295. $\left(\frac{\log 211}{\log 0.5} \approx -7.7211\right)$

297. $\left(\frac{\log 0.452}{\log 0.2} \approx 0.4934\right)$

299. $\sim 17,\ 491$

301. Approximately $131,653 is accumulated in 5 years.
303. i. a. pH = 8 b. Base ii. a. pH = 3 b. Acid iii. a. pH = 4 b. Acid
305. a. ~ 333 million b. 94 years from 2013, or in 2107
307. a. $k \approx 0.0578$ b. ≈ 92 hours
309. The San Francisco earthquake had $10^{3.4}$ or ~ 2512 times more energy than the Japan earthquake.

Review Exercises

311. False
313. False
315. Domain: $x > 5,$ range: all real numbers
317. Domain: $x > 2$ and $x < -4,$ range: all real numbers
319. Degree of 3, y -intercept: 0, zeros: 0, $\sqrt{3} - 1,\ -1 - \sqrt{3}$
321. $\cos^2 x - \sin^2 x = \cos 2x$ or $= \frac{1 - 2\sin^2 x}{2}$ or $= \frac{2\cos^2 x - 1}{2}$
323. $0,\ \pm 2\pi$
325. 4
327. One-to-one; yes, the function has an inverse; inverse: $f^{-1}(x) = \frac{1}{y}$
329. $x \geq -\frac{3}{2},\ f^{-1}(x) = -\frac{3}{2} + \frac{1}{2}\sqrt{4y - 7}$
331. a. $C(x) = 300 + 7x$ b. 100 shirts
333. The population is less than 20,000 from December 8 through January 23 and more than 140,000 from May 29 through August 2
335. 78.51%

Chapter 2

Checkpoint

2.1. 2.25
2.2. 12.006001
2.3. 16 unit^2
2.4. $\lim\limits_{x \to 1} \frac{\frac{1}{x} - 1}{x - 1} = -1$
2.5. $\lim\limits_{x \to 2} h(x) = -1.$
2.6. $\lim\limits_{x \to 2} \frac{|x^2 - 4|}{x - 2}$ does not exist.
2.7. a. $\lim\limits_{x \to 2^-} \frac{|x^2 - 4|}{x - 2} = -4;$ b. $\lim\limits_{x \to 2^+} \frac{|x^2 - 4|}{x - 2} = 4$
2.8. a. $\lim\limits_{x \to 0^-} \frac{1}{x^2} = +\infty;$ b. $\lim\limits_{x \to 0^+} \frac{1}{x^2} = +\infty;$ c. $\lim\limits_{x \to 0} \frac{1}{x^2} = +\infty$
2.9. a. $\lim\limits_{x \to 2^-} \frac{1}{(x - 2)^3} = -\infty;$ b. $\lim\limits_{x \to 2^+} \frac{1}{(x - 2)^3} = +\infty;$ c. $\lim\limits_{x \to 2} \frac{1}{(x - 2)^3}$ DNE. The line $x = 2$ is the vertical asymptote of $f(x) = 1/(x - 2)^3.$
2.10. Does not exist.
2.11. $11\sqrt{10}$
2.12. −13;

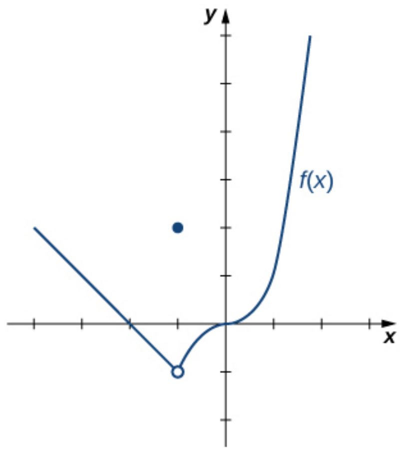
2.13. $\frac{1}{3}$

2.14. $\frac{1}{4}$

2.15. −1;

2.16. $\frac{1}{4}$

2.17.



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

2.18. +∞
2.19. 0
2.20. 0
2.21. *f* is not continuous at 1 because $f(1) = 2 \neq 3 = \lim_{x \to 1} f(x)$.

2.22. $f(x)$ is continuous at every real number.

2.23. Discontinuous at 1; removable
2.24. $[-3, +\infty)$

2.25. 0
2.26. $f(0) = 1 > 0,\ f(1) = -2 < 0;\ f(x)$ is continuous over $[0, 1]$. It must have a zero on this interval.

2.27. Let $\varepsilon > 0$; choose $\delta = \frac{\varepsilon}{3}$; assume $0 < |x - 2| < \delta$. Thus, $|(3x - 2) - 4| = |3x - 6| = |3| \cdot |x - 2| < 3 \cdot \delta = 3 \cdot (\varepsilon/3) = \varepsilon$. Therefore, $\lim_{x \to 2} 3x - 2 = 4$.

2.28. Choose $\delta = \min\{9 - (3 - \varepsilon)^2,\ (3 + \varepsilon)^2 - 9\}$.

2.29. $\left|x^2 - 1\right| = |x - 1| \cdot |x + 1| < \varepsilon/3 \cdot 3 = \varepsilon$

2.30. $\delta = \varepsilon^2$

Section Exercises

1. a. 2.2100000; b. 2.0201000; c. 2.0020010; d. 2.0002000; e. (1.1000000, 2.2100000); f. (1.0100000, 2.0201000); g. (1.0010000, 2.0020010); h. (1.0001000, 2.0002000); i. 2.1000000; j. 2.0100000; k. 2.0010000; l. 2.0001000
3. $y = 2x$

5. 3
7. a. 2.0248457; b. 2.0024984; c. 2.0002500; d. 2.0000250; e. (4.1000000,2.0248457); f. (4.0100000,2.0024984); g. (4.0010000,2.0002500); h. (4.00010000,2.0000250); i. 0.24845673; j. 0.24984395; k. 0.24998438; l. 0.24999844
9. $y = \frac{x}{4} + 1$

11. π
13. a. −0.95238095; b. −0.99009901; c. −0.99502488; d. −0.99900100; e. (−1;.0500000,−0;.95238095); f. (−1;.0100000,−0;.9909901); g. (−1;.0050000,−0;.99502488); h. (1.0010000,−0;.99900100); i. −0.95238095; j. −0.99009901; k. −0.99502488; l. −0.99900100

15. $y = -x - 2$

17. −49 m/sec (velocity of the ball is 49 m/sec downward)
19. 5.2 m/sec
21. −9.8 m/sec
23. 6 m/sec

25. Under, 1 unit^2; over: 4 unit^2. The exact area of the two triangles is $\frac{1}{2}(1)(1) + \frac{1}{2}(2)(2) = 2.5 \text{ units}^2$.

27. Under, 0.96 unit^2; over, 1.92 unit^2. The exact area of the semicircle with radius 1 is $\frac{\pi(1)^2}{2} = \frac{\pi}{2}$ unit^2.

29. Approximately 1.3333333 unit^2

31. $\lim_{x \to 1} f(x)$ does not exist because $\lim_{x \to 1^-} f(x) = -2 \neq \lim_{x \to 1^+} f(x) = 2.$

33. $\lim_{x \to 0} (1 + x)^{1/x} = 2.7183$

35. a. 1.98669331; b. 1.99986667; c. 1.99999867; d. 1.99999999; e. 1.98669331; f. 1.99986667; g. 1.99999867; h. 1.99999999; $\lim_{x \to 0} \frac{\sin 2x}{x} = 2$

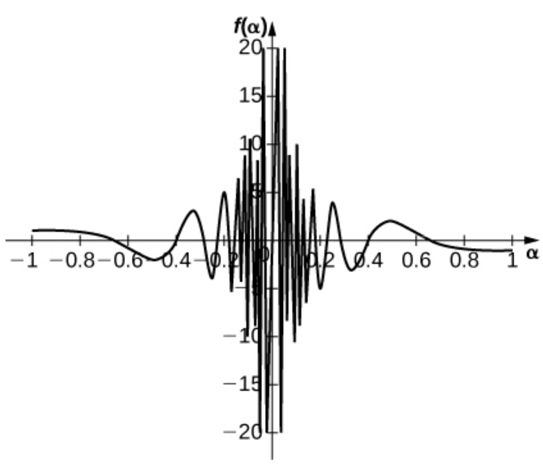
37. $\lim_{x \to 0} \frac{\sin ax}{x} = a$

39. a. −0.80000000; b. −0.98000000; c. −0.99800000; d. −0.99980000; e. −1.2000000; f. −1.0200000; g. −1.0020000; h. −1.0002000; $\lim_{x \to 1} (1 - 2x) = -1$

41. a. −37.931934; b. −3377.9264; c. −333,777.93; d. −33,337,778; e. −29.032258; f. −3289.0365; g. −332,889.04; h. −33,328,889 $\lim_{x \to 0} \frac{z - 1}{z^2 (z + 3)} = -\infty$

43. a. 0.13495277; b. 0.12594300; c. 0.12509381; d. 0.12500938; e. 0.11614402; f. 0.12406794; g. 0.12490631; h. 0.12499063; $\therefore \lim_{x \to 2} \frac{1 - \frac{2}{x}}{x^2 - 4} = 0.1250 = \frac{1}{8}$

45. a. −10.00000; b. −100.00000; c. −1000.0000; d. −10,000.000; Guess: $\lim_{\alpha \to 0^+} \frac{1}{\alpha} \cos\left(\frac{\pi}{\alpha}\right) = \infty,$ actual: DNE

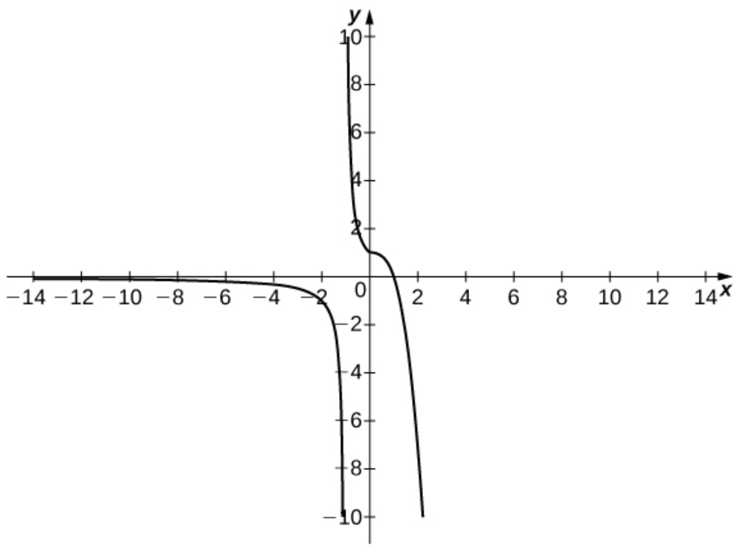


47. False; $\lim_{x \to -2^+} f(x) = +\infty$

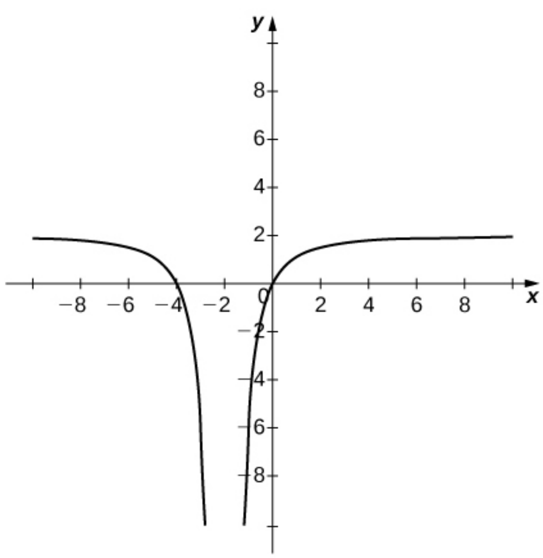
49. False; $\lim_{x \to 6} f(x)$ DNE since $\lim_{x \to 6^-} f(x) = 2$ and $\lim_{x \to 6^+} f(x) = 5.$

51. 2
53. 1
55. 1
57. DNE
59. 0
61. DNE
63. 2
65. 3

67. DNE
69. 0
71. −2
73. DNE
75. 0
77. Answers may vary.



79. Answers may vary.



81. a. ρ_2 b. ρ_1 c. DNE unless $\rho_1 = \rho_2.$ As you approach x_{SF} from the right, you are in the high-density area of the shock. When you approach from the left, you have not experienced the "shock" yet and are at a lower density.
83. Use constant multiple law and difference law: $\lim\limits_{x \to 0}\left(4x^2 - 2x + 3\right) = 4\lim\limits_{x \to 0} x^2 - 2\lim\limits_{x \to 0} x + \lim\limits_{x \to 0} 3 = 3$
85. Use root law: $\lim\limits_{x \to -2} \sqrt{x^2 - 6x + 3} = \sqrt{\lim\limits_{x \to -2}\left(x^2 - 6x + 3\right)} = \sqrt{19}$
87. 49
89. 1
91. $-\frac{5}{7}$
93. $\lim\limits_{x \to 4} \frac{x^2 - 16}{x - 4} = \frac{16 - 16}{4 - 4} = \frac{0}{0};$ then, $\lim\limits_{x \to 4} \frac{x^2 - 16}{x - 4} = \lim\limits_{x \to 4} \frac{(x + 4)(x - 4)}{x - 4} = 8$

95. $\lim_{x \to 6} \frac{3x-18}{2x-12} = \frac{18-18}{12-12} = \frac{0}{0}$; then, $\lim_{x \to 6} \frac{3x-18}{2x-12} = \lim_{x \to 6} \frac{3(x-6)}{2(x-6)} = \frac{3}{2}$

97. $\lim_{x \to 9} \frac{t-9}{\sqrt{t}-3} = \frac{9-9}{3-3} = \frac{0}{0}$; then, $\lim_{t \to 9} \frac{t-9}{\sqrt{t}-3} = \lim_{t \to 9} \frac{t-9}{\sqrt{t}-3} \frac{\sqrt{t}+3}{\sqrt{t}+3} = \lim_{t \to 9} (\sqrt{t}+3) = 6$

99. $\lim_{\theta \to \pi} \frac{\sin\theta}{\tan\theta} = \frac{\sin\pi}{\tan\pi} = \frac{0}{0}$; then, $\lim_{\theta \to \pi} \frac{\sin\theta}{\tan\theta} = \lim_{\theta \to \pi} \frac{\sin\theta}{\frac{\sin\theta}{\cos\theta}} = \lim_{\theta \to \pi} \cos\theta = -1$

101. $\lim_{x \to 1/2} \frac{2x^2+3x-2}{2x-1} = \frac{\frac{1}{2}+\frac{3}{2}-2}{1-1} = \frac{0}{0}$; then, $\lim_{x \to 1/2} \frac{2x^2+3x-2}{2x-1} = \lim_{x \to 1/2} \frac{(2x-1)(x+2)}{2x-1} = \frac{5}{2}$

103. $-\infty$

105. $-\infty$

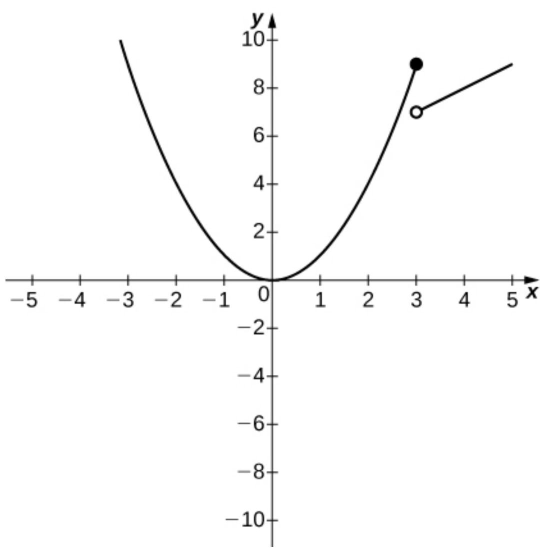
107. $\lim_{x \to 6} 2f(x)g(x) = 2 \lim_{x \to 6} f(x) \lim_{x \to 6} g(x) = 72$

109. $\lim_{x \to 6} \left(f(x) + \frac{1}{3}g(x)\right) = \lim_{x \to 6} f(x) + \frac{1}{3} \lim_{x \to 6} g(x) = 7$

111. $\lim_{x \to 6} \sqrt{g(x) - f(x)} = \sqrt{\lim_{x \to 6} g(x) - \lim_{x \to 6} f(x)} = \sqrt{5}$

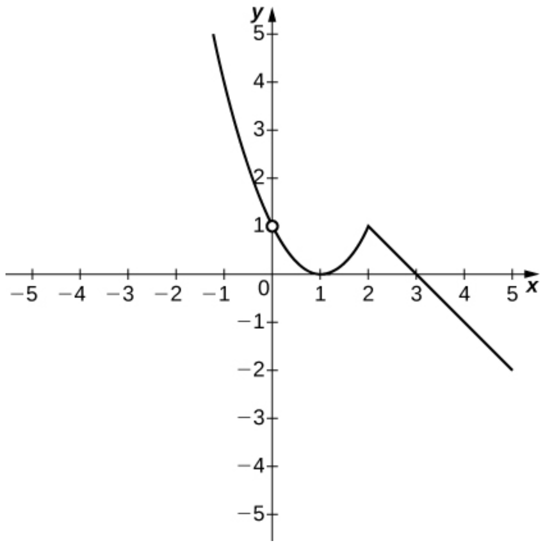
113. $\lim_{x \to 6} [(x+1)f(x)] = \left(\lim_{x \to 6} (x+1)\right)\left(\lim_{x \to 6} f(x)\right) = 28$

115.



a. 9; b. 7

117.



a. 1; b. 1

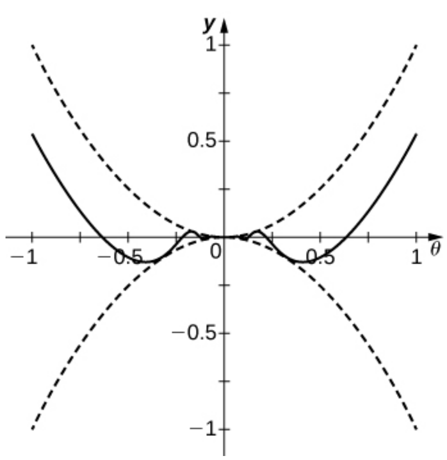
119. $\lim_{x \to -3^-} (f(x) - 3g(x)) = \lim_{x \to -3^-} f(x) - 3 \lim_{x \to -3^-} g(x) = 0 + 6 = 6$

121. $\lim_{x \to -5} \frac{2 + g(x)}{f(x)} = \frac{2 + \left(\lim_{x \to -5} g(x)\right)}{\lim_{x \to -5} f(x)} = \frac{2 + 0}{2} = 1$

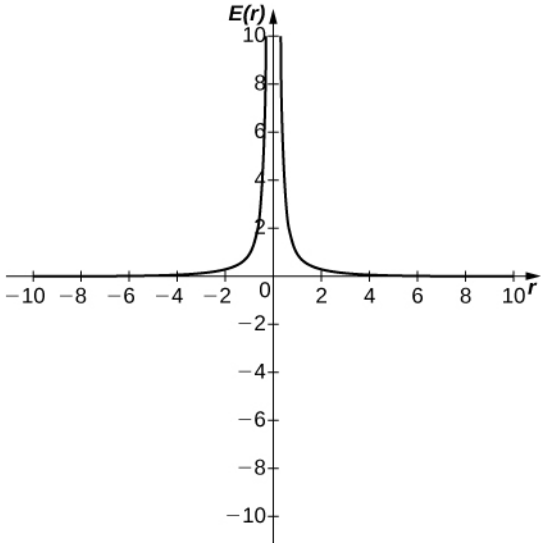
123. $\lim_{x \to 1} \sqrt[3]{f(x) - g(x)} = \sqrt[3]{\lim_{x \to 1} f(x) - \lim_{x \to 1} g(x)} = \sqrt[3]{2 + 5} = \sqrt[3]{7}$

125. $\lim_{x \to -9} (xf(x) + 2g(x)) = \left(\lim_{x \to -9} x\right)\left(\lim_{x \to -9} f(x)\right) + 2 \lim_{x \to -9} (g(x)) = (-9)(6) + 2(4) = -46$

127. The limit is zero.



129. a.



b. ∞. The magnitude of the electric field as you approach the particle q becomes infinite. It does not make physical sense to evaluate negative distance.

131. The function is defined for all x in the interval $(0, \infty)$.

133. Removable discontinuity at $x = 0$; infinite discontinuity at $x = 1$

135. Infinite discontinuity at $x = \ln 2$

137. Infinite discontinuities at $x = \frac{(2k+1)\pi}{4}$, for $k = 0, \pm 1, \pm 2, \pm 3, \ldots$

139. No. It is a removable discontinuity.

141. Yes. It is continuous.

143. Yes. It is continuous.

145. $k = -5$

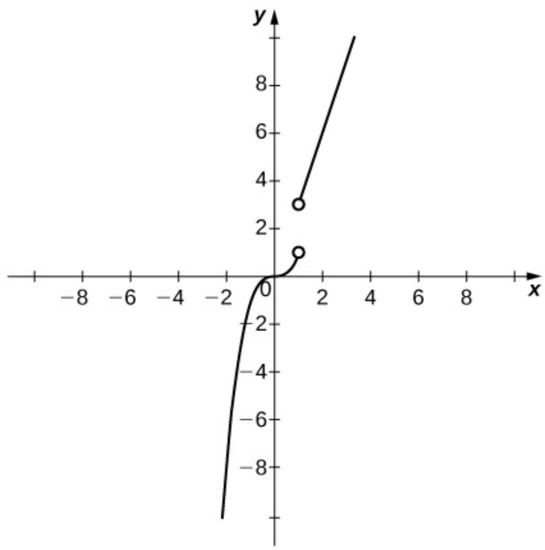
147. $k = -1$

149. $k = \frac{16}{3}$

151. Since both s and $y = t$ are continuous everywhere, then $h(t) = s(t) - t$ is continuous everywhere and, in particular, it is continuous over the closed interval $[2, 5]$. Also, $h(2) = 3 > 0$ and $h(5) = -3 < 0$. Therefore, by the IVT, there is a value $x = c$ such that $h(c) = 0$.

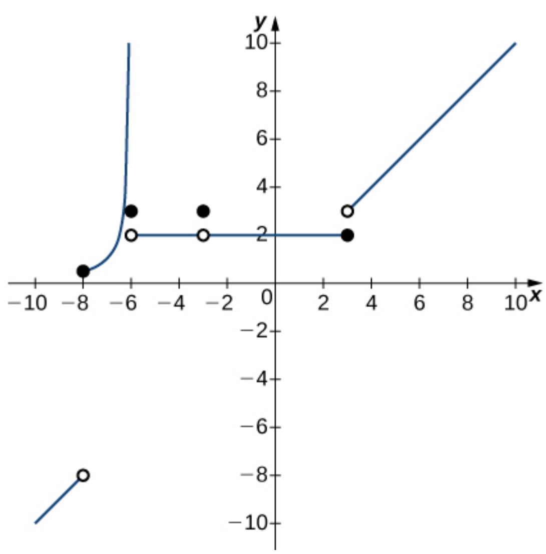
153. The function $f(x) = 2^x - x^3$ is continuous over the interval $[1.25, 1.375]$ and has opposite signs at the endpoints.

155. a.

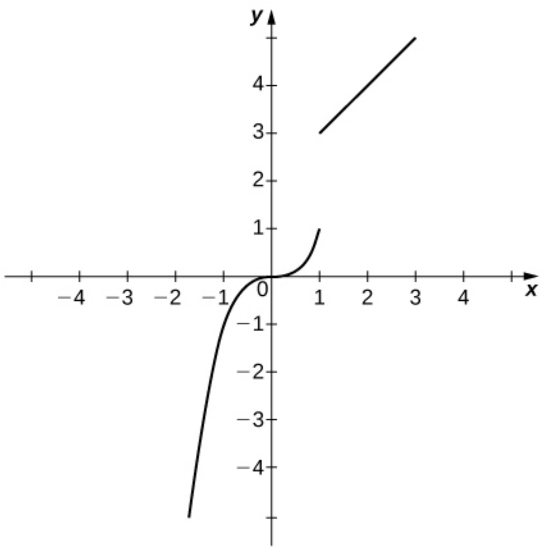


b. It is not possible to redefine $f(1)$ since the discontinuity is a jump discontinuity.

157. Answers may vary; see the following example:



159. Answers may vary; see the following example:



161. False. It is continuous over $(-\infty, 0) \cup (0, \infty)$.

163. False. Consider $f(x) = \begin{cases} x \text{ if } x \neq 0 \\ 4 \text{ if } x = 0 \end{cases}$.

165. False. IVT only says that there is at least one solution; it does not guarantee that there is exactly one. Consider $f(x) = \cos(x)$ on $[-\pi, 2\pi]$.

167. False. The IVT does *not* work in reverse! Consider $(x-1)^2$ over the interval $[-2, 2]$.

169. $R = 0.0001519 \text{ m}$

171. $D = 345{,}826 \text{ km}$

173. For all values of a, $f(a)$ is defined, $\lim\limits_{\theta \to a} f(\theta)$ exists, and $\lim\limits_{\theta \to a} f(\theta) = f(a)$. Therefore, $f(\theta)$ is continuous everywhere.

175. Nowhere

177. For every $\varepsilon > 0$, there exists a $\delta > 0$, so that if $0 < |t - b| < \delta$, then $|g(t) - M| < \varepsilon$

179. For every $\varepsilon > 0$, there exists a $\delta > 0$, so that if $0 < |x - a| < \delta$, then $|\varphi(x) - A| < \varepsilon$

181. $\delta \leq 0.25$

183. $\delta \leq 2$

185. $\delta \leq 1$

187. $\delta < 0.3900$

189. Let $\delta = \varepsilon$. If $0 < |x - 3| < \varepsilon$, then $|x + 3 - 6| = |x - 3| < \varepsilon$.

191. Let $\delta = \sqrt[4]{\varepsilon}$. If $0 < |x| < \sqrt[4]{\varepsilon}$, then $\left|x^4\right| = x^4 < \varepsilon$.

193. Let $\delta = \varepsilon^2$. If $5 - \varepsilon^2 < x < 5$, then $\left|\sqrt{5 - x}\right| = \sqrt{5 - x} < \varepsilon$.

195. Let $\delta = \varepsilon/5$. If $1 - \varepsilon/5 < x < 1$, then $|f(x) - 3| = 5x - 5 < \varepsilon$.

197. Let $\delta = \sqrt{\frac{3}{M}}$. If $0 < |x + 1| < \sqrt{\frac{3}{M}}$, then $f(x) = \frac{3}{(x+1)^2} > M$.

199. 0.328 cm, $\varepsilon = 8$, $\delta = 0.33$, $a = 12$, $L = 144$

201. Answers may vary.

203. 0

205. $f(x) - g(x) = f(x) + (-1)g(x)$

207. Answers may vary.

Review Exercises

209. False

211. False. A removable discontinuity is possible.

213. 5
215. 8/7
217. DNE
219. 2/3
221. −4;
223. Since $-1 \le \cos(2\pi x) \le 1$, then $-x^2 \le x^2 \cos(2\pi x) \le x^2$. Since $\lim_{x \to 0} x^2 = 0 = \lim_{x \to 0} -x^2$, it follows that $\lim_{x \to 0} x^2 \cos(2\pi x) = 0$.
225. $[2, \infty]$
227. $c = -1$
229. $\delta = \sqrt[3]{\varepsilon}$
231. 0 m/sec

Chapter 3

Checkpoint

3.1. $\frac{1}{4}$
3.2. 6
3.3. $f'(1) = 5$
3.4. -32 ft/s
3.5. $P'(3.25) = 20 > 0$; raise prices
3.6. $f'(x) = 2x$
3.7. $(0, +\infty)$
3.8. $a = 6$ and $b = -9$
3.9. $f''(x) = 2$
3.10. $a(t) = 6t$
3.11. 0
3.12. $4x^3$
3.13. $f'(x) = 7x^6$
3.14. $f'(x) = 6x^2 - 12x$.
3.15. $y = 12x - 23$
3.16. $j'(x) = 10x^4\left(4x^2 + x\right) + (8x + 1)\left(2x^5\right) = 56x^6 + 12x^5$.
3.17. $k'(x) = -\frac{13}{(4x-3)^2}$.
3.18. $g'(x) = -7x^{-8}$.
3.19. $3f'(x) - 2g'(x)$.
3.20. $\frac{5}{8}$
3.21. -4.4
3.22. left to right
3.23. 3,300
3.24. $2
3.25. $f'(x) = \cos^2 x - \sin^2 x$
3.26. $\frac{\cos x + x \sin x}{\cos^2 x}$
3.27. $t = \frac{\pi}{3}$, $t = \frac{2\pi}{3}$
3.28. $f'(x) = -\csc^2 x$