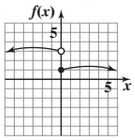
ANSWERS

Chapter 2

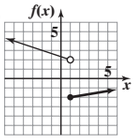
Exercises 2.1

1. $(x-9)(x+9)$ **2.** $(x-8)(x+8)$ **3.** $(x-7)(x+3)$
4. $(x+9)(x-4)$ **5.** $x(x-3)(x-4)$ **6.** $x(x+5)(x+10)$
7. $(2x-1)(3x+1)$ **8.** $(4x+3)(5x-1)$ **9.** 2 **10.** 2 **11.** 1.25
12. 2.25 **13.** (A) 2 (B) 2 (C) 2 (D) 2 **14.** (A) 2 (B) 2 (C) 2 (D) 2
15. (A) 1 (B) 2 (C) Does not exist (D) 2 **16.** (A) 4 (B) 4 (C) 4
(D) Does not exist **17.** 2 **18.** 1.9 **19.** 0.5 **20.** 1.5 **21.** (A) 1 (B) 2
(C) Does not exist (D) Does not exist **22.** (A) 2 (B) 2 (C) 2 (D) 2
23. (A) 1 (B) 1 (C) 1 (D) 3 **24.** (A) 0 (B) 0 (C) 0 (D) 0
25. (A) -2 (B) -2 (C) -2 (D) 1 **26.** (A) 3 (B) -3 (C) Does not exist
(D) -3 **27.** (A) 2 (B) 2 (C) 2 (D) Does not exist **28.** (A) -3 B) 3
(C) Does not exist (D) 3 **29.** 12 **30.** -6 **31.** 1 **32.** 2 **33.** -4
34. -2 **35.** -1.5 **36.** 1/2 **37.** 3 **38.** 4 **39.** 15 **40.** 8 **41.** -6
42. 19 **43.** $\frac{7}{5}$ **44.** $-8/15$ **45.** 3 **46.** -2

47.



48.



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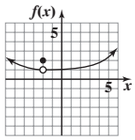

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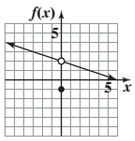
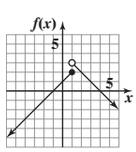
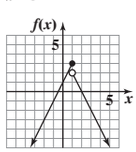


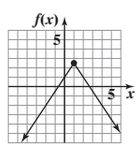
51. (A) 1 (B) 1 (C) 1 (D) 1 **52.** (A) 2 (B) 2
(C) 2 (D) 2 **53.** (A) 2 (B) 1 (C) Does not exist
(D) Does not exist **54.** (A) 0 (B) 1 (C) Does not exist
(D) Does not exist **55.** (A) -6 (B) Does not exist
(C) 6 **56.** (A) Does not exist (B) 0 (C) Does not exist

57. (A) 1 (B) -1 (C) Does not exist (D) Does not exist **58.** (A) 1
(B) -1 (C) Does not exist (D) Does not exist **59.** (A) Does not exist
(B) $\frac{1}{2}$ (C) $\frac{1}{4}$ **60.** (A) $-1/3$ (B) Does not exist (C) 1/3 **61.** (A) -5
(B) -3 (C) 0 **62.** (A) -5 (B) -2 (C) 0 **63.** (A) 0 (B) -1
(C) Does not exist **64.** (A) Does not exist (B) -1 (C) 0 **65.** (A) 1
(B) $\frac{1}{3}$ (C) $\frac{3}{4}$ **66.** (A) 10 (B) -4 (C) 5/4 **67.** False **68.** True **69.** False
70. False **71.** True **72.** False **73.** Yes; 2 **74.** No; Does not exist
75. No; Does not exist **76.** Yes; -4 **77.** Yes; $7/5$ **78.** Yes; $1/2$
79. No; 0 **80.** No; 9 **81.** 3 **82.** 5 **83.** 4 **84.** 4 **85.** -7 **86.** -4
87. 1 **88.** -3

89. (A) $\lim_{x\to 1^-} f(x) = 2$, $\lim_{x\to 1^+} f(x) = 3$ (B) $\lim_{x\to 1^-} f(x) = 3$, $\lim_{x\to 1^+} f(x) = 2$ (C) $m = 1.5$

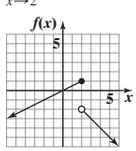


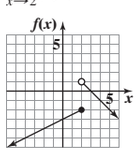


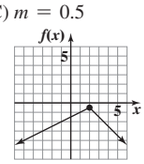


(D) The graph in (A) is broken when it jumps from $(1, 2)$ up to $(1, 3)$. The graph in (B) is also broken when it jumps down from $(1, 3)$ to $(1, 2)$. The graph in (C) is one continuous piece, with no breaks or jumps.

90. (A) $\lim_{x\to 2^-} f(x) = 1$, $\lim_{x\to 2^+} f(x) = -1$ (B) $\lim_{x\to 2^-} f(x) = -2$, $\lim_{x\to 2^+} f(x) = 1$ (C) $m = 0.5$

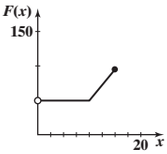






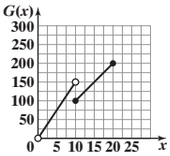
(D) The graph in (A) is broken when it jumps from $(2,1)$ down to $(2, -2)$, the graph in (B) is also broken when it jumps from $(2, -2)$ up to $(2, 1)$, while the graph in (C) is one continuous piece with no jumps or breaks.

91. (A) $F(x) = \begin{cases} 50 & \text{if } 0 \le x \le 10 \\ 9x - 40 & \text{if } x > 10 \end{cases}$ (B)



(C) All 3 limits are 50.

92. (A) $G(x) = \begin{cases} 15x, & 0 \le x \le 10 \\ 10x, & x > 10 \end{cases}$ (B)



(C) \$150; \$100; does not exist

95. (A) $D(x) = \begin{cases} x & \text{if } 0 \le x < 300 \\ 0.97x & \text{if } 300 \le x < 1{,}000 \\ 0.95x & \text{if } 1{,}000 \le x < 3{,}000 \\ 0.93x & \text{if } 3{,}000 \le x < 5{,}000 \\ 0.9x & \text{if } x \ge 5{,}000 \end{cases}$

(B) $\lim_{x\to 1{,}000} D(x)$ does not exist because
$\lim_{x\to 1{,}000^-} D(x) = 970$ and $\lim_{x\to 1{,}000^+} D(x) = 950$;
$\lim_{x\to 3{,}000^-} D(x)$ does not exist because
$\lim_{x\to 3{,}000^-} D(x) = 2{,}850$ and $\lim_{x\to 3{,}000^+} D(x) = 2{,}790$

96. (A)

$$P(x) = \begin{cases} x & \text{if } 0 \le x < 300 \\ 300 + 0.97(x - 300) = 0.97x + 9 & \text{if } 300 \le x < 1{,}000 \\ 0.97(1{,}000) + 9 + 0.95(x - 1{,}000) = 0.95x + 29 & \text{if } 1{,}000 \le x < 3{,}000 \\ 0.95(3{,}000) + 29 + 0.93(x - 3{,}000) = 0.93x + 89 & \text{if } 3{,}000 \le x < 5{,}000 \\ 0.93(5{,}000) + 89 + 0.90(x - 5{,}000) = 0.90x + 239 & \text{if } x \ge 5{,}000 \end{cases}$$

(B) $\lim_{x\to 1{,}000} P(x) = 979$; $\lim_{x\to 3{,}000} = P(x) = 2{,}879$

97. $F(x) = \begin{cases} 20x & \text{if } 0 < x \le 4{,}000 \\ 80{,}000 & \text{if } x \ge 4{,}000 \end{cases}$
$\lim_{x\to 4{,}000} F(x) = 80{,}000$; $\lim_{x\to 8{,}000} F(x) = 80{,}000$

98. $A(x) = \begin{cases} 20 & \text{if } 0 < x \le 4{,}000 \\ \frac{80{,}000}{x} & \text{if } x \ge 4{,}000 \end{cases}$
$\lim_{x\to 4{,}000} A(x) = 20$; $\lim_{x\to 8{,}000} A(x) = 10$

99. $\lim_{x\to 5} f(x)$ does not exist; $\lim_{x\to 10} f(x) = 0$;
$\lim_{x\to 5} g(x) = 0$; $\lim_{x\to 10} g(x) = 1$

Exercises 2.2

1. $y = 4$ **2.** $x = 5$ **3.** $x = -6$ **4.** $y = 1$ **5.** $2x - y = -13$
6. $3x + y = 20$ **7.** $7x + 9y = 63$ **8.** $-5x + y = 25$ **9.** -2 **10.** ∞
11. $-\infty$ **12.** ∞ **13.** Does not exist **14.** ∞ **15.** 0 **16.** Does not exist
17. (A) $-\infty$ (B) ∞ (C) Does not exist **18.** (A) $-\infty$ (B) ∞
(C) Does not exist **19.** (A) ∞ (B) ∞ (C) ∞ **20.** (A) $-\infty$ (B) $-\infty$
(C) $-\infty$ **21.** (A) 3 (B) 3 (C) 3 **22.** (A) $-\infty$ (B) ∞ (C) Does not exist
23. (A) $-\infty$ (B) ∞ (C) Does not exist **24.** (A) -3 (B) -3 (C) -3
25. (A) $-5x^3$ (B) $-\infty$ (C) ∞ **26.** (A) $-x^6$ (B) $-\infty$ (C) $-\infty$
27. (A) $-6x^4$ (B) $-\infty$ (C) $-\infty$ **28.** (A) $-x^5$ (B) $-\infty$ (C) ∞
29. (A) x^2 (B) ∞ (C) ∞ **30.** (A) x^3 (B) ∞ (C) $-\infty$
31. (A) $2x^5$ (B) ∞ (C) $-\infty$ **32.** (A) $4x^4$ (B) ∞ (C) ∞
33. (A) $\frac{47}{41} \approx 1.146$ (B) $\frac{407}{491} \approx 0.829$ (C) $\frac{4}{5} = 0.8$
34. (A) $-\frac{373}{507} \approx -0.736$ (B) $-\frac{2{,}998}{4{,}007} \approx -0.748$ (C) $-\frac{3}{4} = -0.75$
35. (A) $\frac{2{,}011}{138} \approx 14.572$ (B) $\frac{12{,}511}{348} \approx 35.951$ (C) ∞

36. (A) $\frac{29}{3{,}586} \approx 0.008$ (B) $\frac{69}{28{,}674} \approx 0.002$ (C) 0

37. (A) $-\frac{8{,}568}{46{,}653} \approx -0.184$ (B) $-\frac{143{,}136}{1{,}492{,}989} \approx -0.096$ (C) 0

38. (A) $-\frac{8{,}724}{567} \approx -15.386$ (B) $-\frac{1{,}119{,}696}{8{,}100} \approx -138.234$ (C) $-\infty$

39. (A) $-\frac{7{,}010}{996} \approx -7.038$ (B) $-\frac{56{,}010}{7{,}996} \approx -7.005$ (C) -7

40. (A) $\frac{47}{195} \approx 0.241$ (B) $\frac{97}{395} \approx 0.246$ (C) $\frac{1}{4} = 0.25$

41. $\lim_{x\to 2^-} f(x) = -\infty$; $\lim_{x\to 2^+} f(x) = \infty$; $x = 2$ is a vertical asymptote

42. $\lim_{x\to 5^-} f(x) = -\infty$; $\lim_{x\to 5^+} f(x) = \infty$; $x = 5$ is a vertical asymptote

43. $\lim_{x\to -1} f(x) = -0.5$; $\lim_{x\to 1^-} f(x) = -\infty$; $\lim_{x\to 1^+} f(x) = \infty$; $x = 1$ is a vertical asymptote **44.** No zeros of denominator; no vertical asymptotes

45. No zeros of denominator; no vertical asymptotes

46. $\lim_{x\to -4^-} f(x) = -\infty$; $\lim_{x\to -4^+} f(x) = \infty$; $\lim_{x\to 4^-} f(x) = \infty$; $\lim_{x\to 4^+} f(x) = -\infty$; $x = -4$ and $x = 4$ are vertical asymptotes

47. $\lim_{x\to -2^-} f(x) = -\infty$; $\lim_{x\to -2^+} f(x) = \infty$; $\lim_{x\to 5^-} f(x) = \infty$; $\lim_{x\to 5^+} f(x) = -\infty$; $x = -2$ and $x = 5$ are vertical asymptotes

48. $\lim_{x\to -2^-} f(x) = -\infty$; $\lim_{x\to -2^+} f(x) = \infty$; $\lim_{x\to -1} f(x) = 2$; $\lim_{x\to 0^-} f(x) = \infty$; $\lim_{x\to 0^+} f(x) = -\infty$; $x = -2$ and $x = 0$ are vertical asymptotes

49. $\lim_{x\to -2} f(x) = -\frac{2}{3}$; $\lim_{x\to 0^-} f(x) = -\infty$; $\lim_{x\to 0^+} f(x) = \infty$; $\lim_{x\to 1^-} f(x) = \infty$; $\lim_{x\to 1^+} f(x) = -\infty$; $x = 0$ and $x = 1$ are vertical asymptotes

50. $\lim_{x\to -4^-} f(x) = -\infty$; $\lim_{x\to -4^+} f(x) = \infty$; $\lim_{x\to 2} f(x) = \infty$; $\lim_{x\to 2^+} f(x) = -\infty$; $x = -4$ and $x = 2$ are vertical asymptotes

51. Horizontal asymptote: $y = 2$; vertical asymptote: $x = -2$

52. Horizontal asymptote: $y = 3$; vertical asymptote: $x = 4$

53. Horizontal asymptote: $y = 1$; vertical asymptotes: $x = -1$ and $x = 1$

54. Horizontal asymptote: $y = 1$; no vertical asymptotes

55. No horizontal asymptotes; no vertical asymptotes

56. Horizontal asymptote: $y = 0$; vertical asymptotes: $x = -2$, $x = 2$

57. Horizontal asymptote: $y = 0$; no vertical asymptotes

58. No horizontal asymptotes; vertical asymptote: $x = 0$

59. No horizontal asymptotes; vertical asymptote: $x = 3$

60. Horizontal asymptote: $y = 0$; vertical asymptote: $x = 0$

61. Horizontal asymptote: $y = 2$; vertical asymptotes: $x = -1$ and $x = 2$

62. Horizontal asymptote: $y = 1$; vertical asymptotes: $x = -4$ and $x = \frac{3}{2}$

63. Horizontal asymptote: $y = 2$; vertical asymptote: $x = -1$

64. Horizontal asymptote: $y = \frac{1}{2}$; vertical asymptotes: $x = -4$ and $x = \frac{3}{2}$

65. $\lim_{x\to\infty} f(x) = 0$ **66.** $\lim_{x\to\infty} f(x) = -\infty$ **67.** $\lim_{x\to\infty} f(x) = \infty$

68. $\lim_{x\to\infty} f(x) = \frac{4}{5}$ **69.** $\lim_{x\to -\infty} f(x) = -\frac{1}{4}$ **70.** $\lim_{x\to -\infty} f(x) = 0$

71. $\lim_{x\to -\infty} f(x) = -\infty$ **72.** $\lim_{x\to -\infty} f(x) = \infty$ **73.** False **74.** False

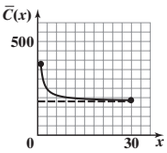
75. False **76.** True **77.** True **78.** False

79. If $n \geq 1$ and $a_n > 0$, then the limit is ∞. If $n \geq 1$ and $a_n < 0$, then the limit is $-\infty$.

80. If $n \geq 1$ is odd and $a_n < 0$, or $n \geq 1$ is even and $a_n > 0$, then the limit is ∞. If $n \geq 1$ is odd and $a_n > 0$, or $n \geq 1$ is even and $a_n < 0$, then the limit is $-\infty$.

81. (A) $C(x) = 180x + 200$ (B) $\overline{C}(x) = \frac{180x + 200}{x}$

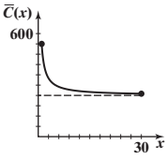
(C)



(D) \$180 per board

82. (A) $C(x) = 240x + 300$ (B) $\overline{C}(x) = \frac{240x + 300}{x}$

(C)

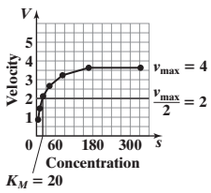


(D) \$240 per board

83. (A) 20%; 50%; 80% (B) $P(t) \to 100\%$ **84.** (A) 33%; 66%; 88% (B) $P(t) \to 99\%$ **85.** The long-term drug concentration is 5 mg/ml.

86. The long-term drug concentration is 0 mg/ml. **87.** (A) \$18 million (B) \$38 million (C) $\lim_{x\to 1^-} P(x) = \infty$ **88.** (A) 40 components/day (B) 21 days (C) $\lim_{x\to\infty} N(t) = 100$

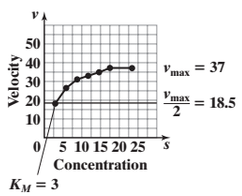
89. (C) $V_{\max} = 4$, $K_M = 20$



(D) $v(s) = \frac{4s}{20 + s}$

(E) $v = \frac{12}{7}$ when $s = 15$; $s = 60$ when $v = 3$

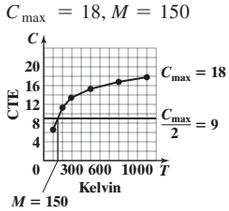
90. (A) $V_{\max} = 37$, $K_M = 3$



(B) $v(s) = \frac{37s}{3 + s}$

(C) $v = 27.75$ when s is 9; $s = 19.2$ when $v = 32$

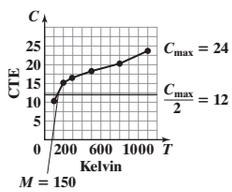
91. (A) $C_{\max} = 18$, $M = 150$



(B) $C(T) = \frac{18T}{150 + T}$

(C) $C = 14.4$ when $T = 600$ K; $T = 300$ K when $C = 12$

92. (A) $C_{\max} = 24$, $M = 150$



(B) $C(T) = \frac{24T}{150 + T}$

(C) $C = 19.2$ at $T = 600$ K; $T = 150$ K when $C = 12$

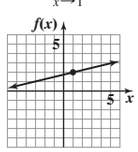
Exercises 2.3

1. $[-3, 5]$ **2.** $(-8, -4]$ **3.** $(-10, 100)$ **4.** $[0.1, 0.3]$

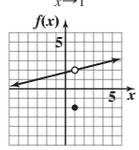
5. $(-\infty, -5) \cup (5, \infty)$ **6.** $(-\infty, -4] \cup [4, \infty)$

7. $(-\infty, -1) \cup (2, \infty)$ **8.** $(-\infty, 6) \cup [9, \infty)$

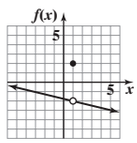
9. f is continuous at $x = 1$, since $\lim_{x\to 1} f(x) = f(1)$.



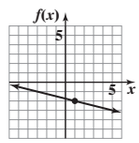
10. f is discontinuous at $x = 1$, since $\lim_{x\to 1} f(x) \neq f(1)$



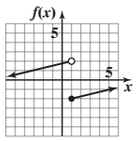
11. f is discontinuous at $x = 1$, since $\lim_{x\to 1} f(x) \neq f(1)$.



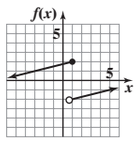
12. f is continuous at $x = 1$, since $\lim_{x\to 1} f(x) = f(1)$



13. f is discontinuous at $x = 1$, since $\lim_{x \to 1} f(x)$ does not exist.

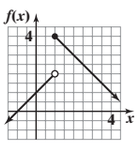


14. f is discontinuous at $x = 1$, since $\lim_{x \to 1} f(x)$ does not exist

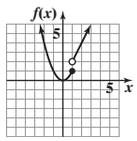


15. 1.9 **16.** 1 **17.** 0.1 **18.** 0.9 **19.** (A) 2 (B) 1 (C) Does not exist (D) 1 (E) No **20.** (A) 2 (B) 2 (C) 2 (D) Does not exist (E) No **21.** (A) 1 (B) 1 (C) 1 (D) 3 (E) No **22.** (A) 0 (B) 0 (C) 0 (D) 0 (E) Yes **23.** -0.1 **24.** 0.9 **25.** 0.1 **26.** 2.95 **27.** (A) 0 (B) 0 (C) 0 (D) 2 (E) No **28.** (A) 1 (B) 3 (C) Does not exist (D) Does not exist (E) No **29.** (A) 1 (B) -2 (C) Does not exist (D) 1 (E) No **30.** (A) 0 (B) 0 (C) 0 (D) 0 (E) Yes **31.** All x **32.** All x **33.** All x, except $x = -2$ **34.** All x, except $x = 4$ **35.** All x, except $x = -4$ and $x = 1$ **36.** All x, except $x = 3$ and $x = -1$ **37.** All x **38.** All x **39.** All x, except $x = \pm\frac{3}{2}$ **40.** All x, except $x = \pm\frac{2}{5}$ **41.** $-\frac{8}{3}, 4$ **42.** $-\frac{7}{2}, \frac{1}{5}$ **43.** $-1, 1$ **44.** $-3, 3$ **45.** $-9, -6, 0, 5$ **46.** $-6, 0, 7$ **47.** $-3 < x < 4$; $(-3, 4)$ **48.** $-2 < x < 4$; $(-2, 4)$ **49.** $x < 3$ or $x > 7$; $(-\infty, 3) \cup (7, \infty)$ **50.** $x < -5$ or $x > -2$; $(-\infty, -5) < (-2, \infty)$ **51.** $x < -2$ or $0 < x < 2$; $(-\infty, -2) \cup (0, 2)$ **52.** $x < -3$ or $x > 3$; $(-\infty, -3) < (3, \infty)$ **53.** $-5 < x < 0$ or $x > 3$; $(-5, 0) \cup (3, \infty)$ **54.** $x < -2$ or $0 < x < 4$; $(-\infty, -2) < (0, 4)$ **55.** (A) $(-4, -2) \cup (0, 2) \cup (4, \infty)$ (B) $(-\infty, -4) \cup (-2, 0) \cup (2, 4)$ **56.** (A) $(-\infty, -4) < (4, \infty)$ (B) $(-4, 1) < (1, 4)$ **57.** (A) $(-\infty, -2.5308) \cup (-0.7198, \infty)$ (B) $(-2.5308, -0.7198)$ **58.** (A) $(-\infty, 0.5113) \cup (2.1209, \infty)$ (B) $(0.5113, 2.1209)$ **59.** (A) $(-\infty, -2.1451) \cup (-1, -0.5240) \cup (1, 2.6691)$ (B) $(-2.1451, -1) \cup (-0.5240, 1) \cup (2.6691, \infty)$ **60.** (A) $(-2.3301, -1) \cup (0.2016, 1) \cup (2.1284, \infty)$ (B) $(-\infty, -2.3301) \cup (-1, 0.2016) \cup (1, 2.1284)$ **61.** $[6, \infty)$ **62.** $(-\infty, 7]$ **63.** $(-\infty, \infty)$ **64.** $(-\infty, \infty)$ **65.** $(-\infty, -3] \cup [3, \infty)$ **66.** $[-2, 2]$ **67.** $(-\infty, \infty)$ **68.** $(-\infty, \infty)$

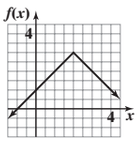
69. Since $\lim_{x \to 1^-} f(x) = 2$ and $\lim_{x \to 1^+} f(x) = 4$, $\lim_{x \to 1} f(x)$ does not exist and f is not continuous at $x = 1$.



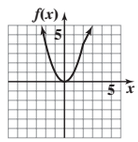
70. Since $\lim_{x \to 1^-} f(x) = 1$ and $\lim_{x \to 1^+} f(x) = 2$, $\lim_{x \to 1} f(x)$ does not exist and f is not continuous at $x = 1$.



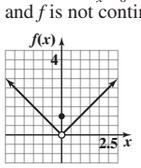
71. This function is continuous for all x.



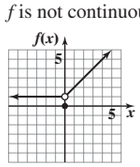
72. This function is continuous for all x.



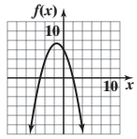
73. Since $\lim_{x \to 0^-} f(x) = 0$ and $f(0) = 1$, $\lim_{x \to 0} f(x) \neq f(0)$ and f is not continuous at $x = 0$.



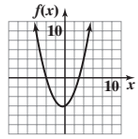
74. Since $\lim_{x \to 0} f(x) = 1 \neq f(0) = 0$, f is not continuous at $x = 0$.



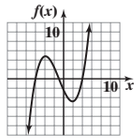
75. (A) Yes (B) No (C) Yes(D) No (E) Yes
76. (A) Yes (B) No (C) Yes (D) No (E) Yes
77. True **78.** True **79.** False **80.** True **81.** True **82.** False
83. x int.: $-5, 2$



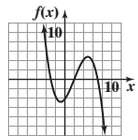
84. x int.: $x = -4, 3$



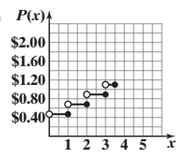
85. x int.: $x = -6, -1, 4$



86. x int.: $x = -3, 2, 7$

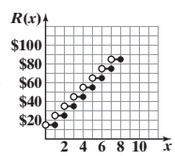


87. No, but this does not contradict Theorem 2, since f is discontinuous at $x = 1$.
88. No, but this does not contradict Theorem 2 since f is discontinuous at $x = 4$.
89. (A) $P(x) = \begin{cases} 0.47 & \text{if } 0 < x \leq 1 \\ 0.68 & \text{if } 1 < x \leq 2 \\ 0.89 & \text{if } 2 < x \leq 3 \\ 1.10 & \text{if } 3 < x \leq 3.5 \end{cases}$ (B)



(C) Yes; no

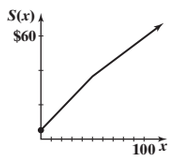
90. (A) $R(x) = \begin{cases} 15 & \text{if } 0 < x \leq 1 \\ 25 & \text{if } 1 < x \leq 2 \\ 35 & \text{if } 2 < x \leq 3 \\ 45 & \text{if } 3 < x \leq 4 \\ 55 & \text{if } 4 < x \leq 5 \\ 65 & \text{if } 5 < x \leq 6 \\ 75 & \text{if } 6 < x \leq 7 \\ 85 & \text{if } 7 < x \leq 8 \end{cases}$ (B)



(C) Yes; no

93. (A) $S(x) = \begin{cases} 5 + 0.63x & \text{if } 0 \leq x \leq 50 \\ 14 + 0.45x & \text{if } 50 < x \end{cases}$

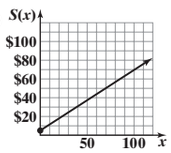
(B)



(C) Yes

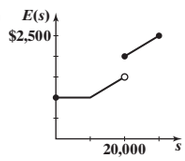
94. (A) $S(x) = \begin{cases} 5 + 0.69x & \text{if } 0 \leq x < 5 \\ 5.2 + 0.65x & \text{if } 5 < x \leq 50 \\ 6.2 + 0.63x & \text{if } 50 < x \end{cases}$

(B)

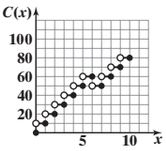


(C) Yes; yes

95. (A)



(B) $\lim_{x \to 10{,}000} E(s) = \$1{,}000$; $E(10{,}000) = \$1{,}000$
(C) $\lim_{x \to 20{,}000} E(s)$ does not exist; $E(20{,}000) = \$2{,}000$
(D) Yes; no

96. (A) 

(B) $\lim_{x \to 4.5} C(x) = 50$; $C(4.5) = 50$
(C) $\lim_{x \to 8} C(x)$ does not exist; $C(8) = 60$
(D) Yes; no

97. (A) t_2, t_3, t_4, t_6, t_7
(B) $\lim_{t \to t_5} N(t) = 7$; $N(t_5) = 7$
(C) $\lim_{t \to t_3} N(t)$ does not exist; $N(t_3) = 4$

98. (A) t_2, t_4
(B) $\lim_{t \to t_1} p(t) = 10$; $p(t_1) = 10$
(C) $\lim_{t \to t_2} p(t) = 30$; $p(t_2) = 10$
(D) $\lim_{t \to t_4} p(t)$ does not exist; $p(t_4) = 80$

Exercises 2.4

1. $\frac{9}{4} = 2.25$ **2.** $-\frac{3}{2} = 21.5$ **3.** $-\frac{27}{5} = -5.4$ **4.** $\frac{3}{8} = 0.375$

5. $\frac{1}{3}\sqrt{3}$ **6.** $\frac{2}{5}\sqrt{5}$ **7.** $\frac{15}{2} - \frac{5}{2}\sqrt{7}$ **8.** $\frac{7}{23} - \frac{6}{23}\sqrt{2}$

9. (A) -3; slope of the secant line through $(1, f(1))$ and $(2, f(2))$
(B) $-2 - h$; slope of the secant line through $(1, f(1))$ and $(1 + h, f(1 + h))$ (C) -2; slope of the tangent line at $(1, f(1))$

10. (A) 3; slope of the secant line through $(-2, f(-2))$ and $(-1, f(-1))$
(B) $4 - h$; slope of the secant line through $(-2, f(-2))$ and $(-2 + h, f(-2 + h))$ (C) 4; slope of the tangent line at $(-2, f(-2))$

11. (A) 15 (B) $6 + 3h$ (C) 6 **12.** (A) 21 (B) $12 + 3h$ (C) 12

13. (A) 40 km/hr (B) 40 (C) $y - 80 = 45(x - 2)$ or $y = 45x - 10$ **14.** (A) 132 mi/hr (B) 132 (C) $y - 528 = 150(x - 4)$ or $y = 150x - 72$ **15.** $y - \frac{1}{2} = -\frac{1}{2}(x - 1)$ or $y = -\frac{x}{2} + 1$

16. $y - 0.2 = -0.16(x - 2)$ or $y = -0.16x + 0.52$

17. $y - 16 = -32(x + 2)$ or $y = -32x - 48$

18. $y - 1 = -4(x + 1)$ or $y = -4x - 3$

19. $f'(x) = 0$; $f'(1) = 0, f'(2) = 0, f'(3) = 0$

20. $f'(x) = 0$; $f'(1) = 0, f'(2) = 0, f'(3) = 0$

21. $f'(x) = 3$; $f'(1) = 3, f'(2) = 3, f'(3) = 3$

22. $f'(x) = -6$; $f'(1) = -6, f'(2) = -6, f'(3) = -6$

23. $f'(x) = -6x$; $f'(1) = -6, f'(2) = -12, f'(3) = -18$

24. $f'(x) = 4x$; $f'(1) = 4, f'(2) = 8, f'(3) = 12$

25. $f'(x) = 2x - 2$; $f'(1) = 0, f'(2) = 2, f'(3) = 4$

26. $f'(x) = 6x + 2$; $f'(1) = 8$; $f'(2) = 14$; $f'(3) = 20$

27. $f'(x) = 8x + 3$; $f'(1) = 11, f'(2) = 19, f'(3) = 27$

28. $f'(x) = 2x - 4$; $f'(1) = -2$; $f'(2) = 0$; $f'(3) = 2$

29. $f'(x) = -2x + 5$; $f'(1) = 3, f'(2) = 1, f'(3) = -1$

30. $f'(x) = 12x - 3$; $f'(1) = 9$; $f'(2) = 21$; $f'(3) = 33$

31. $f'(x) = 20x - 9$; $f'(1) = 11, f'(2) = 31, f'(3) = 51$

32. $f'(x) = -2x + 3$; $f'(1) = 1$; $f'(2) = -1$; $f'(3) = -3$

33. $f'(x) = 6x^2$; $f'(1) = 6, f'(2) = 24, f'(3) = 54$

34. $f'(x) = -6x^2$; $f'(1) = -6, f'(2) = -24, f'(3) = -54$

35. $f'(x) = -\frac{4}{x^2}$; $f'(1) = -4, f'(2) = -1, f'(3) = -\frac{4}{9}$

36. $f'(x) = -\frac{6}{x^2}$; $f'(1) = -6, f'(2) = -\frac{3}{2}, f'(3) = -\frac{2}{3}$

37. $f'(x) = \frac{3}{2\sqrt{x}}$; $f'(1) = \frac{3}{2}, f'(2) = \frac{3}{2\sqrt{2}}$ or $\frac{3\sqrt{2}}{4}, f'(3) = \frac{3}{2\sqrt{3}}$ or $\frac{\sqrt{3}}{2}$ **38.** $f'(x) = \frac{-7}{2\sqrt{x}}$; $f'(1) = -\frac{7}{2}, f'(2) = -\frac{7}{2\sqrt{2}}$ or $-\frac{7\sqrt{2}}{4}$, $f'(3) = -\frac{7}{2\sqrt{3}}$ or $-\frac{7\sqrt{3}}{6}$ **39.** $f'(x) = \frac{5}{\sqrt{x+5}}$; $f'(1) = \frac{5}{\sqrt{6}}$ or $\frac{5\sqrt{6}}{6}, f'(2) = \frac{5}{\sqrt{7}}$ or $\frac{5\sqrt{7}}{7}, f'(3) = \frac{5}{2\sqrt{2}}$ or $\frac{5\sqrt{2}}{4}$ **40.** $f'(x) = \frac{8}{\sqrt{x+9}}$; $f'(1) = \frac{8}{\sqrt{10}}$ or $\frac{4\sqrt{10}}{5}, f'(2) = \frac{8}{\sqrt{11}}$ or $\frac{8\sqrt{11}}{11}, f'(3) = \frac{8}{\sqrt{12}}$ or $\frac{4\sqrt{3}}{3}$ **41.** $f'(x) = -\frac{1}{(x-4)^2}$; $f'(1) = -\frac{1}{9}; f'(2) = -\frac{1}{4}; f'(3) = -1$

42. $f'(x) = -\frac{1}{(x+4)^2}$; $f'(1) = -\frac{1}{25}; f'(2) = -\frac{1}{36}; f'(3) = -\frac{1}{49}$

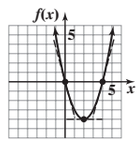
43. $f'(x) = \frac{1}{(x+1)^2}$; $f'(1) = \frac{1}{4}; f'(2) = \frac{1}{9}; f'(3) = \frac{1}{16}$

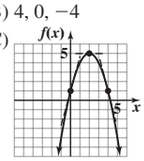
44. $f'(x) = \frac{2}{(x+2)^2}$; $f'(1) = \frac{2}{9}; f'(2) = \frac{1}{8}; f'(3) = \frac{2}{25}$

45. (A) 5 (B) $3 + h$ (C) 3 (D) $y = 3x - 1$ **46.** (A) 7 (B) $5 + h$ (C) 5 (D) $y = 5x - 4$ **47.** (A) 5 m/s (B) $3 + h$ m/s (C) 3 m/s

48. (A) 7 m/s (B) $5 + h$ m/s (C) 5 m/s **49.** Yes **50.** No **51.** No **52.** Yes

53. Yes **54.** No **55.** Yes **56.** No

57. (A) $f'(x) = 2x - 4$
(B) $-4, 0, 4$
(C) 

58. (A) $f'(x) = 4 - 2x$
(B) $4, 0, -4$
(C) 

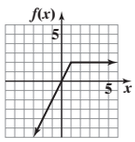
59. $v = f'(x) = 8x - 2$; 6 ft/s, 22 ft/s, 38 ft/s

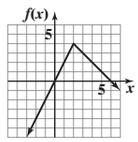
60. $v = f'(x) = 16x - 4$; 12 ft/s, 44 ft/s, 76 ft/s

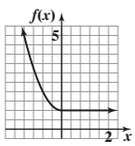
61. (A) The graphs of g and h are vertical translations of the graph of f. All three functions should have the same derivative. (B) $2x$

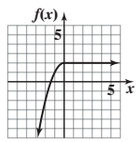
62. (A) The graphs of g and h are vertical translations of the graph of f. All three functions should have the same derivative. (B) $-2x$

63. True **64.** True **65.** False **66.** True **67.** False **68.** False

69. f is nondifferentiable at $x = 1$ 

70. f is not differentiable at $x = 2$ 

71. f is differentiable for all real numbers 

72. f is differentiable for all real numbers 

73. No **74.** No **75.** No **76.** No **77.** $f'(0) = 0$

78. $f'(0) = 0$ **79.** 6 s; 192 ft/s **80.** 8 s; 256 ft/s **81.** (A) \$8.75 (B) $R'(x) = 60 - 0.05x$ (C) $R(1{,}000) = 35{,}000$; $R'(1{,}000) = 10$; At a production level of 1,000 car seats, the revenue is \$35,000 and is increasing at the rate of \$10 per seat.

82. (A) \$3.75 (B) $P'(x) = 45 - 0.05x$ (C) $P(800) = 15{,}000$; $P'(800) = 5$; At a production level of 800 car seats, the revenue is \$15,000 and is increasing at the rate of \$5 per seat. **83.** (A) $S'(t) = 1/(2\sqrt{t})$ (B) $S(4) = 6$; $S'(4) = 0.25$; After 4 months, the total sales are \$6 million and are increasing at the rate of \$0.25 million per month. (C) \$6.25 million; \$6.5 million **84.** (A) $S'(t) = \frac{1}{2\sqrt{t}}$ (B) $S(9) = 11$; $S'(9) = 1/6$; After 9 months, the total sales are \$11 million and are increasing at the rate of \$0.167 million per month. (C) \$11.167 million; \$11.333 million

85. (A) $p'(t) = 276t + 1{,}072$ (B) $p(15) = 62{,}047$, $p'(15) = 5{,}212$; In 2025, 62,047 metric tons of tungsten are consumed and this quantity is increasing at the rate of 5,212 metric tons per year.

86. (A) $p'(t) = 96t - 37$ (B) $p(17) = 14{,}941$; $p'(17) = 1{,}595$; In 2027, 14,941 thousand metric tons of copper are consumed and this quantity is increasing at the rate of 1,595 thousand metric tons per year.

87. (A)

```
QuadReg
y=ax²+bx+c
a=-1.109126984
b=29.49404762
c=1196.964286
```

(B) $R(30) \approx 1083.6$ billion kilowatts, $R'(30) \approx -37.1$ billion kilowatts per year. In 2030, 1083.6 billion kilowatts will be sold and the amount sold is decreasing at the rate of 37.1 billion kilowatts per year.

88. (A)

```
QuadReg
y=ax²+bx+c
a=-1.763888889
b=44.61071429
c=1068.607143
```

(B) $C(30) \approx 819.4$, $C'(30) \approx -61.2$ In 2030, 819.4 billion kilowatts will be sold and the amount sold is decreasing at the rate of 61.2 billion kilowatts per year.

89. (A) $P'(t) = 12 - 2t$ (B) $P(3) = 107$; $P'(3) = 6$. After 3 hours, the ozone level is 107 ppb and is increasing at the rate of 6 ppb per hour.

90. (A) $F'(t) = -\dfrac{4}{(t+1)^2}$ (B) $F(3) = 99$; $F'(3) = -0.25$. After 3 hours, the body temperature is 99°F and is decreasing at the rate of 0.25°F per hour.

Exercises 2.5

1. $x^{1/2}$ **2.** $x^{1/3}$ **3.** x^{-5} **4.** x^{-1} **5.** x^{12} **6.** x^{-10} **7.** $x^{-1/4}$ **8.** $x^{-1/5}$
9. 0 **10.** 0 **11.** $7x^6$ **12.** $8x^7$ **13.** $4x^3$ **14.** $9x^8$ **15.** $-3x^{-4}$ **16.** $-5x^{-6}$
17. $\dfrac{4}{3}x^{1/3}$ **18.** $\dfrac{5}{2}x^{3/2}$ **19.** $-\dfrac{9}{x^{10}}$ **20.** $-\dfrac{7}{x^8}$ **21.** $6x^2$ **22.** $-6x$
23. $1.8x^5$ **24.** $2.1x^2$ **25.** $\dfrac{x^3}{3}$ **26.** $\dfrac{x^2}{3}$ **27.** 12 **28.** -5 **29.** 2 **30.** -4
31. 9 **32.** -17 **33.** 2 **34.** -4 **35.** $4t - 3$ **36.** $5 - 24t^2$
37. $-10x^{-3} - 9x^{-2}$ **38.** $-35x^{-8} + 8x^{-5}$ **39.** $1.5u^{-0.7} - 8.8u^{1.2}$
40. $9u^{3.5} - 3.1$ **41.** $0.5 - 3.3t^2$ **42.** $0.6t^2 - 3.1$ **43.** $-\dfrac{8}{5}x^{-5}$
44. $-\dfrac{14}{5u^3}$ **45.** $3x + \dfrac{14}{5}x^{-3}$ **46.** $\dfrac{15x^2}{4} + \dfrac{6}{5x^4}$ **47.** $-\dfrac{20}{9}\omega^{-5} + \dfrac{5}{3}\omega^{-2/3}$
48. $-\dfrac{30}{w^7} - \dfrac{1}{\sqrt{2}}$ **49.** $2u^{-1/3} - \dfrac{5}{3}u^{-2/3}$ **50.** $6u^{-1/4} - u^{-5/4}$
51. $-\dfrac{9}{5}t^{-8/5} + 3t^{-3/2}$ **52.** $-t^{-6/5} + 12t^{-5/2}$ **53.** $-\dfrac{1}{3}x^{-4/3}$ **54.** $-2u^{-6/5}$
55. $-0.6x^{-3/2} + 6.4x^{-3} + 1$ **56.** $-8.4x^{-4} + 0.4x^{-5/3}$
57. (A) $f'(x) = 6 - 2x$ (B) $f'(2) = 2$; $f'(4) = -2$ (C) $y = 2x + 4$; $y = -2x + 16$ (D) $x = 3$ **58.** (A) $f'(x) = 4x + 8$ (B) $f'(2) = 16$; $f'(4) = 24$ (C) $y = 16x - 8$; $y = 24x - 32$ (D) $x = 22$
59. (A) $f'(x) = 12x^3 - 12x$ (B) $f'(2) = 72$; $f'(4) = 720$ (C) $y = 72x - 127$; $y = 720x - 2{,}215$ (D) $x = -1, 0, 1$
60. (A) $f'(x) = 4x^3 - 64x$ (B) $f'(2) = -96$; $f'(4) = 0$ (C) $y = -96x + 90$; $y = -246$ (D) $x = -4, 0, 4$
61. (A) $v = f'(x) = 176 - 32x$ (B) $f'(0) = 176$ ft/s; $f'(3) = 80$ ft/s (C) 5.5 s **62.** (A) $v = f'(x) = 80 - 20x$ (B) $f'(0) = 80$ ft/s; $f'(3) = 20$ ft/s (C) 4 s **63.** (A) $v = f'(x) = 3x^2 - 18x + 15$ (B) $f'(0) = 15$ ft/s; $f'(3) = -12$ ft/s (C) $x = 1$ s, $x = 5$ s
64. (A) $v = f'(x) = 3x^2 - 18x + 24$ (B) $f'(0) = 24$ ft/s; $f'(3) = -3$ ft/s (C) $x = 2$ s, $x = 4$ s
65. $f'(x) = 2x - 3 - 2x^{-1/2} = 2x - 3 - \dfrac{2}{x^{1/2}}$; $x = 2.1777$
66. $f'(x) = 2x + 1 - 5x^{-1/2} = 2x + 1 - \dfrac{5}{x^{1/2}}$; $x = 1.5247$
67. $f'(x) = 4\sqrt[3]{x} - 3x - 3$; $x = -2.9018$
68. $f'(x) = 4\sqrt[3]{x} - 4x + 4$; $x = 2.3247$
69. $f'(x) = 0.2x^3 + 0.3x^2 - 3x - 1.6$; $x = -4.4607, -0.5159, 3.4765$
70. $f'(x) = 0.08x^3 - 0.18x^2 - 1.56x + 0.94$; $x = -3.7626, 0.5742, 5.4384$
71. $f'(x) = 0.8x^3 - 9.36x^2 + 32.5x - 28.25$; $x = 1.3050$
72. $f'(x) = x^3 - 7.8x^2 - 16.2x - 10$; $x = 1.2391, 1.6400, 4.9209$
76. No **77.** $8x - 4$ **78.** $8x - 20$ **79.** $-20x^{-2}$ **80.** $-50x^{-3}$
81. $-\dfrac{1}{4}x^{-2} + \dfrac{2}{3}x^{-3}$ **82.** $4x - 4x^{-3}$ **83.** False **84.** False **85.** True
86. False **89.** (A) $S'(t) = 0.09t^2 + t + 2$ (B) $S(5) = 29.25$, $S'(5) = 9.25$. After 5 months, sales are \$29.25 million and are increasing at the rate of \$9.25 million per month. (C) $S(10) = 103$, $S'(10) = 21$. After 10 months, sales are \$103 million and are increasing at the rate of \$21 million per month. **90.** (A) $S'(t) = 0.06t^3 + 1.2t^2 + 6.8t + 10$ (B) $S(4) = 120.84$, $S'(4) = 60.24$. After 4 months, sales are \$120.84 million and are increasing at the rate of \$60.24 million per month. (C) $S(8) = 560.84$, $S'(8) = 171.92$. After 8 months, sales are \$560.84 million and are increasing at the rate of \$171.92 million per month. **91.** (A) $N'(x) = 3{,}780/x^2$ (B) $N'(10) = 37.8$. At the \$10,000 level of advertising, sales are increasing at the rate of 37.8 boats per \$1,000 spent on advertising. $N'(20) = 9.45$. At the \$20,000 level of advertising, sales are increasing at the rate of 9.45 boats per \$1,000 spent on advertising. **92.** $x(5) = 46$; $x'(5) = -7.2$. When the price is \$5 per quarter pound, the demand is 46 pounds and is decreasing at a rate of 7.2 pounds per dollar.

93. (A)

```
CubicReg
y=ax³+bx²+cx+d
a=-8.083333E-4
b=.0624285714
c=-1.081309524
d=40.57571429
```

(B) In 2025, 35.5% of male high school graduates enroll in college and the percentage is decreasing at the rate of 1.5% per year.

94. (A)

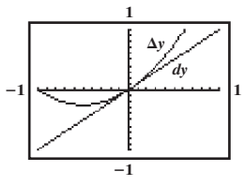
```
CubicReg
y=ax³+bx²+cx+d
a=-4.666667E-4
b=.0276428571
c=.265952381
d=25.46857143
```

(B) In 2025, 46.1% of female high school graduates enroll in college and the percentage is decreasing at the rate of 0.9% per year.

95. (A) -1.37 beats/min (B) -0.58 beats/min **96.** (A) -0.2 parts per million per mile (B) -0.025 parts per million per mile **97.** (A) 25 items/hr (B) 8.33 items/hr **98.** (A) 14 items per hour (B) 7 items per hour

Exercises 2.6

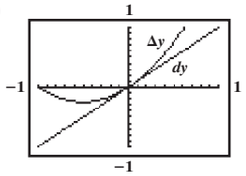
1. 3; 3.01 **2.** 3.7; 3.71 **3.** 2.8; 2.799 **4.** 2; 1.999 **5.** 0; 0.01
6. 1; 1.21 **7.** 100; 102.01 **8.** 25; 24.01 **9.** $\Delta x = 3$; $\Delta y = 75$; $\Delta y/\Delta x = 25$ **10.** $\Delta x = 3$; $\Delta y = 105$; $\Delta y/\Delta x = 35$ **11.** 20
12. 25 **13.** 20 **14.** 25 **15.** $dy = (24x - 3x^2)dx$
16. $dy = \left(200 - \dfrac{x}{15}\right)dx$ **17.** $dy = \left(2x - \dfrac{x^2}{3}\right)dx$
18. $dy = (180x^2 - 4x^3)dx$ **19.** $dy = -\dfrac{295}{x^{3/2}}dx$
20. $dy = (26x^{-1/2})dx$ **21.** (A) $12 + 3\Delta x$ (B) 12 **22.** (A) $18 + 3\Delta x$ (B) 18
23. $dy = 6(3x - 1)dx$ **24.** $dy = 4(2x + 3)dx$ **25.** $dy = \left(\dfrac{x^2 + 5}{x^2}\right)dx$
26. $dy = \dfrac{18}{x^3}dx$ **27.** $dy = 1.4$; $\Delta y = 1.44$ **28.** $dy = 3.6$; $\Delta y = 3.66$
29. $dy = -3$; $\Delta y = -\dfrac{10}{3}$ **30.** $dy = -20$; $\Delta y = -20.803$
31. 120 in.^{3} **32.** 31.4 cm^3
33. (A) $\Delta y = \Delta x + (\Delta x)^2$; $dy = \Delta x$
(B)



(C)

Δx	Δy	dy
.1	.24	.1
.2	.24	.2
.3	.39	.3

34. (A) $\Delta y = -2\Delta x + (\Delta x)^2$; $dy = -2dx$
(B)

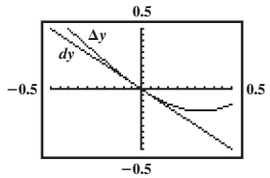


(C)

Δx	Δy	dy
.1	.24	.1
.2	.24	.2
.3	.39	.3

35. (A) $\Delta y = -\Delta x + (\Delta x)^2 + (\Delta x)^3$; $dy = -\Delta x$

(B)

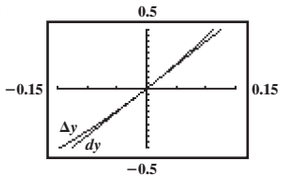


(C)

Δx	Δy	dy
.05	-.0574	.05
.1	-.089	.1
.15	-.1241	.15

36. (A) $\Delta y = 4\Delta x + 4(\Delta x)^2 + (\Delta x)^3$; $dy = 4dx$

(B)



(C)

Δx	Δy	dy
-.15	-.5134	.6
-.1	-.364	.4
-.05	-.1709	.2

Y1=-.190125

37. True **38.** False **39.** False **40.** True

41. $dy = \left(\frac{2}{3}x^{-1/3} - \frac{10}{3}x^{2/3}\right)dx$ **42.** $dy = \left(\frac{2}{3}x^{-1/3} - \frac{10}{3}x^{2/3}\right)dx$

43. $dy = 3.9$; $\Delta y = 3.83$ **44.** $dy = -0.576$; $\Delta y = -0.57$

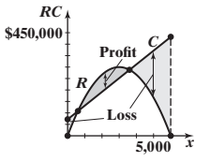
45. 40-unit increase; 20-unit increase **46.** 48-lb decrease **47.** −$2.50; $1.25 **48.** $1,000, $400; −$1,000, −$1,600 **49.** −1.37 beats/min; −0.58 beats/min **50.** 94.2 mm^3 **51.** 1.26 mm^2 **52.** (A) 0.27°F (B) 0.3°F (C) 0.27°F **53.** 3 wpm **54.** 2.6 item increase; 1.3 item increase **55.** (A) 2,100 increase (B) 4,800 increase (C) 2,100 increase

Exercises 2.7

1. $22,889.80 **2.** $23,000.00 **3.** $110.20 **4.** $31,929.80 **5.** $32,000.00 **6.** $70.20 **7.** $230.00 **8.** $160.00 **9.** $C'(x) = 0.7$ **10.** $C'(x) = 6$ **11.** $C'(x) = -0.2(0.1x - 23)$ **12.** $C'(x) = 12 - 0.2x$ **13.** $R'(x) = 4 - 0.02x$ **14.** $R'(x) = 36 - 0.06x$ **15.** $R'(x) = 12 - 0.08x$ **16.** $R'(x) = 25 - 0.1x$ **17.** $P'(x) = 3.3 - 0.02x$ **18.** $P'(x) = 30 - 0.06x$ **19.** $P'(x) = 7.4 - 0.06x$ **20.** $P'(x) = 13 + 0.1x$ **21.** $\bar{C}(x) = 1.1 + \frac{145}{x}$ **22.** $\bar{R}'(x) = 5 - 0.02x$ **23.** $\bar{C}'(x) = -\frac{145}{x^2}$ **24.** $\bar{R}'(x) = -0.02$ **25.** $P(x) = 3.9x - 0.02x^2 - 145$ **26.** $P'(x) = 3.9 - 0.04x$ **27.** $\bar{P}(x) = 3.9 - 0.02x - \frac{145}{x}$ **28.** $\bar{P}'(x) = 20.02 + \frac{145}{x^2}$ **29.** True **30.** True **31.** False **32.** False **33.** (A) $29.50 (B) $30 **34.** (A) $74.75 (B) $75 **35.** (A) $420 (B) $\bar{C}'(500) = -0.24$. At a production level of 500 frames, average cost is decreasing at the rate of 24¢ per frame. (C) Approximately $419.76 **36.** (A) $\bar{C}(1{,}000) = \$30$. (B) $\bar{C}'(1{,}000) = -1¢$. At a production level of 1,000 board games, average cost is decreasing at the rate of 1¢ per game. (C) Approximately $29.99 **37.** (A) $14.70 (B) $15 **38.** (A) $5.80 (B) $6 **39.** (A) $P'(450) = 0.5$. At a production level of 450 sweatshirts, profit is increasing at the rate of 50¢ per sweatshirt. (B) $P'(750) = -2.5$. At a production level of 750 sweatshirts, profit is decreasing at the rate of $2.50 per sweatshirt. **40.** (A) $P'(200) = \$4$. At a production level of 200 cameras, profit is increasing at the rate of $4 per camera. (B) $P'(350) = -\$2$. At a production level of 350 cameras, profit is decreasing at the rate of $2 per camera. **41.** (A) $13.50 (B) $\bar{P}'(50) = \$0.27$. At a production level of 50 mowers, the average profit per mower is increasing at the rate of $0.27 per mower. (C) Approximately $13.77 **42.** (A) $11.20 (B) $\bar{P}'(40) = \$0.18$. At a production level of 40 grills, the average profit per grill is increasing at the rate of $0.18 per grill. (C) Approximately $11.38 **43.** (A) $p = 100 - 0.025x$, domain: $0 \le x \le 4{,}000$ (B) $R(x) = 100x - 0.025x^2$, domain: $0 \le x \le 4{,}000$ (C) $R'(1{,}600) = 20$. At a production level of 1,600 pairs of running shoes, revenue is increasing at the rate of $20 per pair. (D) $R'(2{,}500) = -25$. At a production level of 2,500 pairs of running shoes, revenue is decreasing at the rate of $25 per pair.

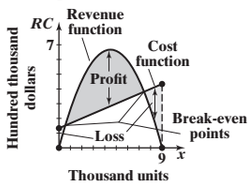
44. (A) $p = 50 - 0.05x$, domain: $0 \le x \le 1{,}000$ (B) $R(x) = 50x - 0.05x^2$, domain: $0 \le x \le 1{,}000$ (C) $R'(400) = 10$. At a production level of 400 steam irons, revenue is increasing at the rate of $10 per steam iron. (D) $R'(650) = -15$. At a production level of 650 steam irons, revenue is decreasing at the rate of $15 per steam iron.

45. (A) $p = 200 - \frac{1}{30}x$, domain: $0 \le x \le 6{,}000$ (B) $C'(x) = 60$ (C) $R(x) = 200x - (x^2/30)$, domain: $0 \le x \le 6{,}000$ (D) $R'(x) = 200 - (x/15)$ (E) $R'(1{,}500) = 100$. At a production level of 1,500 saws, revenue is increasing at the rate of $100 per saw. $R'(4{,}500) = -100$. At a production level of 4,500 saws, revenue is decreasing at the rate of $100 per saw. (F) Break-even points: (600, 108,000) and (3,600, 288,000)

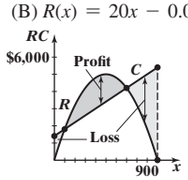


(G) $P(x) = -(x^2/30) + 140x - 72{,}000$ (H) $P'(x) = -(x/15) + 140$ (I) $P'(1{,}500) = 40$. At a production level of 1,500 saws, profit is increasing at the rate of $40 per saw. $P'(3{,}000) = -60$. At a production level of 3,000 saws, profit is decreasing at the rate of $60 per saw.

46. (A) $p = 300 - \frac{1}{30}x$, domain: $0 \le x \le 9{,}000$ (B) $C'(x) = 30$ (C) $R(x) = 300x - \frac{1}{30}x^2$, domain: $0 \le x \le 9{,}000$ (D) $R'(x) = 300 - \frac{1}{15}x$ (E) $R'(3{,}000) = 100$. At a production level of 3,000 TVs, revenue is increasing at the rate of $100 per TV. $R'(6000) = -100$. At a production level of 6,000 TVs, revenue is decreasing at the rate of $100 per TV. (F) Break-even points: (600, 168,000) and (7,500, 375,000)



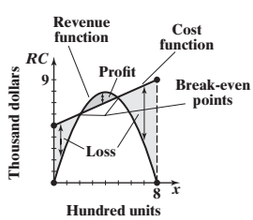
(G) $P(x) = -\frac{1}{30}x^2 + 270x - 150{,}000$ (H) $P'(x) = -\frac{1}{15}x + 270$ (I) $P'(1{,}500) = 170$. At a production level of 1,500 sets, profit is increasing at the rate of $170 per set. $P'(4{,}500) = -30$. At a production level of 4,500 sets, profit is decreasing at the rate of $30 per set. **47.** (A) $p = 20 - 0.02x$, domain: $0 \le x \le 1{,}000$ (B) $R(x) = 20x - 0.02x^2$, domain: $0 \le x \le 1{,}000$ (C) $C(x) = 4x + 1{,}400$



(D) Break-even points: (100, 1,800) and (700, 4,200)

(E) $P(x) = 16x - 0.02x^2 - 1{,}400$ (F) $P'(250) = 6$. At a production level of 250 toasters, profit is increasing at the rate of $6 per toaster. $P'(475) = -3$. At a production level of 475 toasters, profit is decreasing at the rate of $3 per toaster.

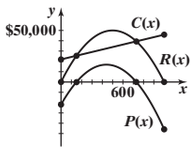
48. (A) $p = 40 - \frac{x}{20}$, domain: $0 \le x \le 800$ (B) $R(x) = 40x - \frac{x^2}{20}$, domain: $0 \le x \le 800$ (C) $C(x) = 5x + 5{,}000$ (D) Break-even points: (200, 6,000) and (500, 7,500)



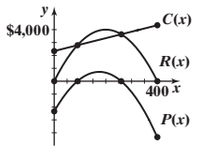
(E) $P(x) = 35x - \frac{x^2}{20} - 5{,}000$

(F) $P'(325) = 2.5$. At a production level of 325 toasters, profit is increasing at the rate of \$2.50 per toaster. $P'(425) = -7.5$. At a production level of 425 toasters, profit is decreasing at the rate of \$7.50 per toaster.

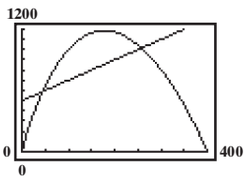
49. (A) $x = 500$ (B) $P(x) = 176x - 0.2x^2 - 21{,}900$ (C) $x = 440$
(D) Break-even points: $(150, 25{,}500)$ and $(730, 39{,}420)$; x intercepts for $P(x)$: $x = 150$ and $x = 730$



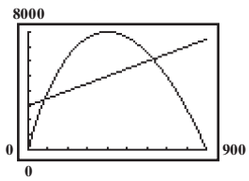
50. (A) $x = 200$ (B) $P(x) = 35x - 0.1x^2 - 2{,}340$ (C) $x = 175$
(D) Break-even points: $(90, 2{,}790)$ and $(260, 3{,}640)$; x intercepts for $P(x)$: $x = 90$ and $x = 260$



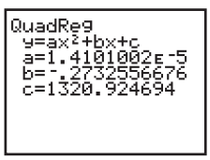
51. (A) $R(x) = 20x - x^{3/2}$
(B) Break-even points: $(44, 588)$, $(258, 1{,}016)$



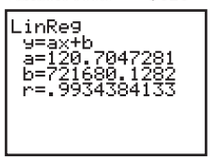
52. (A) $R(x) = 60x - 2x^{3/2}$
(B) Break-even points: $(81, 3{,}405)$, $(631, 6{,}155)$



53. (A)

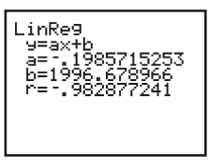


(B) Fixed costs $\approx$ \$721,680; variable costs $\approx$ \$121

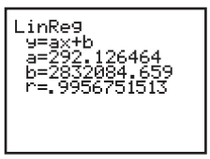


(C) $(713, 807{,}703)$, $(5{,}423, 1{,}376{,}227)$ (D) $\$254 \le p \le \$1{,}133$

54. (A)



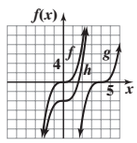
(B) Fixed costs: \$2,832,085; variable costs: \$292



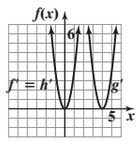
(C) Break-even points: $(2{,}253, 3{,}490{,}130)$, $(6{,}331, 4{,}681{,}675)$
(D) $\$740 \le p \le \$1{,}549$

Chapter 2 Review Exercises

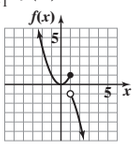
1. (A) 16 (B) 8 (C) 8 (D) 4 (E) 4 (F) 4 *(2.2)* **2.** $f'(x) = -3$ *(2.2)*
3. (A) 22 (B) 8 (C) 2 (D) -5 *(2.1)* **4.** 1.5 *(2.1)* **5.** 3.5 *(2.1)*
6. 3.75 *(2.1)* **7.** 3.75 *(2.1)* **8.** (A) 1 (B) 1 (C) 1 (D) 1 *(2.1)*
9. (A) 2 (B) 3 (C) Does not exist (D) 3 *(2.1)* **10.** (A) 4 (B) 4
(C) 4 (D) Does not exist *(2.1)* **11.** (A) Does not exist (B) 3
(C) No *(2.3)* **12.** (A) 2 (B) Not defined (C) No *(2.3)* **13.** (A) 1
(B) 1 (C) Yes *(2.3)* **14.** 10 *(2.2)* **15.** 5 *(2.2)* **16.** ∞ *(2.2)* **17.** $-\infty$ *(2.2)*
18. ∞ *(2.2)* **19.** ∞ *(2.2)* **20.** ∞ *(2.2)* **21.** $x = 2$; $x = 6$ *(2.2)*
22. $y = 5$; $y = 10$ *(2.2)* **23.** $x = 2$; $x = 6$ *(2.3)* **24.** $f'(x) = 6x$ *(2.4)*
25. (A) -3 (B) 6 (C) -2 (D) 3 (E) -11 **26.** $x^2 - 10x$ *(2.5)*
27. $x^{-1/2} - 3 = \frac{1}{x^{1/2}} - 3$ *(2.5)* **28.** 0 *(2.5)*
29. $-\frac{3}{2}x^{-2} + \frac{15}{4}x^2 = \frac{-3}{2x^2} + \frac{15x^2}{4}$ *(2.5)*
30. $-2x^{-5} + x^3 = \frac{-2}{x^5} + x^3$ *(2.5)*
31. $f'(x) = 12x^3 + 9x^2 - 2$ *(2.5)* **32.** $\Delta x = 2$, $\Delta y = 10$, $\Delta y/\Delta x = 5$ *(2.6)*
33. 5 *(2.6)* **34.** 6 *(2.6)* **35.** $\Delta y = 0.64$; $dy = 0.6$ *(2.6)*
36. (A) 4 (B) 6 (C) Does not exist (D) 6 (E) No *(2.3)*
37. (A) 3 (B) 3 (C) 3 (D) 3 (E) Yes *(2.3)* **38.** (A) $(8, \infty)$
(B) $[0, 8]$ *(2.3)* **39.** $(-3, 4)$ *(2.3)* **40.** $(-3, 0) \cup (5, \infty)$ *(2.3)*
41. $(-2.3429, -0.4707) \cup (1.8136, \infty)$ *(2.3)* **42.** (A) 3
(B) $2 + 0.5h$ (C) 2 *(2.4)* **43.** $-x^{-4} + 10x^{-3}$ *(2.4)*
44. $\frac{3}{4}x^{-1/2} - \frac{5}{6}x^{-3/2} = \frac{3}{4\sqrt{x}} - \frac{5}{6\sqrt{x^3}}$ *(2.5)*
45. $0.6x^{-2/3} - 0.3x^{-4/3} = \frac{0.6}{x^{2/3}} - \frac{0.3}{x^{4/3}}$ *(2.4)*
46. $-\frac{3}{5}(-3)x^{-4} = \frac{9}{5x^4}$ *(2.5)* **47.** (A) $m = f'(1) = 2$
(B) $y = 2x + 3$ *(2.4, 2.5)* **48.** $x = 5$ *(2.4)* **49.** $x = -5$, $x = 3$ *(2.5)*
50. $x = -1.3401, 0.5771, 2.2630$ *(2.4)* **51.** ± 2.4824 *(2.5)*
52. (A) $v = f'(x) = 16x - 4$ (B) 44 ft/sec *(2.5)*
53. (A) $v = f'(x) = -10x + 16$ (B) $x = 1.6$ sec *(2.5)*
54. (A) The graph of g is the graph of f shifted 4 units to the right, and the graph of h is the graph of f shifted 4 units down:



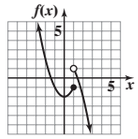
(B) The graph of g' is the graph of f' shifted 4 units to the right, and the graph of h' is the graph of f':



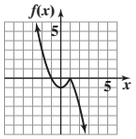
55. $(-\infty, \infty)$ *(2.3)* **56.** $(-\infty, 2) \cup (2, \infty)$ *(2.3)*
57. $(-\infty, -4) \cup (-4, 1) \cup (1, \infty)$ *(2.3)* **58.** $(-\infty, \infty)$ *(2.3)*
59. $[-2, 2]$ *(2.3)* **60.** (A) -1 (B) Does not exist (C) $-\frac{2}{3}$ *(2.1)*
61. (A) $\frac{1}{2}$ (B) 0 (C) Does not exist *(2.1)* **62.** (A) -1 (B) 1
(C) Does not exist *(2.1)*
63. (A) $-\frac{1}{6}$ (B) Does not exist (C) $-\frac{1}{3}$ *(2.1)* **64.** (A) 0 (B) -1
(C) Does not exist *(2.1)* **65.** (A) $\frac{2}{3}$ (B) $\frac{2}{3}$ (C) Does not exist *(2.3)*
66. (A) ∞ (B) $-\infty$ (C) ∞ *(2.3)* **67.** (A) 0 (B) 0
(C) Does not exist *(2.2)* **68.** 4 *(2.1)* **69.** $\frac{-1}{(x+2)^2}$ *(2.1)*
70. $2x - 1$ *(2.4)* **71.** $1/(2\sqrt{x})$ *(2.4)* **72.** Yes *(2.4)* **73.** No *(2.4)*
74. No *(2.4)* **75.** No *(2.4)* **76.** Yes *(2.4)* **77.** Yes *(2.4)*
78. Horizontal asymptote: $y = 5$; vertical asymptote: $x = 7$ *(2.2)*
79. Horizontal asymptote: $y = 0$; vertical asymptote: $x = 4$ *(2.2)*
80. No horizontal asymptote; vertical asymptote: $x = 3$ *(2.2)*
81. Horizontal asymptote: $y = 1$; vertical asymptotes: $x = -2$, $x = 1$ *(2.2)*
82. Horizontal asymptote: $y = 1$; vertical asymptotes: $x = -1$, $x = 1$ *(2.2)*
83. The domain of $f'(x)$ is all real numbers except $x = 0$. At $x = 0$, the graph of $y = f(x)$ is smooth, but it has a vertical tangent. *(2.4)*
84. (A) $\lim_{x \to 1} f(x) = 1$; $\lim_{x \to 1} f(x) = -1$



(B) $\lim_{x \to 1^-} f(x) = -1$; $\lim_{x \to 1^+} f(x) = 1$



(C) $m = 1$

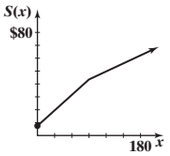


(D) The graphs in (A) and (B) have discontinuities at $x = 1$; the graph in (C) does not. *(2.2)*

85. (A) 1 (B) -1 (C) Does not exist (D) No *(2.4)*

86. (A) $S(x) = \begin{cases} 7.47 + 0.4x & \text{if } 0 \le x \le 90 \\ 24.786 + 0.2076x & \text{if } 90 < x \end{cases}$

(B)



(C) Yes *(2.2)*

87. (A) \$179.90 (B) \$180 *(2.7)* **88.** (A) $C(100) = 9{,}500$; $C'(100) = 50$. At a production level of 100 bicycles, the total cost is \$9,500, and cost is increasing at the rate of \$50 per bicycle.
(B) $\overline{C}(100) = 95$; $\overline{C}'(100) = -0.45$. At a production level of 100 bicycles, the average cost is \$95, and average cost is decreasing at a rate of \$0.45 per bicycle. *(2.7)*

89. The approximate cost of producing the 201st printer is greater than that of the 601st printer. Since these marginal costs are decreasing, the manufacturing process is becoming more efficient. *(2.7)*

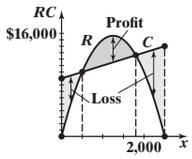
90. (A) $C'(x) = 2$; $\overline{C}(x) = 2 + \dfrac{9{,}000}{x}$; $\overline{C}'(x) = \dfrac{-9{,}000}{x^2}$

(B) $R(x) = xp = 25x - 0.01x^2$; $R'(x) = 25 - 0.02x$; $\overline{R}(x) = 25 - 0.01x$; $\overline{R}'(x) = -0.01$ (C) $P(x) = R(x) - C(x) = 23x - 0.01x^2 - 9{,}000$; $P'(x) = 23 - 0.02x$; $\overline{P}(x) = 23 - 0.01x - \dfrac{9{,}000}{x}$; $\overline{P}'(x) = -0.01 + \dfrac{9{,}000}{x^2}$

(D) (500, 10,000) and (1,800, 12,600)

(E) $P'(1{,}000) = 3$. Profit is increasing at the rate of \$3 per umbrella.
$P'(1{,}150) = 0$. Profit is flat.
$P'(1{,}400) = -5$. Profit is decreasing at the rate of \$5 per umbrella.

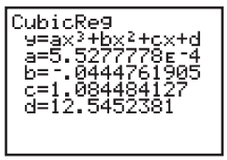
(F)



91. (A) 8 (B) 20 *(2.5)* (C) Long-term employees should near 40 components per day since as $t \to \infty$, $N(t) \to 40$. *(2.2)*

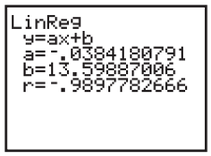
92. $N(9) = 27$; $N'(9) = 3.5$; After 9 months, 27,000 pools have been sold and the total sales are increasing at the rate of 3,500 pools per month. *(2.5)*

93. (A)

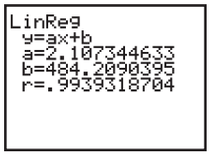


(B) $N(60) = 36.9$; $N'(60) = 1.7$. In 2020, natural-gas consumption is 36.9 trillion cubic feet and is increasing at the rate of 1.7 trillion cubic feet per year *(2.4)*

94. (A)



(B) Fixed costs: \$484.21; variable costs per kringle: \$2.11



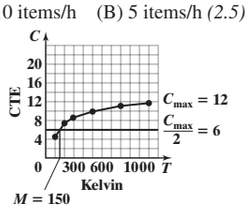
(C) (51, 591.15), (248, 1,007.62) (D) $\$4.07 < p < \$11.64$ *(2.7)*

95. $C'(10) = -1$; $C'(100) = -0.001(2.5)$

96. $F(4) = 98.16$; $F'(4) = -0.32$; After 4 hours the patient's temperature is 98.16°F and is decreasing at the rate of 0.32°F per hour. *(2.5)*

97. (A) 10 items/h (B) 5 items/h *(2.5)*

98. (A)



(B) $C(T) = \dfrac{12T}{150 + T}$

(C) $C = 9.6$ at $T = 600$ K; $T = 750$ K when $C = 10$ *(2.3)*