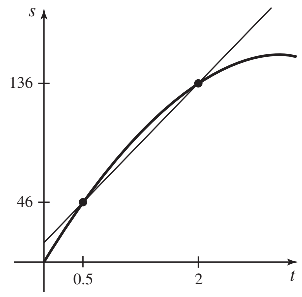
CHAPTER 2

Section 2.1 Exercises, pp. 61–62

1. $\frac{s(b) - s(a)}{b - a}$ **3.** 20 **5. a.** 36 **b.** 44 **c.** 52 **d.** 60

7. 47.84, 47.984, 47.9984; instantaneous velocity appears to be 48

9. $\frac{f(b) - f(a)}{b - a}$ **11.** The instantaneous velocity at $t = a$ is the slope of the line tangent to the position curve at $t = a$. **13. a.** 48 **b.** 64 **c.** 80 **d.** $16(6 - h)$ **15.** $m_{sec} = 60$; the slope is the average velocity of the object over the interval $[0.5, 2]$.



17.

Time interval	Average velocity
[1, 2]	80
[1, 1.5]	88
[1, 1.1]	94.4
[1, 1.01]	95.84
[1, 1.001]	95.984
$v_{inst} = 96$	

19.

Time interval	Average velocity
[2, 3]	20
[2.9, 3]	5.60
[2.99, 3]	4.16
[2.999, 3]	4.016
[2.9999, 3]	4.002
$v_{inst} = 4$	

21.

Time interval	Average velocity
[3, 3.5]	−24
[3, 3.1]	−17.6
[3, 3.01]	−16.16
[3, 3.001]	−16.016
[3, 3.0001]	−16.002
$v_{inst} = -16$	

23.

Time interval	Average velocity
[0, 1]	36.372
[0, 0.5]	67.318
[0, 0.1]	79.468
[0, 0.01]	79.995
[0, 0.001]	80.000
$v_{inst} = 80$	

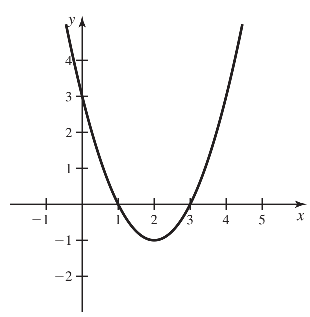
25.

Interval	Slope of secant line
[1, 2]	6
[1.5, 2]	7
[1.9, 2]	7.8
[1.99, 2]	7.98
[1.999, 2]	7.998
$m_{tan} = 8$	

27.

Interval	Slope of secant line
[0, 1]	1.718
[0, 0.5]	1.297
[0, 0.1]	1.052
[0, 0.01]	1.005
[0, 0.001]	1.001
$m_{tan} = 1$	

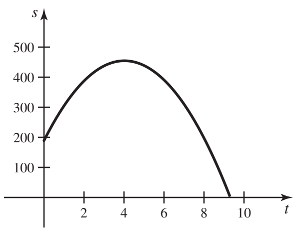
29. a.



b. $(2, -1)$

c.

Interval	Slope of secant line
[2, 2.5]	0.5
[2, 2.1]	0.1
[2, 2.01]	0.01
[2, 2.001]	0.001
[2, 2.0001]	0.0001
$m_{tan} = 0$	

31. a. 

b. $t = 4$

c.

Interval	Average velocity
$[4, 4.5]$	-8
$[4, 4.1]$	-1.6
$[4, 4.01]$	-0.16
$[4, 4.001]$	-0.016
$[4, 4.0001]$	-0.0016
$v_{\text{inst}} = 0$	

d. $0 \le t < 4$ **e.** $4 < t \le 9$ **33.** 0.6366, 0.9589, 0.9996, 1

Section 2.2 Exercises, pp. 67–71

1. As x approaches a from either side, the values of $f(x)$ approach L.
3. a. 5 **b.** 3 **c.** Does not exist **d.** 1 **e.** 2
5. a. -1 **b.** 1 **c.** 2 **d.** 2
7. a.

x	$f(x)$	x	$f(x)$
1.9	3.9	2.1	4.1
1.99	3.99	2.01	4.01
1.999	3.999	2.001	4.001
1.9999	3.9999	2.0001	4.0001

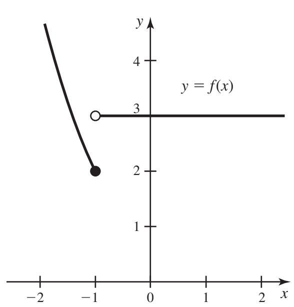
b. 4

9. a.

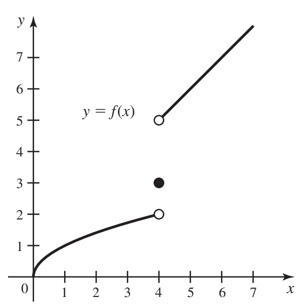
t	$g(t)$	t	$g(t)$
8.9	5.983287	9.1	6.016621
8.99	5.998333	9.01	6.001666
8.999	5.999833	9.001	6.000167

b. 6

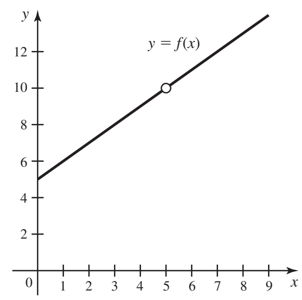
11. As x approaches a from the right, the values of $f(x)$ approach L.
13. $L = M$ **15. a.** 0 **b.** 1 **c.** 0
d. Does not exist; $\lim_{x\to 1^-} f(x) \ne \lim_{x\to 1^+} f(x)$ **17. a.** 3 **b.** 2
c. 2 **d.** 2 **e.** 2 **f.** 4 **g.** 1 **h.** Does not exist
i. 3 **j.** 3 **k.** 3 **l.** 3

19. 

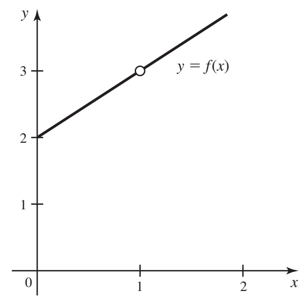
2; 2; 3; does not exist

21. 

3; 2; 5; does not exist

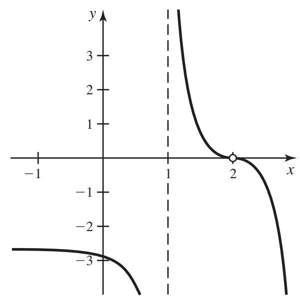
23. 

undefined; 10; 10; 10

25. 

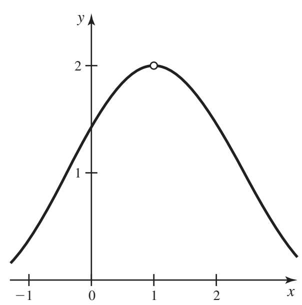
undefined; 3; 3; 3

27. From the graph and table, the limit appears to be 0.

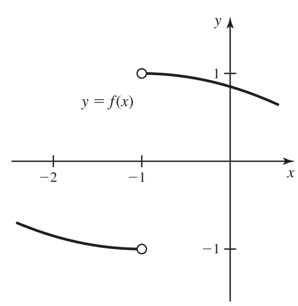


x	1.99	1.999	1.9999
$f(x)$	0.0021715	0.00014476	0.000010857
x	2.0001	2.001	2.01
$f(x)$	-0.000010857	-0.00014476	-0.0021715

29. From the graph and table, the limit appears to be 2.



x	0.9	0.99	0.999
$f(x)$	1.993342	1.999933	1.999999
x	1.001	1.01	1.1
$f(x)$	1.999999	1.999933	1.993342

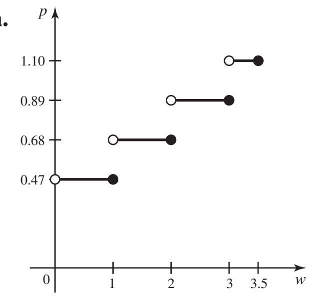
31. 

x	-1.1	-1.01	-1.001
$g(x)$	-0.9983342	-0.9999833	-0.9999998
x	-0.999	-0.99	-0.9
$g(x)$	0.9999998	0.9999833	0.9983342

From the table and the graph, it appears that the limit does not exist.

33. a. False **b.** False **c.** False **d.** False **e.** True

35. a.



b. 0.89 **c.** Because $\lim_{w\to 3^-} f(w) = 0.89$ and $\lim_{w\to 3^+} f(w) = 1.1$, we know that $\lim_{w\to 3^-} f(w) \neq \lim_{w\to 3^+} f(w)$. So $\lim_{w\to 3} f(w)$ does not exist.

37. 3 **39.** 16 **41.** 1

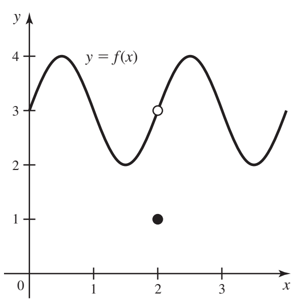
43. a.

x	$\sin(1/x)$
$2/\pi$	1
$2/(3\pi)$	-1
$2/(5\pi)$	1
$2/(7\pi)$	-1
$2/(9\pi)$	1
$2/(11\pi)$	-1

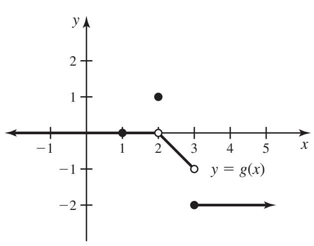
The function values alternate between 1 and -1.

b. The function values alternate between 1 and -1 infinitely many times on the interval $(0, h)$ no matter how small $h > 0$ becomes. **c.** Does not exist

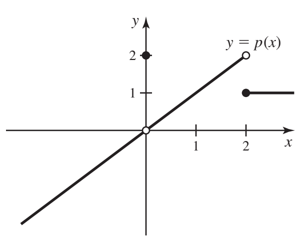
45.



47.



49.



51. a. $-2, -1, 1, 2$ **b.** 2, 2, 2

c. $\lim_{x\to a^-} \lfloor x \rfloor = a - 1$ and $\lim_{x\to a^+} \lfloor x \rfloor = a$, if a is an integer

d. $\lim_{x\to a^-} \lfloor x \rfloor = \lfloor a \rfloor$ and $\lim_{x\to a^+} \lfloor x \rfloor = \lfloor a \rfloor$, if a is not an integer

e. Limit exists provided a is not an integer

53. a. 8 **b.** 5 **55. a.** 2; 3; 4 **b.** p **57.** p/q

Section 2.3 Exercises, pp. 79–82

1. $\lim_{x\to a} p(x) = p(a)$ **3.** Those values of a for which the denominator is not zero **5.** $\dfrac{x^2 - 7x + 12}{x - 3} = x - 4$, for $x \neq 3$; -1

7. 32; Constant Multiple Law **9.** 5; Difference Law

11. 8; Quotient and Difference Laws **13.** 4; Root and Power Laws **15.** 5; 1 **17.** 20 **19.** 5 **21.** -45 **23.** 8 **25.** 3

27. 3 **29.** -5 **31.** 8 **33.** 2 **35.** -8 **37.** -1 **39.** -12 **41.** $\frac{1}{6}$

43. $-\frac{1}{36}$ **45.** $2\sqrt{a}$ **47.** $\frac{1}{8}$ **49.** $-\frac{1}{16}$ **51.** 5 **53.** 10 **55.** 2

57. -54 **59.** 0 **61.** 1 **63.** 1 **65.** $1/2$ **67.** Does not exist

69. Does not exist **71. a.** False **b.** False **c.** False **d.** False

e. False **73. a.** 2 **b.** 0 **c.** Does not exist **75. a.** 0

b. $\sqrt{x - 2}$ is undefined for $x < 2$. **77.** 0.0435 N/C

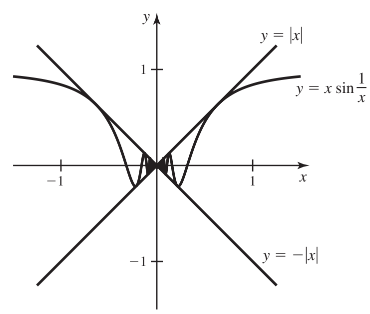
79. $\lim_{S\to 0^+} r(S) = 0$; the radius of the cylinder approaches 0 as the surface area of the cylinder approaches 0.

81. a. Because $\left|\sin \frac{1}{x}\right| \leq 1$, for all $x \neq 0$, we have that

$$|x|\left|\sin \frac{1}{x}\right| \leq |x|.$$

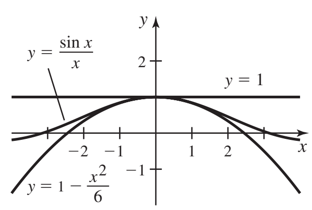
That is, $\left|x \sin \frac{1}{x}\right| \leq |x|$, so $-|x| \leq x \sin \frac{1}{x} \leq |x|$, for all $x \neq 0$.

b.



c. $\lim_{x\to 0} -|x| = 0$ and $\lim_{x\to 0} |x| = 0$; by part (a) and the Squeeze Theorem, $\lim_{x\to 0} x \sin \frac{1}{x} = 0$.

83. a.

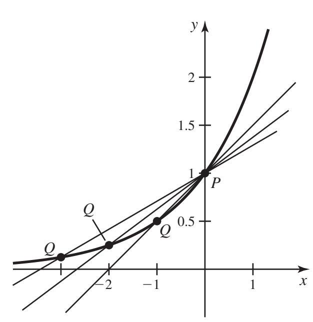


b. $\lim_{x\to 0} \dfrac{\sin x}{x} = 1$

85. Because $\lim_{x\to 0^-} |x| = \lim_{x\to 0^-} (-x) = 0$ and $\lim_{x\to 0^+} |x| = \lim_{x\to 0^+} x = 0$, we know that $\lim_{x\to 0} |x| = 0$. **87.** 1 **89.** $a = -13$; $\lim_{x\to -1} g(x) = 6$

91. 6 **93.** $5a^4$

95. a.



b. $\dfrac{2^x - 1}{x}$

c.

x	$\frac{2^x - 1}{x}$
-1	0.5
-0.1	0.6697
-0.01	0.6908
-0.001	0.6929
-0.0001	0.6931
-0.00001	0.6931
Limit $\approx$ 0.693	

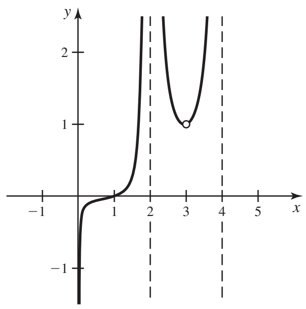
97. 6; 5 **99.** $\frac{1}{3}$ **101.** $f(x) = x - 1$, $g(x) = \frac{5}{x - 1}$
103. $b = 2$ and $c = -8$; yes **105.** 6; 4

Section 2.4 Exercises, pp. 88–91

1. As x approaches a from the right, the values of $f(x)$ are negative and become arbitrarily large in magnitude.
3. A vertical asymptote for a function f is a vertical line $x = a$, where one (or more) of the following is true:

$$\lim_{x \to a^-} f(x) = \pm\infty; \lim_{x \to a^+} f(x) = \pm\infty.$$

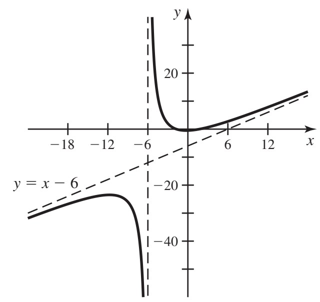
5. ∞ **7. a.** ∞ **b.** ∞ **c.** ∞ **d.** ∞ **e.** $-\infty$ **f.** Does not exist
9. a. $-\infty$ **b.** $-\infty$ **c.** $-\infty$ **d.** ∞ **e.** $-\infty$ **f.** Does not exist
11. a. ∞ **b.** $-\infty$ **c.** $-\infty$ **d.** ∞ **13.** $-\infty$ **15.** No; there is a vertical asymptote at $x = 2$ but not at $x = 1$.
17.



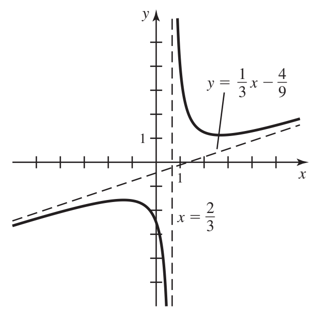
19. a and b are correct. **21. a.** ∞ **b.** $-\infty$ **c.** Does not exist
23. a. $-\infty$ **b.** $-\infty$ **c.** $-\infty$ **25. a.** ∞ **b.** $-\infty$ **c.** Does not exist **27. a.** $-\infty$ **b.** $-\infty$ **c.** $-\infty$ **29. a.** ∞ **b.** Does not exist **c.** Does not exist **31. a.** ∞ **b.** $1/54$ **c.** Does not exist
33. -5 **35.** ∞ **37.** $-\infty$ **39.** ∞ **41.** $-\infty$ **43.** ∞
45. a. $1/10$ **b.** $-\infty$ **c.** ∞; vertical asymptote: $x = -5$
47. $x = 3$; $\lim_{x \to 3^+} f(x) = -\infty$; $\lim_{x \to 3^-} f(x) = \infty$; $\lim_{x \to 3} f(x)$ does not exist **49.** $x = 0$ and $x = 2$; $\lim_{x \to 0^+} f(x) = \infty$; $\lim_{x \to 0^-} f(x) = -\infty$; $\lim_{x \to 0} f(x)$ does not exist; $\lim_{x \to 2^+} f(x) = \infty$; $\lim_{x \to 2^-} f(x) = \infty$; $\lim_{x \to 2} f(x) = \infty$
51. a. $-\infty$ **b.** ∞ **c.** $-\infty$ **d.** ∞ **53. a.** False **b.** True
c. False **55.** $r(x) = \frac{(x - 1)^2}{(x - 1)(x - 2)^2}$ **57.** $f(x) = \frac{1}{x - 6}$
59. $x = 0$ **61.** $x = -1$ **63.** $\theta = 10k + 5$, for any integer k
65. $x = 0$ **67. a.** $a = 4$ or $a = 3$ **b.** Either $a > 4$ or $a < 3$
c. $3 < a < 4$ **69. a.** $\frac{1}{\sqrt[3]{h}}$ regardless of the sign of h
b. $\lim_{h \to 0^+} \frac{1}{\sqrt[3]{h}} = \infty$; $\lim_{h \to 0^-} \frac{1}{\sqrt[3]{h}} = -\infty$; the tangent line at $(0, 0)$ is vertical.

Section 2.5 Exercises, pp. 100–102

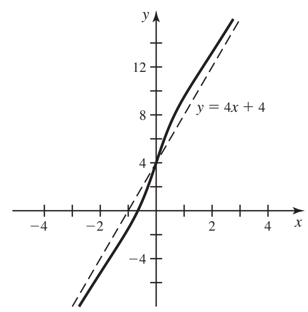
1. As $x < 0$ becomes arbitrarily large in magnitude, the corresponding values of f approach 10. **3.** ∞ **5.** 0 **7.** 0 **9.** 3 **11.** 0
13. ∞; 0; 0 **15.** 3; 3 **17.** 0 **19.** 0 **21.** ∞ **23.** $-\infty$
25. $2/3$ **27.** $-\infty$ **29.** 5 **31.** -4 **33.** $-3/2$ **35.** 0
37. $\lim_{x \to \infty} f(x) = \lim_{x \to -\infty} f(x) = \frac{1}{5}$; $y = \frac{1}{5}$
39. $\lim_{x \to \infty} f(x) = \lim_{x \to -\infty} f(x) = 2$; $y = 2$
41. $\lim_{x \to \infty} f(x) = \lim_{x \to -\infty} f(x) = 0$; $y = 0$
43. $\lim_{x \to \infty} f(x) = \infty$; $\lim_{x \to -\infty} f(x) = -\infty$; none
45. $\lim_{x \to \infty} f(x) = \lim_{x \to -\infty} f(x) = \frac{4}{9}$; $y = \frac{4}{9}$
47. $\lim_{x \to \infty} f(x) = \frac{2}{3}$; $\lim_{x \to -\infty} f(x) = -2$; $y = \frac{2}{3}$; $y = -2$
49. $\lim_{x \to \infty} f(x) = \lim_{x \to -\infty} f(x) = \frac{1}{4 + \sqrt{3}}$; $y = \frac{1}{4 + \sqrt{3}}$
51. a. $y = x - 6$ **b.** $x = -6$
c.



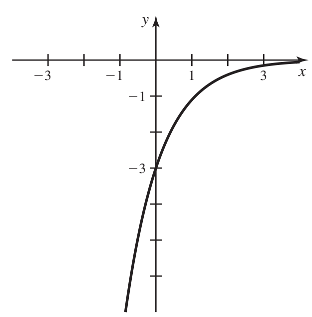
53. a. $y = \frac{1}{3}x - \frac{4}{9}$ **b.** $x = \frac{2}{3}$
c.



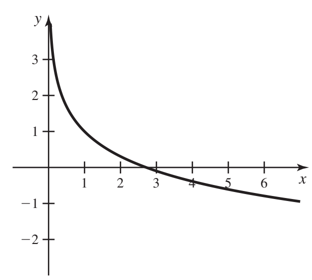
55. a. $y = 4x + 4$ **b.** No vertical asymptote
c.



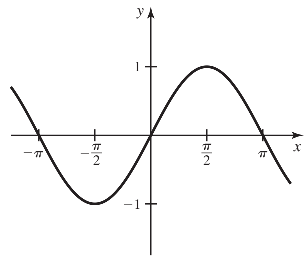
57. $\lim_{x \to \infty} (-3e^{-x}) = 0$; $\lim_{x \to -\infty} (-3e^{-x}) = -\infty$



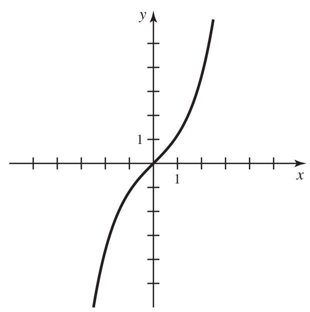
59. $\lim_{x \to \infty} (1 - \ln x) = -\infty$; $\lim_{x \to 0^+} (1 - \ln x) = \infty$



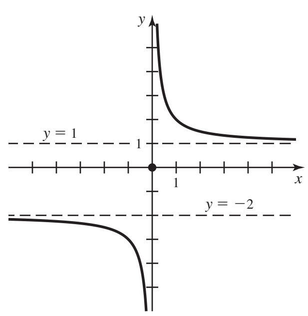
61. $\lim_{x\to\infty} \sin x$ does not exist; $\lim_{x\to-\infty} \sin x$ does not exist



63. a. False **b.** False **c.** True **d.** False **65.** 3500
67. No steady state **69.** 2
71. a. $\lim_{x\to\infty} f(x) = \lim_{x\to-\infty} f(x) = 2; y = 2$
b. $x = 0; \lim_{x\to 0^+} f(x) = \infty; \lim_{x\to 0^-} f(x) = -\infty$
73. a. $\lim_{x\to\infty} f(x) = \lim_{x\to-\infty} f(x) = 3; y = 3$
b. $x = -3$ and $x = 4$; $\lim_{x\to -3^-} f(x) = \infty; \lim_{x\to -3^+} f(x) = -\infty;$
$\lim_{x\to 4^-} f(x) = -\infty; \lim_{x\to 4^+} f(x) = \infty$
75. a. $\lim_{x\to\infty} f(x) = \lim_{x\to-\infty} f(x) = 1; y = 1$
b. $x = 0; \lim_{x\to 0^+} f(x) = \infty; \lim_{x\to 0^-} f(x) = -\infty$
77. a. $\lim_{x\to\infty} f(x) = 1; \lim_{x\to-\infty} f(x) = -1; y = 1$ and $y = -1$
b. No vertical asymptote
79. a. $\lim_{x\to\infty} f(x) = 0; \lim_{x\to-\infty} f(x) = 0; y = 0$
b. No vertical asymptote **81. a.** $\lim_{x\to\infty} f(x) = 2; \lim_{x\to-\infty} f(x)$ does not exist; $y = 2$ **b.** $x = 0; \lim_{x\to 0^+} f(x) = \infty; \lim_{x\to 0^-} f(x)$ does not exist
83. a. $\frac{\pi}{2}$ **b.** $\frac{\pi}{2}$ **85. a.** $\lim_{x\to\infty} \sinh x = \infty; \lim_{x\to-\infty} \sinh x = -\infty$
b. $\sinh 0 = 0$

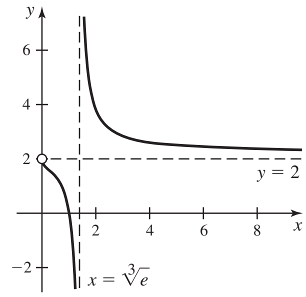


87.



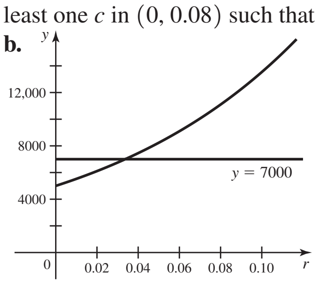
89. 1 **91.** 0 **93. a.** No; f has a horizontal asymptote if $m = n$, and it has a slant asymptote if $m = n + 1$. **b.** Yes; $f(x) = x^4/\sqrt{x^6 + 1}$ **95.** $y = 3$ and $y = 2$

97. $y = 2; x = \sqrt[3]{e}$



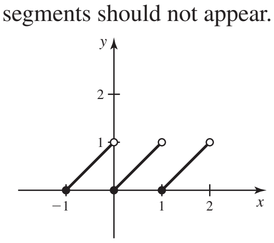
Section 2.6 Exercises, pp. 112–115

1. a, c **3.** A function is continuous on an interval if it is continuous at each point of the interval. If the interval contains endpoints, then the function must be right- or left-continuous at those points. **5.** $a = 1$, item 1; $a = 2$, item 3; $a = 3$, item 2 **7.** $a = 1$, item 1; $a = 2$, item 2; $a = 3$, item 1 **9. a.** $\lim_{x\to a^-} f(x) = f(a)$ **b.** $\lim_{x\to a^+} f(x) = f(a)$
11. $(0, 1), (1, 2), (2, 3], (3, 5)$; left-continuous at 3
13. $(0, 1), (1, 2), [2, 3), (3, 5)$; right-continuous at 2
15. $\{x: x \neq 0\}, \{x: x \neq 0\}$ **17.** No; $f(-5)$ is undefined.
19. No; $f(1)$ is undefined. **21.** No; $\lim_{x\to 1} f(x) = 2$ but $f(1) = 3$.
23. No; $f(4)$ is undefined. **25.** $(-\infty, \infty)$
27. $(-\infty, -3), (-3, 3), (3, \infty)$ **29.** $(-\infty, -2), (-2, 2), (2, \infty)$
31. 1 **33.** $2\sqrt{6}$ **35.** 16 **37.** ln 2 **39. a.** $\lim_{x\to 1} f(x)$ does not exist.
b. Continuous from the right **c.** $(-\infty, 1), [1, \infty)$ **41.** $(-\infty, 5]$; left-continuous at 5 **43.** $(-\infty, -2\sqrt{2}], [2\sqrt{2}, \infty)$; left-continuous at $-2\sqrt{2}$; right-continuous at $2\sqrt{2}$ **45.** $(-\infty, \infty)$ **47.** $(-\infty, \infty)$
49. 3 **51.** 1 **53.** 4 **55.** 2 **57.** $-\frac{1}{2}$ **59.** 4
61. $(n\pi, (n + 1)\pi)$, where n is an integer; $\sqrt{2}; -\infty$
63. $\left(\frac{n\pi}{2}, \left(\frac{n}{2} + 1\right)\frac{\pi}{2}\right)$, where n is an odd integer; ∞; $\sqrt{3} - 2$
65. $(-\infty, 0), (0, \infty); \infty; -\infty$ **67. b.** $x \approx 0.835$
69. b. $x \approx -0.285; x \approx 0.778; x \approx 4.507$ **71. b.** $x \approx -0.567$
73. a. True **b.** True **c.** False **d.** False **75. a.** $A(r)$ is continuous on $[0, 0.08]$, and 7000 is between $A(0) = 5000$ and $A(0.08) = 11{,}098.20$. By the Intermediate Value Theorem, there is at least one c in $(0, 0.08)$ such that $A(c) = 7000$.
b.

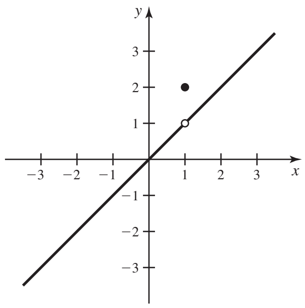


$c \approx 0.034$ or 3.4%

77. $[0, \pi/2]$; 0.45 **79.** $(-\infty, \infty)$ **81.** $[0, 16), (16, \infty)$
83. The vertical line segments should not appear.

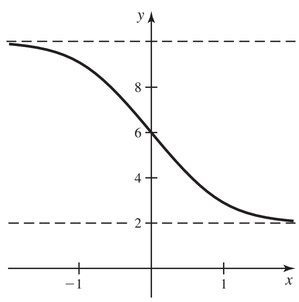


85. a, b.



87. a. 2 **b.** 8 **c.** No; $\lim_{x\to 1^-} g(x) = 2$ and $\lim_{x\to 1^+} g(x) = 8$.

89. $\lim_{x\to 0} f(x) = 6$, $\lim_{x\to -\infty} f(x) = 10$, and $\lim_{x\to\infty} f(x) = 2$; no vertical asymptote; $y = 2$ and $y = 10$ are the horizontal asymptotes.



91. $x_1 = \frac{1}{7}$; $x_2 = \frac{1}{2}$; $x_3 = \frac{3}{5}$ **93.** Yes. Imagine there is a clone of the monk who walks down the path at the same time the monk walks up the path. The monk and his clone must cross paths at some time between dawn and dusk. **95.** No; f cannot be made continuous at $x = a$ by redefining $f(a)$. **97.** $\lim_{x\to 2} f(x) = -3$; define $f(2)$ to be -3.
99. $a = 0$ removable discontinuity; $a = 1$ infinite discontinuity
101. a. Yes **b.** No **103. a.** For example, $f(x) = 1/(x - 1)$, $g(x) = x + 1$ **b.** For continuity, g must be continuous at 0, and f must be continuous at $g(0)$.

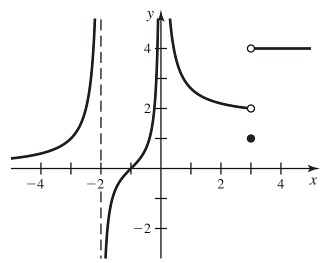
Section 2.7 Exercises, pp. 124–128

1. 1 **3.** c **5.** Given any $\varepsilon > 0$ there exists a $\delta > 0$ such that $|f(x) - L| < \varepsilon$ whenever $0 < |x - a| < \delta$. **7.** $0 < \delta \le 2$
9. a. $\delta = 1$ **b.** $\delta = \frac{1}{2}$ **11. a.** $\delta = 2$ **b.** $\delta = \frac{1}{2}$
13. a. $0 < \delta \le 1$ **b.** $0 < \delta \le 0.79$ **15. a.** $0 < \delta \le 1$
b. $0 < \delta \le \frac{1}{2}$ **c.** $0 < \delta \le \varepsilon$ **17. a.** $0 < \delta \le 1$ **b.** $0 < \delta \le \frac{1}{2}$
c. $0 < \delta \le \frac{\varepsilon}{2}$ **19.** $\delta = \varepsilon/8$ **21.** $\delta = \varepsilon$ **23.** $\delta = \varepsilon$
25. $\delta = \varepsilon/3$ **27.** $\delta = \sqrt{\varepsilon}$ **29.** $\delta = \min\{1, \varepsilon/8\}$ **31.** $\delta = \varepsilon/2$
33. $\delta = \min\{1, 6\varepsilon\}$ **35.** $\delta = \min\{1/20, \varepsilon/200\}$
37. $\delta = \min\{1, \sqrt{\varepsilon/2}\}$ **39.** $\delta = \varepsilon/|m|$ if $m \ne 0$; use any $\delta > 0$ if $m = 0$ **41.** $\delta = \min\{1, 8\varepsilon/15\}$ **45.** $\delta = 1/\sqrt{N}$
47. $\delta = 1/\sqrt{N - 1}$ **49. a.** False **b.** False **c.** True **d.** True
51. For $x > a$, $|x - a| = x - a$. **53. a.** $\delta = \varepsilon/2$ **b.** $\delta = \varepsilon/3$
c. Because $\lim_{x\to 0^+} f(x) = \lim_{x\to 0^-} f(x) = -4$, $\lim_{x\to 0} f(x) = -4$.
55. $\delta = \varepsilon^2$ **57. a.** For each $N > 0$ there exists $\delta > 0$ such that $f(x) > N$ whenever $0 < x - a < \delta$. **b.** For each $N < 0$ there exists $\delta > 0$ such that $f(x) < N$ whenever $0 < a - x < \delta$.
c. For each $N > 0$ there exists $\delta > 0$ such that $f(x) > N$ whenever $0 < a - x < \delta$. **59.** $\delta = 1/N$ **61.** $\delta = (-10/M)^{1/4}$
65. $N = 1/\varepsilon$ **67.** $N = M - 1$

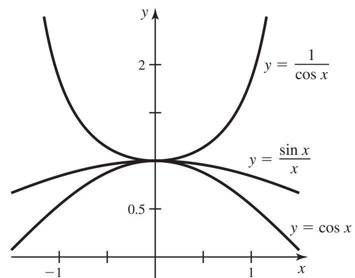
Chapter 2 Review Exercises, pp. 128–130

1. a. False **b.** False **c.** False **d.** True **e.** False **f.** False
g. False **h.** True **3.** 12 ft/s **5.** $x = -1$; $\lim_{x\to -1} f(x)$ does not exist; $x = 1$; $\lim_{x\to 1} f(x) \ne f(1)$; $x = 3$; $f(3)$ is undefined.

7. a. 1.414 **b.** $\sqrt{2}$
9.



11. $\sqrt{11}$ **13.** 13 **15.** 2 **17.** $\frac{1}{3}$ **19.** $-\frac{1}{16}$ **21.** 108 **23.** $\frac{1}{108}$
25. 0 **27.** $-\infty$ **29.** ∞ **31.** 4 **33.** $-\infty$ **35.** $\frac{1}{2}$ **37.** $-3/\sqrt{a}$
39. $2/(1 - a)$ **41.** $3\pi/2 + 2$ **43.** $1; \infty$ **45.** $2/3$
47. $-1/3; 2/7$ **49.** 5 **51.** $-\infty$
53. a.

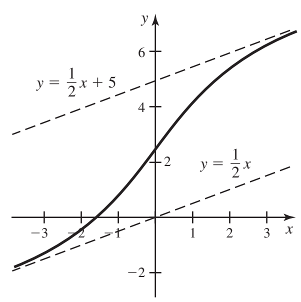


b. $\lim_{x\to 0} \cos x \le \lim_{x\to 0} \frac{\sin x}{x} \le \lim_{x\to 0} \frac{1}{\cos x}$;

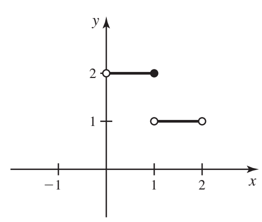
$$1 \le \lim_{x\to 0} \frac{\sin x}{x} \le 1;$$

$$\lim_{x\to 0} \frac{\sin x}{x} = 1$$

55. $\lim_{x\to\infty} f(x) = -4$; $\lim_{x\to -\infty} f(x) = -4$
57. $\lim_{x\to\infty} f(x) = 1$; $\lim_{x\to -\infty} f(x) = -\infty$
59. $\lim_{x\to\infty} f(x) = 2$; $\lim_{x\to -\infty} f(x) = 5$ **61. a.** $\infty; -\infty$
b. $y = 3x + 2$ is the slant asymptote.
63. a. $-\infty; \infty$ **b.** $y = -x - 2$ is the slant asymptote.
65. a. $\infty, -\infty$ **b.** $y = 4x + 5$ is the slant asymptote.
67. Horizontal asymptotes at $y = 2/\pi$ and $y = -2/\pi$; vertical asymptote at $x = 0$
69.



71. No; $f(5)$ does not exist. **73.** Yes; $h(5) = \lim_{x\to 5} h(x) = 4$
75. $(-\infty, -\sqrt{5}]$ and $[\sqrt{5}, \infty)$; left-continuous at $-\sqrt{5}$ and right-continuous at $\sqrt{5}$ **77.** $(-\infty, -5)$, $(-5, 0)$, $(0, 5)$, and $(5, \infty)$
79. $a = 3, b = 0$
81.



83. a. Let $f(x) = x - \cos x$; $f(0) < 0 < f\left(\frac{\pi}{2}\right)$ **b.** $x \approx 0.739$

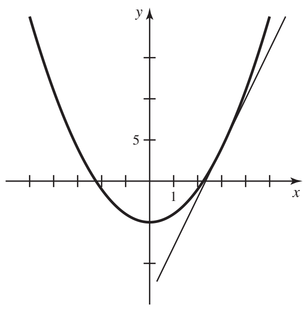
85. a. $m(0) < 30 < m(5)$ and $m(5) > 30 > m(15)$
b. $m = 30$ when $t \approx 2.4$ hr and $t \approx 10.8$ hr **c.** No; the maximum amount is approximately $m(5.5) \approx 38.5$. **87.** $\delta = \varepsilon$

89. $\delta = \min\left\{1, \frac{\varepsilon}{15}\right\}$ **91.** $\delta = 1/\sqrt[4]{N}$

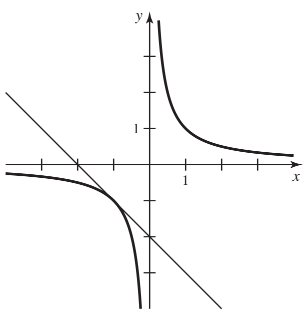
CHAPTER 3

Section 3.1 Exercises, pp. 137–140

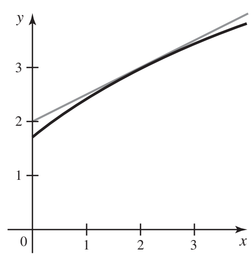
1. Given the point $(a, f(a))$ and any point $(x, f(x))$ near $(a, f(a))$, the slope of the secant line joining these points is $\frac{f(x) - f(a)}{x - a}$. The limit of this quotient as x approaches a is the slope of the tangent line at the point. **3.** The average rate of change over the interval $[a, x]$ is $\frac{f(x) - f(a)}{x - a}$. The value of $\lim_{x \to a} \frac{f(x) - f(a)}{x - a}$ is the slope of the tangent line; it is also the limit of average rates of change, which is the instantaneous rate of change at $x = a$. **5.** $f'(a)$ is the slope of the tangent line at $(a, f(a))$ or the instantaneous rate of change in f at a.
7. $f(2) = 7$; $f'(2) = 4$ **9.** $y = 3x - 1$ **11.** -5 **13.** 68 ft/s
15. a. 6 **b.** $y = 6x - 14$
c.



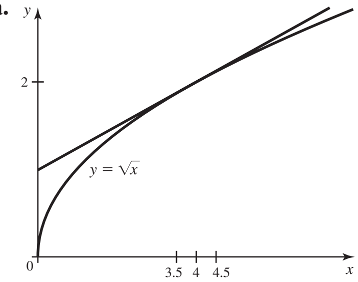
17. a. -1 **b.** $y = -x - 2$
c.



19. a. $\frac{1}{2}$ **b.** $y = \frac{1}{2}x + 2$
c.



21. a. 2 **b.** $y = 2x + 1$ **23. a.** 2 **b.** $y = 2x - 3$
25. a. 4 **b.** $y = 4x - 8$ **27. a.** 3 **b.** $y = 3x - 2$
29. a. $\frac{2}{25}$ **b.** $y = \frac{2}{25}x + \frac{7}{25}$ **31. a.** $\frac{1}{4}$ **b.** $y = \frac{1}{4}x + \frac{7}{4}$
33. a. 8 **b.** $y = 8x$ **35. a.** -14 **b.** $y = -14x - 16$
37. a. -4 **b.** $y = -4x + 3$ **39. a.** $\frac{1}{3}$ **b.** $y = \frac{1}{3}x + \frac{5}{3}$
41. a. $-\frac{1}{100}$ **b.** $y = -\frac{x}{100} + \frac{3}{20}$ **43.** $-\frac{1}{4}$ **45.** $\frac{1}{5}$ **47. a.** True **b.** False **c.** True **49.** $d'(4) = 128$ ft/s; the object falls with an instantaneous speed of 128 ft/s four seconds after being dropped.
51. $v'(3) = -4$ m/s per second; the instantaneous rate of change in the car's speed is -4 m/s^2 at $t = 3$ s.
53. a. $L'(1.5) \approx 4.3$ mm/week; the talon is growing at a rate of approximately 4.3 mm/week at $t = 1.5$ weeks (answers will vary). **b.** $L'(a) \approx 0$, for $a \geq 4$; the talon stops growing at $t = 4$ weeks. **55.** $D'(60) \approx 0.05$ hr/day; the number of daylight hours is increasing at about 0.05 hr/day, 60 days after Jan 1. $D'(170) \approx 0$ hr/day; the number of daylight hours is neither increasing nor decreasing 170 days after Jan 1. **57.** $f(x) = 5x^2$; $a = 2$; 20
59. $f(x) = x^4$; $a = 2$; 32 **61.** $f(x) = |x|$; $a = -1$; -1
63. a.



b.

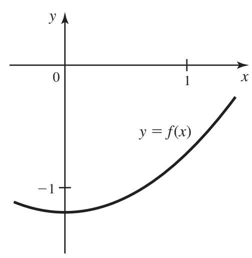
h	Approximation	Error
0.1	0.25002	2.0×10^{-5}
0.01	0.25000	2.0×10^{-7}
0.001	0.25000	2.0×10^{-9}

c. Values of x on both sides of 4 are used in the formula.
d. The centered difference approximations are more accurate than the forward and backward difference approximations. **65. a.** 0.39470, 0.41545 **b.** 0.02, 0.0003

Section 3.2 Exercises, pp. 148–152

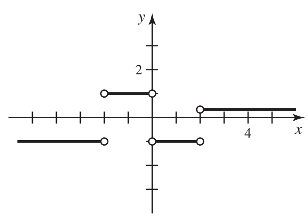
1. f' is the slope function of f. **3.** $\frac{dy}{dx}$ is the limit of $\frac{\Delta y}{\Delta x}$ as $\Delta x \to 0$.

5.



7. Yes

9. A line with a y-intercept of 1 and a slope of 3
11. $f'(x) = 7$ **13.** $\frac{dy}{dx} = 2x$; $\left.\frac{dy}{dx}\right|_{x=3} = 6$; $\left.\frac{dy}{dx}\right|_{x=-2} = -4$
15. a–C; b–C; c–A; d–B
17.



19. a. Not continuous at $x = 1$ **b.** Not differentiable at $x = 0, 1$
21. a. $f'(x) = 5$ **b.** $f'(1) = 5$; $f'(2) = 5$
23. a. $f'(x) = 8x$ **b.** $f'(2) = 16$; $f'(4) = 32$
25. a. $f'(x) = -\frac{1}{(x + 1)^2}$ **b.** $f'\left(-\frac{1}{2}\right) = -4$; $f'(5) = -\frac{1}{36}$
27. a. $f'(t) = -\frac{1}{2t^{3/2}}$ **b.** $f'(9) = -\frac{1}{54}$; $f'\left(\frac{1}{4}\right) = -4$
29. a. $f'(s) = 12s^2 + 3$ **b.** $f'(-3) = 111$; $f'(-1) = 15$
31. a. $v(t) = -32t + 100$ **b.** $v(1) = 68$ ft/s; $v(2) = 36$ ft/s
33. $\frac{dy}{dx} = \frac{1}{(x + 2)^2}$; $\left.\frac{dy}{dx}\right|_{x=2} = \frac{1}{16}$ **35. a.** $6x + 2$
b. $y = 8x - 13$ **37. a.** $\frac{3}{2\sqrt{3x + 1}}$ **b.** $y = 3x/10 + 13/5$