

G | Answers to Odd-Numbered Exercises

CHAPTER 1

EXERCISES 1.1 ■ PAGE 17

1. Yes

3. (a) 2, -2, 1, 2.5 (b) -4 (c) [-4, 4]

(d) [-4, 4], [-2, 3] (e) [0, 2]

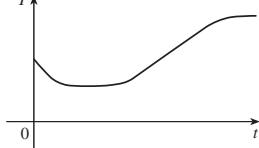
5. [-85, 115] 7. Yes 9. No 11. Yes

15. No 17. Yes, [-3, 2], [-3, -2) \cup [-1, 3]

19. (a) 13.8°C (b) 1990 (c) 1910, 2000

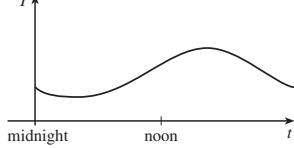
(d) [13.5, 14.4]

21.

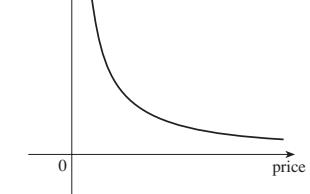


23. (a) 500 MW; 730 MW (b) 4 AM; noon; yes

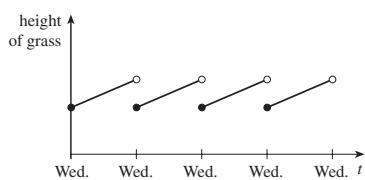
25.



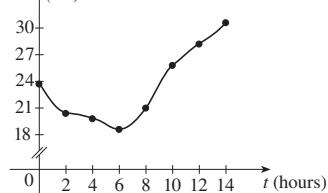
27.



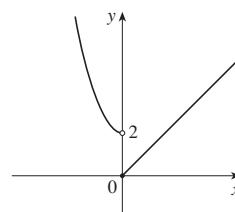
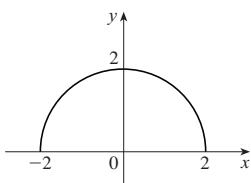
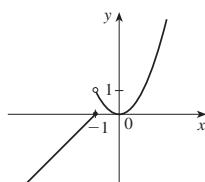
29.



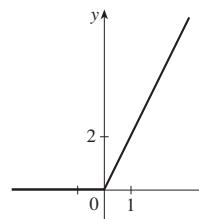
31. (a)



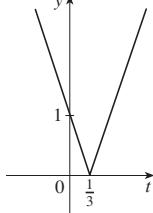
(b) 23°C

33. $12, 16, 3a^2 - a + 2, 3a^2 + a + 2, 3a^2 + 5a + 4,$
 $6a^2 - 2a + 4, 12a^2 - 2a + 2, 3a^4 - a^2 + 2,$
 $9a^4 - 6a^3 + 13a^2 - 4a + 4, 3a^2 + 6ah + 3h^2 - a - h + 2$ 35. $-3 - h \quad 37. -1/(ax)$ 39. $(-\infty, -3) \cup (-3, 3) \cup (3, \infty) \quad 41. (-\infty, \infty)$ 43. $(-\infty, 0) \cup (5, \infty) \quad 45. [0, 4]$ 47. $[-2, 2], [0, 2] \quad 49. 11, 0, 2$ 51. $-2, 0, 4$ 

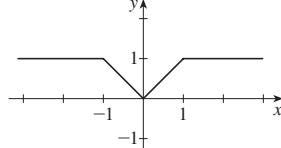
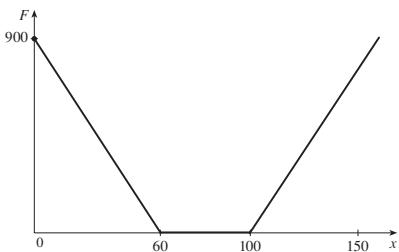
53.

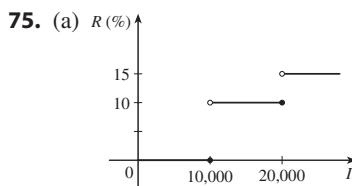


55.

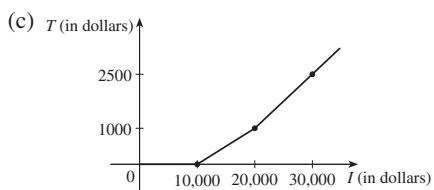
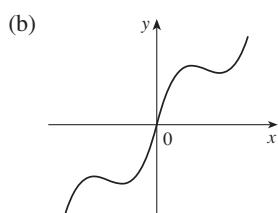
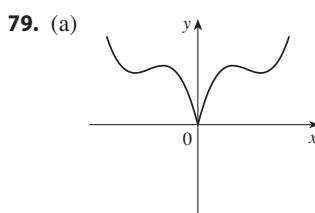


57.

59. $f(x) = \frac{5}{2}x - \frac{11}{2}, 1 \leq x \leq 5 \quad 61. f(x) = 1 - \sqrt{-x}$ 63. $f(x) = \begin{cases} -x + 3 & \text{if } 0 \leq x \leq 3 \\ 2x - 6 & \text{if } 3 < x \leq 5 \end{cases}$ 65. $A(L) = 10L - L^2, 0 < L < 10$ 67. $A(x) = \sqrt{3}x^2/4, x > 0 \quad 69. S(x) = x^2 + (8/x), x > 0$ 71. $V(x) = 4x^3 - 160x^2 + 150x, 0 < x < 15$ 73. $F(x) = \begin{cases} 15(60 - x) & \text{if } 0 < x < 60 \\ 0 & \text{if } 60 < x < 100 \\ 15(x - 100) & \text{if } 100 < x < 150 \end{cases}$ 



(b) \$400, \$1900

77. f is odd, g is even

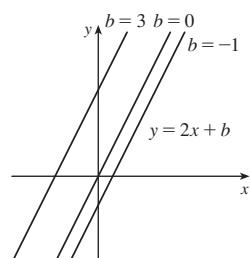
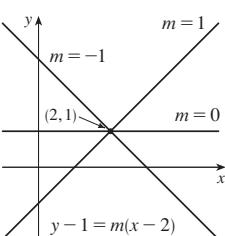
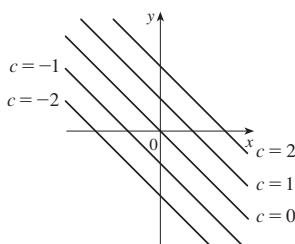
81. Odd

83. Neither

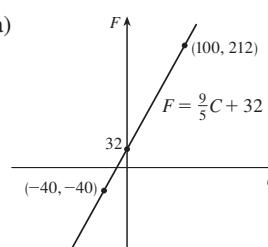
85. Even

87. Even; odd; neither (unless $f = 0$ or $g = 0$)**EXERCISES 1.2 ■ PAGE 33**

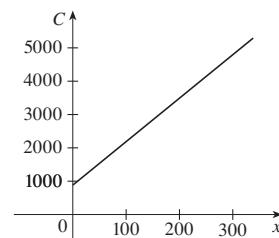
1. (a) Polynomial, degree 3 (b) Trigonometric (c) Power
 (d) Exponential (e) Algebraic (f) Logarithmic

3. (a) h (b) f (c) g 5. $\{x \mid x \neq \pi/2 + 2n\pi\}$, n an integer7. (a) $y = 2x + b$,
where b is the y -intercept.(b) $y = mx + 1 - 2m$,
where m is the slope.(c) $y = 2x - 3$ 9. Their graphs have slope -1 .11. $f(x) = 2x^2 - 12x + 18$ 13. $f(x) = -3x(x + 1)(x - 2)$

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

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

19. (a)
- $C = 13x + 900$



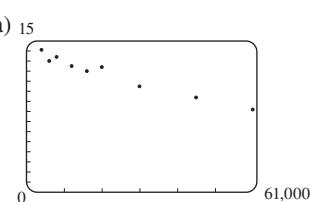
- (b) 13; cost (in dollars) of producing each additional chair
 (c) 900; daily fixed costs

21. (a) $P = 0.1d + 1.05$ (b) 59.5 m

23. Four times brighter

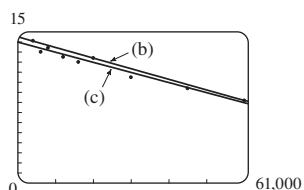
25. (a) 8 (b) 4 (c) 605,000 W; 2,042,000 W; 9,454,000 W

27. (a) Cosine (b) Linear



A linear model is appropriate.

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

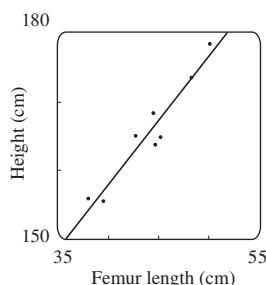


(c) $y = -0.00009979x + 13.951$

- (d) About 11.5 per 100 population
(e) About 6% (f) No

31. (a) See the graph in part (b).

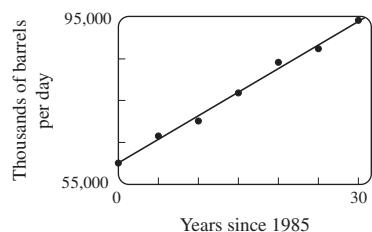
(b) $y = 1.88074x + 82.64974$



(c) 182.3 cm

33. (a) A linear model is appropriate. See the graph in part (b).

(b) $y = 1124.86x + 60,119.86$



(c) In thousands of barrels per day: 79,242 and 96,115

35. (a) 2 (b) 334 m^2

EXERCISES 1.3 ■ PAGE 42

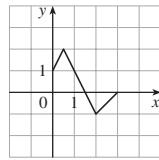
1. (a) $y = f(x) + 3$ (b) $y = f(x) - 3$ (c) $y = f(x - 3)$

(d) $y = f(x + 3)$ (e) $y = -f(x)$ (f) $y = f(-x)$

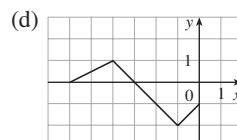
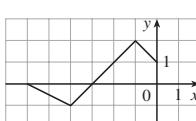
(g) $y = 3f(x)$ (h) $y = \frac{1}{3}f(x)$

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

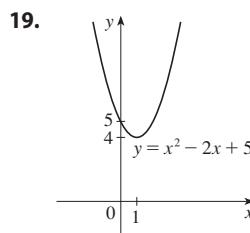
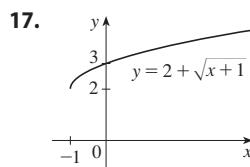
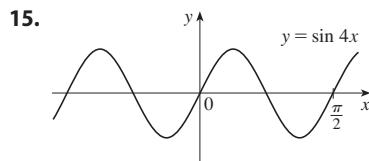
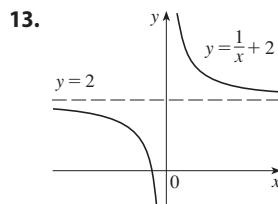
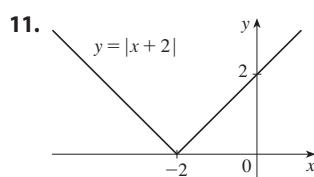
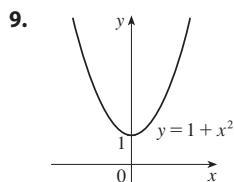
5. (a)



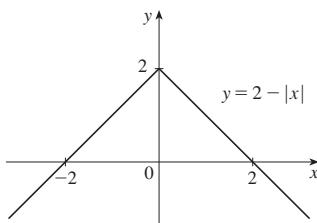
(b)



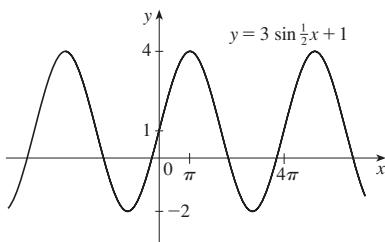
7. $y = -\sqrt{-x^2 - 5x - 4} - 1$



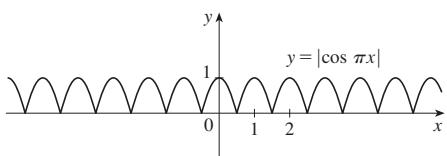
21.



23.



25.

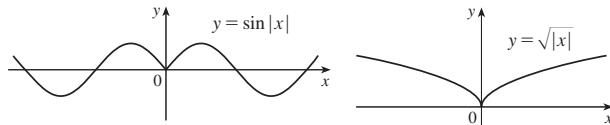


$$27. L(t) = 12 + 2 \sin\left[\frac{2\pi}{365}(t - 80)\right]$$

$$29. D(t) = 5 \cos[(\pi/6)(t - 6.75)] + 7$$

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

(b) (c)



$$33. (a) (f + g)(x) = \sqrt{25 - x^2} + \sqrt{x + 1}, [-1, 5]$$

$$(b) (f - g)(x) = \sqrt{25 - x^2} - \sqrt{x + 1}, [-1, 5]$$

$$(c) (fg)(x) = \sqrt{-x^3 - x^2 + 25x + 25}, [-1, 5]$$

$$(d) (f/g)(x) = \sqrt{\frac{25 - x^2}{x + 1}}, (-1, 5]$$

$$35. (a) (f \circ g)(x) = x + 5, (-\infty, \infty)$$

$$(b) (g \circ f)(x) = \sqrt[3]{x^3 + 5}, (-\infty, \infty)$$

$$(c) (f \circ f)(x) = (x^3 + 5)^3 + 5, (-\infty, \infty)$$

$$(d) (g \circ g)(x) = \sqrt[3]{x}, (-\infty, \infty)$$

$$37. (a) (f \circ g)(x) = \frac{1}{\sqrt{x+1}}, (-1, \infty)$$

$$(b) (g \circ f)(x) = \frac{1}{\sqrt{x}} + 1, (0, \infty)$$

$$(c) (f \circ f)(x) = \sqrt[4]{x}, (0, \infty)$$

$$(d) (g \circ g)(x) = x + 2, (-\infty, \infty)$$

$$39. (a) (f \circ g)(x) = \frac{2}{\sin x}, \{x \mid x \neq n\pi\}, n \text{ an integer}$$

$$(b) (g \circ f)(x) = \sin\left(\frac{2}{x}\right), \{x \mid x \neq 0\}$$

$$(c) (f \circ f)(x) = x, \{x \mid x \neq 0\}$$

$$(d) (g \circ g)(x) = \sin(\sin x), \mathbb{R}$$

$$41. (f \circ g \circ h)(x) = 3 \sin(x^2) - 2$$

$$43. (f \circ g \circ h)(x) = \sqrt{x^6 + 4x^3 + 1}$$

$$45. g(x) = 2x + x^2, f(x) = x^4$$

$$47. g(x) = \sqrt[3]{x}, f(x) = x/(1+x)$$

$$49. g(t) = t^2, f(t) = \sec t \tan t$$

$$51. h(x) = \sqrt{x}, g(x) = x - 1, f(x) = \sqrt{x}$$

$$53. h(t) = \cos t, g(t) = \sin t, f(t) = t^2$$

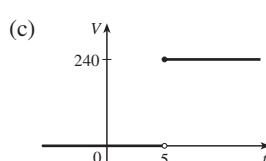
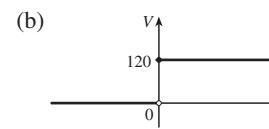
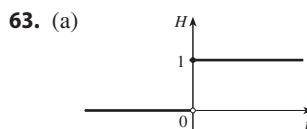
$$55. (a) 6 (b) 5 (c) 5 (d) 3$$

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

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

$$61. (a) s = \sqrt{d^2 + 36} \quad (b) d = 30t$$

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



$$V(t) = 120H(t - 5)$$

65. Yes; $m_1 m_2$

$$67. (a) f(x) = x^2 + 6 \quad (b) g(x) = x^2 + x - 1$$

69. Yes

71. (d) $f(x) = \frac{1}{2}E(x) + \frac{1}{2}O(x)$, where $E(x) = 2^x + 2^{-x} + (x - 3)^2 + (x + 3)^2$ and $O(x) = 2^x - 2^{-x} + (x - 3)^2 - (x + 3)^2$

EXERCISES 1.4 ■ PAGE 50

$$1. (a) -44.4, -38.8, -27.8, -22.2, -16.6$$

$$(b) -33.3 \quad (c) -33\frac{1}{3}$$

$$3. (a) (i) 2 (ii) 1.111111 (iii) 1.010101 (iv) 1.001001$$

$$(v) 0.666667 (vi) 0.909091 (vii) 0.990099$$

$$(viii) 0.999001 (b) 1 (c) y = x - 3$$

$$5. (a) (i) -40 \text{ m/s} (ii) -39.4 \text{ m/s} (iii) -39.3 \text{ m/s}$$

$$(b) -39 \text{ m/s}$$

$$7. (a) (i) 8.9 \text{ m/s} (ii) 9.9 \text{ m/s} (iii) 13.9 \text{ m/s}$$

$$(iv) 14.9 \text{ m/s} (b) 8.9 \text{ m/s}$$

$$9. (a) 0, 1.7321, -1.0847, -2.7433, 4.3301, -2.8173, 0, -2.1651, -2.6061, -5, 3.4202; \text{no} \quad (c) -31.4$$

EXERCISES 1.5 ■ PAGE 60

1. Yes

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

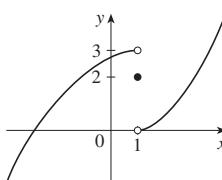
(b) $\lim_{x \rightarrow 4^+} f(x) = -\infty$ means that the values of $f(x)$ can be made arbitrarily large negative by taking x sufficiently close to 4 through values larger than 4 .

5. (a) 2 (b) 1 (c) 4 (d) Does not exist (e) 3

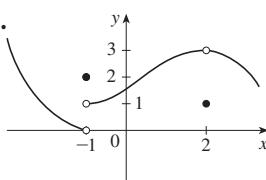
7. (a) 4 (b) 5 (c) 2, 4 (d) 4

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

15.



17.

19. $\frac{1}{2}$ 21. $\frac{1}{2}$

23. 1.5

25. 1

27. ∞ 29. ∞ 31. $-\infty$ 33. $-\infty$ 35. ∞ 37. $x = -2$ 39. $-\infty; \infty$

41. (a) 0.998000, 0.638259, 0.358484, 0.158680, 0.038851,

0.008928, 0.001465; 0

(b) 0.000572, -0.000614 , -0.000907 , -0.000978 , -0.000993 , -0.001000 ; -0.001 43. $x \approx \pm 0.90, \pm 2.24$; $x = \pm \sin^{-1}(\pi/4), \pm(\pi - \sin^{-1}(\pi/4))$ 45. $m \rightarrow \infty$ **EXERCISES 1.6 ■ PAGE 70**1. (a) -6 (b) -8 (c) 2 (d) -6

(e) Does not exist (f) 0

3. 75

5. 88

7. 5

9. $-\frac{1}{27}$ 11. -13

13. 6

15. Does not exist

17. $\frac{5}{7}$ 19. $\frac{9}{2}$ 21. -6 23. $\frac{1}{6}$ 25. $-\frac{1}{9}$

27. 1

29. $\frac{1}{128}$ 31. $-\frac{1}{2}$ 33. $3x^2$ 35. (a), (b) $\frac{2}{3}$

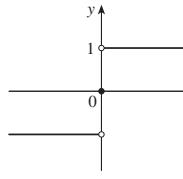
39. 7

43. 8

45. -4

47. Does not exist

49. (a)



(b) (i) 1

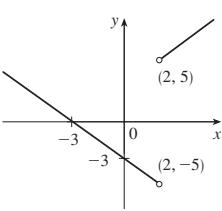
(ii) -1

(iii) Does not exist

(iv) 1

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

(c)



53. 7

55. (a) (i) -2 (ii) Does not exist (iii) -3 (b) (i) $n - 1$ (ii) n (c) a is not an integer.61. 8 67. 15; -1 **EXERCISES 1.7 ■ PAGE 81**

1. 0.1 (or any smaller positive number)

3. 1.44 (or any smaller positive number)

5. 0.4269 (or any smaller positive number)

7. 0.0219 (or any smaller positive number); 0.011 (or any smaller positive number)

9. (a) 0.041 (or any smaller positive number)

(b) $\lim_{x \rightarrow 4^+} \frac{x^2 + 4}{\sqrt{x - 4}} = \infty$ 11. (a) $\sqrt{1000/\pi}$ cm (b) Within approximately 0.0445 cm(c) Radius; area; $\sqrt{1000/\pi}$; 1000; 5; ≈ 0.0445

13. (a) 0.025 (b) 0.0025

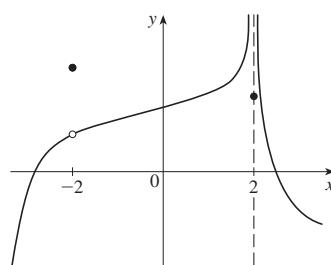
35. (a) 0.093 (b) $d = (B^{2/3} - 12)/(6B^{1/3}) - 1$, where $B = 216 + 108\varepsilon + 12\sqrt{336 + 324\varepsilon + 81\varepsilon^2}$

41. Within 0.1

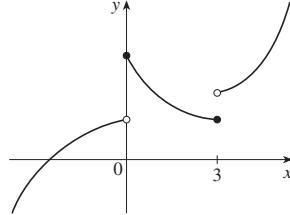
EXERCISES 1.8 ■ PAGE 921. $\lim_{x \rightarrow 4} f(x) = f(4)$ 3. (a) $-4, -2, 2, 4$; $f(-4)$ is not defined and $\lim_{x \rightarrow a} f(x)$ does not exist for $a = -2, 2$, and 4(b) -4 , neither; -2 , left; 2, right; 4, right

5. (a) 1 (b) 1, 3 (c) 3

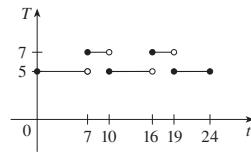
7.

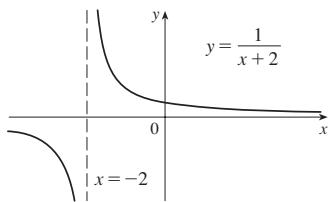
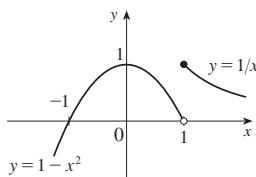
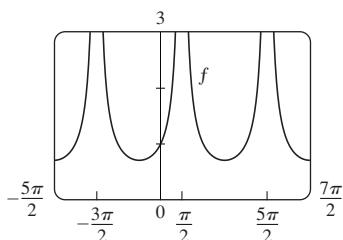


9.

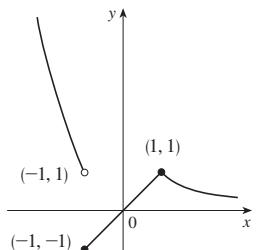


11. (a)

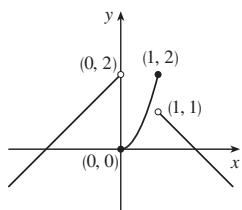


19. $f(-2)$ is undefined.21. $\lim_{x \rightarrow 1} f(x)$ does not exist.25. (b) Define $f(3) = \frac{1}{6}$.29. $(-\infty, -1) \cup (-1, 1) \cup (1, \infty)$ 33. $(-\infty, -1] \cup (0, \infty)$ 39. $x = \frac{\pi}{2} + 2n\pi$, n any integer

43. -1, right

47. $\frac{2}{3}$ 51. (a) $g(x) = x^3 + x^2 + x + 1$ 59. (b) $(0.86, 0.87)$

45. 0, right; 1, left



49. 4

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

61. (b) 1.434

71. None

CHAPTER 1 REVIEW ■ PAGE 95**True-False Quiz**

1. False 3. False 5. True 7. False 9. True
 11. True 13. False 15. True 17. True
 19. False 21. True 23. True 25. True 27. False

Exercises

1. (a) 2.7 (b) 2.3, 5.6 (c) $[-6, 6]$ (d) $[-4, 4]$
 (e) $[-4, 4]$ (f) Odd; its graph is symmetric about the origin.

3. $2a + h - 2$ 5. $(-\infty, \frac{1}{3}) \cup (\frac{1}{3}, \infty)$, $(-\infty, 0) \cup (0, \infty)$ 7. $(-\infty, \infty)$, $[0, 2]$

9. (a) Shift the graph 5 units upward.

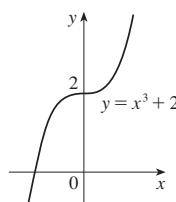
(b) Shift the graph 5 units to the left.

(c) Stretch the graph vertically by a factor of 2, then shift it 1 unit upward.

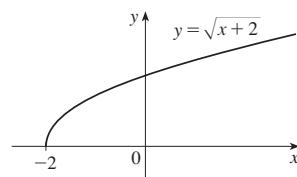
(d) Shift the graph 2 units to the right and 2 units downward.

(e) Reflect the graph about the x -axis.(f) Reflect the graph about the x -axis, then shift 3 units upward.

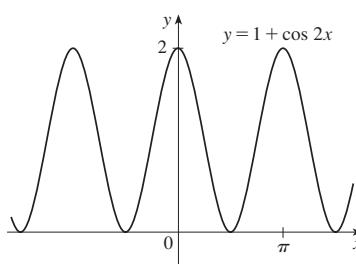
11.



13.



15.



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

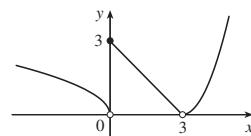
19. (a) $(f \circ g)(x) = \sqrt{\sin x}$,{ $x | x \in [2n\pi, \pi + 2n\pi], n$ an integer}(b) $(g \circ f)(x) = \sin \sqrt{x}$, $[0, \infty)$ (c) $(f \circ f)(x) = \sqrt[4]{x}$, $[0, \infty)$ (d) $(g \circ g)(x) = \sin(\sin x)$, \mathbb{R} 21. $y = 0.2441x - 413.3960$; about 82.1 years

23. (a) (i) 3 (ii) 0 (iii) Does not exist (iv) 2
 (v) ∞ (vi) $-\infty$

(b) $x = 0, x = 2$ (c) $-3, 0, 2, 4$ 25. 1 27. $\frac{3}{2}$ 29. 3 31. ∞ 33. $\frac{5}{7}$ 35. $-\frac{1}{8}$

37. 0 39. 1

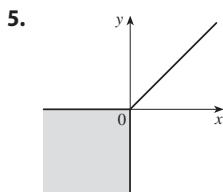
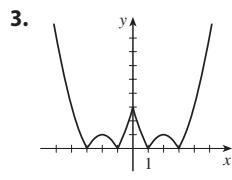
45. (a) (i) 3 (ii) 0 (iii) Does not exist
 (iv) 0 (v) 0 (vi) 0
 (b) At 0 and 3 (c)

47. $[0, \infty)$

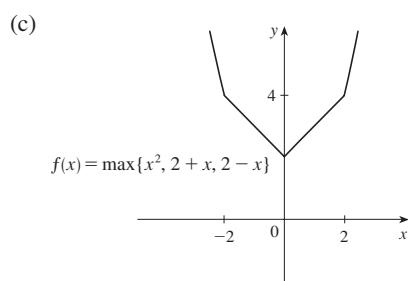
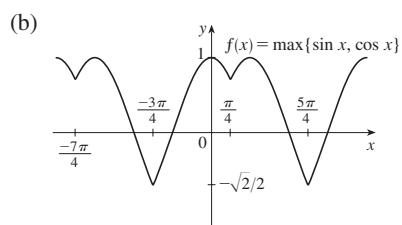
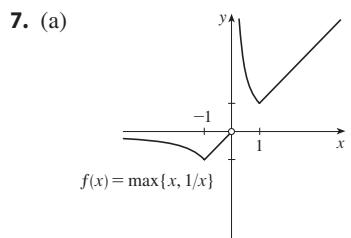
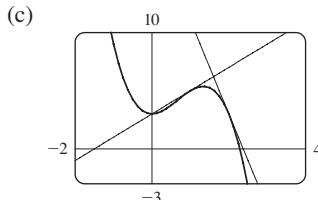
51. 0

PRINCIPLES OF PROBLEM SOLVING ■ PAGE 104

1. $-\frac{2}{3}, \frac{4}{3}$



5. $y = 7x - 17$ 7. $y = -5x + 6$
 9. (a) $8a - 6a^2$ (b) $y = 2x + 3, y = -8x + 19$

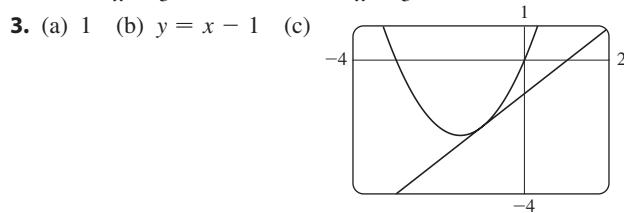


9. 0 11. 40 mi/h 15. $f_n(x) = x^{2^{n+1}}$
 17. $\frac{2}{3}$ 19. -4 21. (a) Does not exist (b) 1
 23. $a = \frac{1}{2} \pm \frac{1}{2}\sqrt{5}$ 25. $\frac{3}{4}$ 27. (b) Yes (c) Yes; no

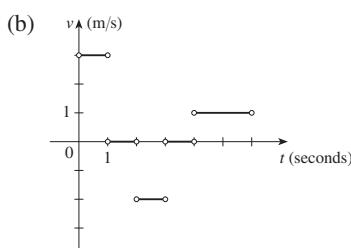
CHAPTER 2

EXERCISES 2.1 ■ PAGE 116

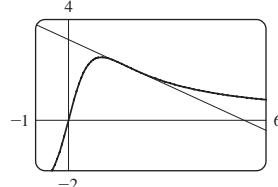
1. (a) $\frac{f(x) - f(3)}{x - 3}$ (b) $\lim_{x \rightarrow 3} \frac{f(x) - f(3)}{x - 3}$



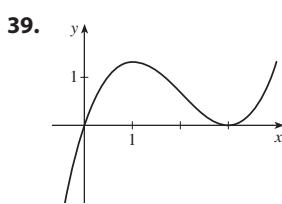
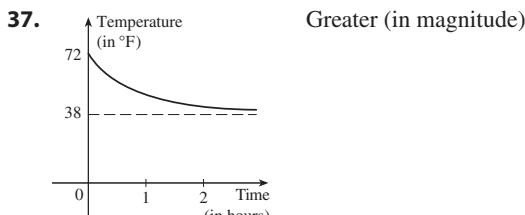
11. (a) 2.5 s (b) 24.5 m/s
 13. $-2/a^3$ m/s; -2 m/s; $-\frac{1}{4}$ m/s; $-\frac{2}{27}$ m/s
 15. (a) Right: $0 < t < 1$ and $4 < t < 6$; left: $2 < t < 3$; standing still: $1 < t < 2$ and $3 < t < 4$



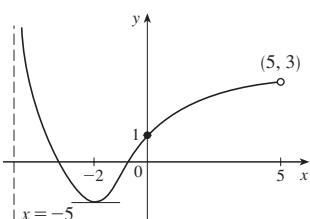
17. $g'(0), 0, g'(4), g'(2), g'(-2)$
 19. $\frac{2}{5}$ 21. $\frac{5}{9}$ 23. $4a - 5$
 25. $-\frac{2a}{(a^2 + 1)^2}$ 27. $y = -\frac{1}{2}x + 3$ 29. $y = 3x - 1$
 31. (a) $-\frac{3}{5}$; $y = -\frac{3}{5}x + \frac{16}{5}$ (b)



33. $f(2) = 3; f'(2) = 4$
 35. 32 m/s; 32 m/s



41.



43. $f(x) = \sqrt{x}$, $a = 9$

45. $f(x) = x^6$, $a = 2$

47. $f(x) = \tan x$, $a = \pi/4$

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

51. (a) The rate at which the cost is changing per ounce of gold produced; dollars per ounce

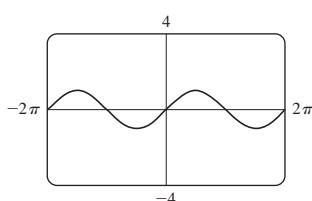
(b) When the 22nd kilogram of gold is produced, the cost of production is \$17/kg

(c) Decrease in the short term; increase in the long term

53. (a) The rate at which the oxygen solubility changes with respect to the water temperature; $(\text{mg/L})/\text{°C}$ (b) $S'(16) \approx -0.25$; as the temperature increases past 16°C , the oxygen solubility is decreasing at a rate of $0.25 (\text{mg/L})/\text{°C}$.55. (a) In $(\text{g/dL})/\text{h}$: (i) -0.015 (ii) -0.012 (iii) -0.012 (iv) -0.011 (b) $-0.012 (\text{g/dL})/\text{h}$; After 2 hours, the BAC is decreasing at a rate of $0.012 (\text{g/dL})/\text{h}$.

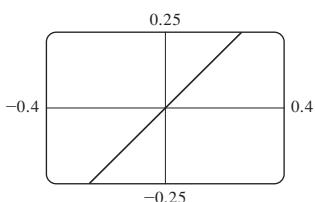
57. Does not exist

59. (a)



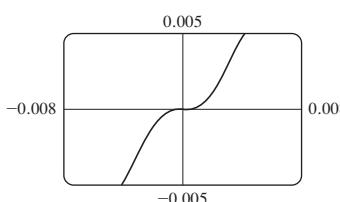
Slope appears to be 1.

(b)



Yes

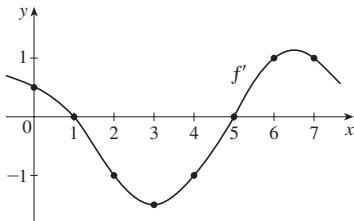
(c)



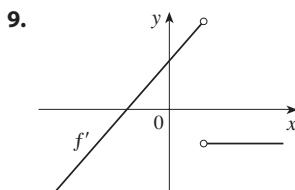
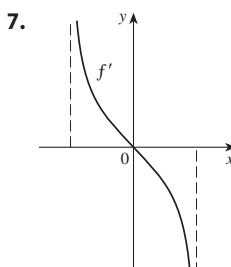
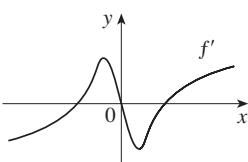
Yes; 0

EXERCISES 2.2 ■ PAGE 128

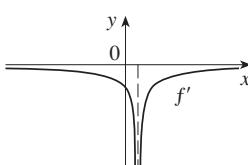
1. (a) 0.5 (b) 0 (c) -1 (d) -1.5
 (e) -1 (f) 0 (g) 1 (h) 1



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

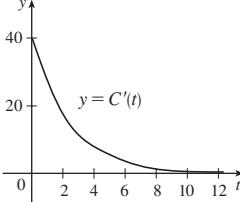


11.

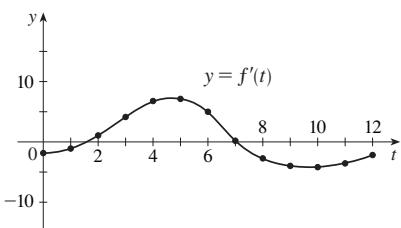


13. (a) The instantaneous rate of change of percentage of full capacity with respect to elapsed time in hours

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



15.

When $t \approx 5.25$

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

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

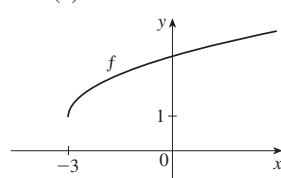
23. $A'(p) = 12p^2 + 3, \mathbb{R}, \mathbb{R}$

25. $f'(x) = -\frac{2x}{(x^2 - 4)^2}, (-\infty, -2) \cup (-2, 2) \cup (2, \infty), (-\infty, -2) \cup (-2, 2) \cup (2, \infty)$

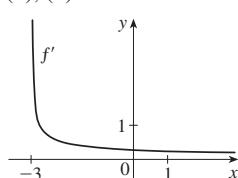
27. $g'(u) = -\frac{5}{(4u - 1)^2}, (-\infty, \frac{1}{4}) \cup (\frac{1}{4}, \infty), (-\infty, \frac{1}{4}) \cup (\frac{1}{4}, \infty)$

29. $f'(x) = -\frac{1}{2(1+x)^{3/2}}, (-1, \infty), (-1, \infty)$

31. (a)



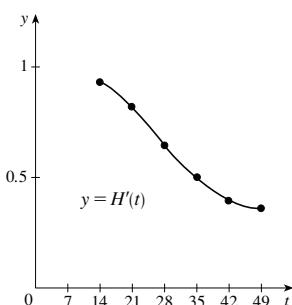
(b), (d)



(c) $f'(x) = \frac{1}{2\sqrt{x+3}}, [-3, \infty), (-3, \infty)$

33. (a) $f'(x) = 4x^3 + 2$

t	14	21	28	35	42	49
$H'(t)$	0.57	0.43	0.33	0.29	0.14	0.5

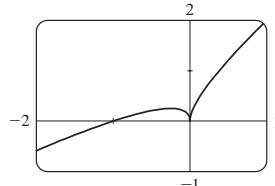


37. (a) The rate at which the percentage of electrical power produced by solar panels is changing, in percentage points per year. (b) On January 1, 2022, the percentage of electrical power produced by solar panels was increasing at a rate of 3.5 percentage points per year.

39. -4 (corner); 0 (discontinuity)

41. 1 (not defined); 5 (vertical tangent)

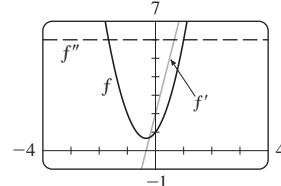
43.

Differentiable at -1;
not differentiable at 0

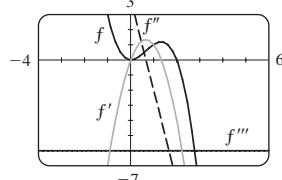
45. $f''(1)$ 47. $a = f, b = f', c = f''$

49. $a = \text{acceleration}, b = \text{velocity}, c = \text{position}$

51. $6x + 2; 6$



53.

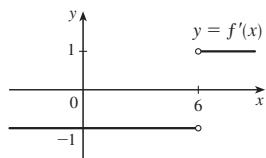


$$\begin{aligned}f'(x) &= 4x - 3x^2, \\f''(x) &= 4 - 6x, \\f'''(x) &= -6, \\f^{(4)}(x) &= 0\end{aligned}$$

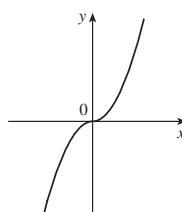
55. (a) $\frac{1}{3}a^{-2/3}$

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

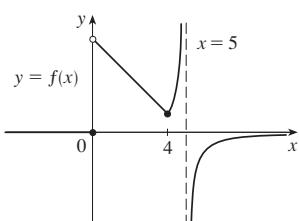
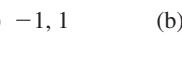
or $f'(x) = \frac{x-6}{|x-6|}$



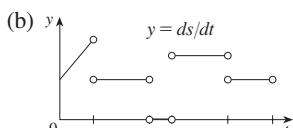
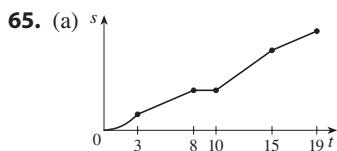
59. (a)

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

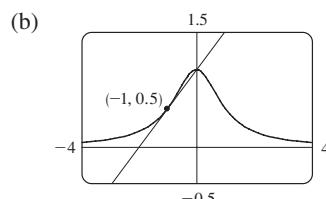
63. (a) -1, 1



(c) 0, 5 (d) 0, 4, 5



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



EXERCISES 2.3 ■ PAGE 143

1. $g'(x) = 4$ 3. $f'(x) = 75x^{74} - 1$ 5. $W'(v) = -5.4v^{-4}$

7. $f'(x) = \frac{3}{2}x^{1/2} - 3x^{-4}$ 9. $s'(t) = -\frac{1}{t^2} - \frac{2}{t^3}$

11. $y' = 2 + 1/(2\sqrt{x})$ 13. $g'(x) = -\frac{1}{2}x^{-3/2} + \frac{1}{4}x^{-3/4}$

15. $f'(x) = 4x^3 + 9x^2$ 17. $f'(x) = 3 + 2x$

19. $G'(q) = -2q^{-2} - 2q^{-3}$ 21. $G'(r) = \frac{3}{2}r^{-1/2} + \frac{3}{2}r^{1/2}$

23. $P'(w) = 3\sqrt{w} - \frac{1}{2}w^{-1/2} - 2w^{-3/2}$

25. $dy/dx = 2tx + t^3$; $dy/dt = x^2 + 3t^2x$

27. $1 - 2x + 6x^2 - 8x^3$ 29. $f'(x) = 12x^3 - 15x^2$

31. $y' = 24x^2 + 40x + 6$

33. $y' = \frac{5}{(1+x)^2}$ 35. $g'(t) = \frac{-17}{(5t+1)^2}$

37. $f'(t) = \frac{-10t^3 - 5}{(t^3 - t - 1)^2}$ 39. $y' = \frac{3 - 2\sqrt{s}}{2s^{5/2}}$

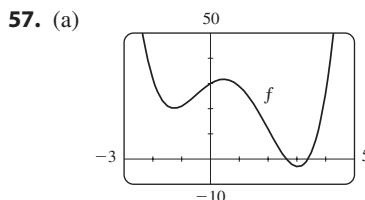
41. $F'(x) = 4x + 1 + \frac{12}{x^3}$ 43. $H'(u) = 2u - 1$

45. $J'(u) = -\left(\frac{1}{u^2} + \frac{2}{u^3} + \frac{3}{u^4}\right)$ 47. $f'(t) = \frac{-2t - 3}{3t^{2/3}(t - 3)^2}$

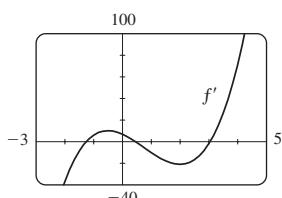
49. $G'(y) = -\frac{3ABy^2}{(Ay^3 + B)^2}$ 51. $f'(x) = \frac{2cx}{(x^2 + c)^2}$

53. $P'(x) = na_nx^{n-1} + (n-1)a_{n-1}x^{n-2} + \dots + 2a_2x + a_1$

55. $45x^{14} - 15x^2$



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



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

61. $y = \frac{3}{2}x + \frac{1}{2}$, $y = -\frac{2}{3}x + \frac{8}{3}$

63. $y = -\frac{1}{3}x + \frac{5}{6}$; $y = 3x - \frac{5}{2}$

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

69. $f'(x) = \frac{2x^2 + 2x}{(1+2x)^2}$; $f''(x) = \frac{2}{(1+2x)^3}$

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

73. (a) $v(t) = 3t^2 - 3$, $a(t) = 6t$ (b) 12 m/s²
(c) $a(1) = 6$ m/s²

75. 4.198; at 12 years, the length of the fish is increasing at a rate of 4.198 cm/year

77. (a) $V = 5.3/P$
(b) -0.00212; instantaneous rate of change of the volume with respect to the pressure at 25°C; m³/kPa

79. (a) -16 (b) $-\frac{20}{9}$ (c) 20 81. 16

83. (a) 3 (b) $-\frac{7}{12}$

85. (a) $y' = xg'(x) + g(x)$ (b) $y' = \frac{g(x) - xg'(x)}{[g(x)]^2}$
(c) $y' = \frac{xg'(x) - g(x)}{x^2}$

87. (-3, 37), (1, 5) 91. $y = 3x - 3$, $y = 3x - 7$

93. $y = -2x + 3$ 95. $(\pm 2, 4)$ 97. $a = -\frac{1}{2}$, $b = 2$

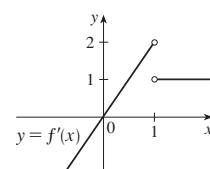
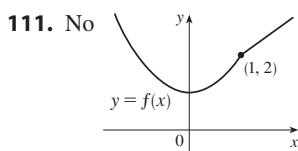
99. $P(x) = x^2 - x + 3$ 101. $y = \frac{3}{16}x^3 - \frac{9}{4}x + 3$

103. \$359.6 million/year

105. $\frac{0.0021}{(0.015 + [S])^2}$;

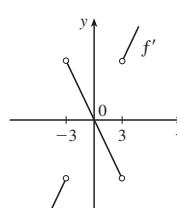
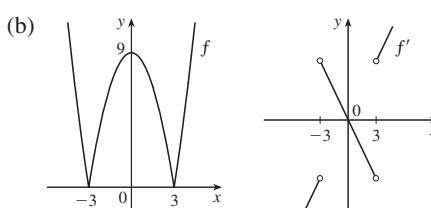
the rate of change of the rate of an enzymatic reaction with respect to the concentration of a substrate S.

107. (c) $3(x^4 + 3x^3 + 17x + 82)^2(4x^3 + 9x^2 + 17)$



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

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



115. $m = 4, b = -4$ **117.** 3; 1 **119.** 1000

EXERCISES 2.4 ■ PAGE 154

1. $f'(x) = 3 \cos x + 2 \sin x$ **3.** $y' = 2x - \csc^2 x$

5. $h'(\theta) = \theta(\theta \cos \theta + 2 \sin \theta)$

7. $y' = \sec \theta (\sec^2 \theta + \tan^2 \theta)$

9. $f'(\theta) = \theta \cos \theta - \cos^2 \theta + \sin \theta + \sin^2 \theta$

11. $H'(t) = -2 \sin t \cos t$ **13.** $f'(\theta) = \frac{1}{1 + \cos \theta}$

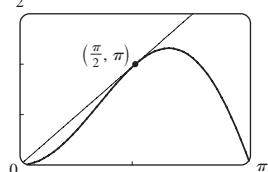
15. $y' = \frac{2 - \tan x + x \sec^2 x}{(2 - \tan x)^2}$

17. $f'(w) = \frac{2 \sec w \tan w}{(1 - \sec w)^2}$ **19.** $y' = \frac{(t^2 + t) \cos t + \sin t}{(1 + t)^2}$

21. $f'(\theta) = \frac{1}{2} \sin 2\theta + \theta \cos 2\theta$

27. $y = x + 1$ **29.** $y = 2x - \pi$

31. (a) $y = 2x$ (b) $\frac{3\pi}{2}$



33. (a) $\sec x \tan x - 1$

35. $\frac{\theta \cos \theta - \sin \theta}{\theta^2}; \frac{-\theta^2 \sin \theta - 2\theta \cos \theta + 2 \sin \theta}{\theta^3}$

37. (a) $f'(x) = (1 + \tan x)/\sec x$ (b) $f'(x) = \cos x + \sin x$

39. $(2n+1)\pi \pm \frac{1}{3}\pi$, n an integer

41. (a) $v(t) = 8 \cos t$, $a(t) = -8 \sin t$

(b) $4\sqrt{3}, -4, -4\sqrt{3}$; to the left

43. 3 m/rad **45.** $\frac{5}{3}$ **47.** 3 **49.** 0 **51.** 2

53. $-\frac{3}{4}$ **55.** $\frac{1}{2}$ **57.** $-\frac{1}{4}$ **59.** $-\sqrt{2}$

61. $-\cos x$ **63.** $A = -\frac{3}{10}$, $B = -\frac{1}{10}$

65. (a) $\sec^2 x = \frac{1}{\cos^2 x}$ (b) $\sec x \tan x = \frac{\sin x}{\cos^2 x}$

(c) $\cos x - \sin x = \frac{\cot x - 1}{\csc x}$ **67.** 1

EXERCISES 2.5 ■ PAGE 162

1. $dy/dx = -12x^3(5 - x^4)^2$ **3.** $dy/dx = -\sin x \cos(\cos x)$

5. $dy/dx = \frac{\cos x}{2\sqrt{\sin x}}$

7. $f'(x) = 10x(2x^3 - 5x^2 + 4)^4(3x - 5)$

9. $f'(x) = \frac{5}{2\sqrt{5x+1}}$ **11.** $g'(t) = \frac{-4}{(2t+1)^3}$

13. $A'(t) = \frac{2(\sin t - \sec^2 t)}{(\cos t + \tan t)^3}$ **15.** $f'(\theta) = -2\theta \sin(\theta^2)$

17. $h'(v) = \frac{5v^2 + 3}{3(\sqrt[3]{1 + v^2})^2}$

19. $F'(x) = 4(4x + 5)^2(x^2 - 2x + 5)^3(11x^2 - 4x + 5)$

21. $h'(t) = \frac{2}{3}(t+1)^{-1/3}(2t^2 - 1)^2(20t^2 + 18t - 1)$

23. $y' = \frac{1}{2\sqrt{x}(x+1)^{3/2}}$ **25.** $g'(u) = \frac{48u^2(u^3 - 1)^7}{(u^3 + 1)^9}$

27. $H'(r) = \frac{2(r^2 - 1)^2(r^2 + 3r + 5)}{(2r + 1)^6}$

29. $y' = -4 \sin(\sec 4x) \sec 4x \tan 4x$

31. $y' = -\frac{1}{2}\sqrt{1 + \sin x}$

33. $y' = \frac{16 \sin 2x(1 - \cos 2x)^3}{(1 + \cos 2x)^5}$

35. $f'(x) = 2x \sin x \sin(1 - x^2) + \cos x \cos(1 - x^2)$

37. $F'(t) = \frac{t \sec^2 \sqrt{1+t^2}}{\sqrt{1+t^2}}$

39. $y' = 4x \sin(x^2 + 1) \cos(x^2 + 1)$

41. $y' = -12 \cos^3(\sin^3 x) \sin(\sin^3 x) \sin^2 x \cos x$

43. $f'(t) = -\sec^2(\sec(\cos t)) \sec(\cos t) \tan(\cos t) \sin t$

45. $g'(x) = p(2r \sin rx + n)^{p-1}(2r^2 \cos rx)$

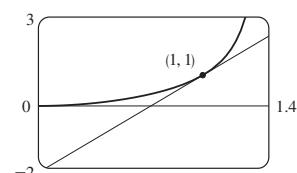
47. $y' = -\frac{\pi \cos(\tan \pi x) \sec^2(\pi x) \sin \sqrt{\sin(\tan \pi x)}}{2\sqrt{\sin(\tan \pi x)}}$

49. $y' = -3 \cos 3\theta \sin(\sin 3\theta);$
 $y'' = -9 \cos^2(3\theta) \cos(\sin 3\theta) + 9(\sin 3\theta) \sin(\sin 3\theta)$

51. $y' = \frac{-\sin x}{2\sqrt{\cos x}}$; $y'' = -\frac{1 + \cos^2 x}{4(\cos x)^{3/2}}$

53. $y = 18x + 1$ **55.** $y = -x + \pi$

57. (a) $y = \pi x - \pi + 1$ (b)



59. (a) $f'(x) = \frac{2 - 2x^2}{\sqrt{2 - x^2}}$

61. $((\pi/2) + 2n\pi, 3), ((3\pi/2) + 2n\pi, -1)$, n an integer

63. 24 **65.** (a) 30 (b) 36

67. (a) $\frac{1}{4}$ (b) -2 (c) $-\frac{1}{2}$ **69.** $-\frac{1}{6}\sqrt{2}$

71. 120 **73.** 96 **75.** $2^{103} \sin 2x$

77. $v(t) = \frac{5}{2}\pi \cos(10\pi t)$ cm/s

79. (a) $\frac{dB}{dt} = \frac{7\pi}{54} \cos \frac{2\pi t}{5.4}$ (b) 0.16

81. dv/dt is the rate of change of velocity with respect to time;
 dv/ds is the rate of change of velocity with respect to displacement

EXERCISES 2.6 ■ PAGE 169

1. (a) $y' = \frac{10x}{3y^2}$ (b) $y = \sqrt[3]{5x^2 - 7}, y' = \frac{10x}{3(5x^2 - 7)^{2/3}}$

3. (a) $y' = -\sqrt{y}/\sqrt{x}$ (b) $y = (1 - \sqrt{x})^2, y' = 1 - 1/\sqrt{x}$

5. $y' = \frac{2y - x}{y - 2x}$ 7. $y' = -\frac{2x(2x^2 + y^2)}{y(2x^2 + 3y)}$

9. $y' = \frac{x(x + 2y)}{2x^2y + 4xy^2 + 2y^3 + x^2}$ 11. $y' = \frac{2 - \cos x}{3 - \sin y}$

13. $y' = -\frac{\cos(x + y) + \sin x}{\cos(x + y) + \sin y}$ 15. $y' = \frac{y \sec^2(x/y) - y^2}{y^2 + x \sec^2(x/y)}$

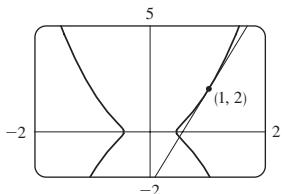
17. $y' = \frac{1 - 8x^3\sqrt{x+y}}{8y^3\sqrt{x+y} - 1}$ 19. $y' = \frac{4xy\sqrt{xy} - y}{x - 2x^2\sqrt{xy}}$

21. $-\frac{16}{13}$ 23. $x' = \frac{-2x^4y + x^3 - 6xy^2}{4x^3y^2 - 3x^2y + 2y^3}$ 25. $y = \frac{1}{2}x$

27. $y = \frac{1}{\sqrt{3}}x + 4$ 29. $y = \frac{3}{4}x - \frac{1}{2}$ 31. $y = x + \frac{1}{2}$

33. $y = -\frac{9}{13}x + \frac{40}{13}$

35. (a) $y = \frac{9}{2}x - \frac{5}{2}$ (b)

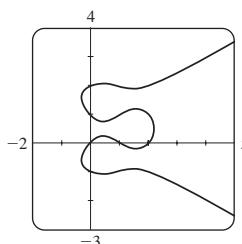


37. $-1/(4y^3)$

39. $\frac{\cos^2 y \cos x + \sin^2 x \sin y}{\cos^3 y}$

41. 0

43. (a)

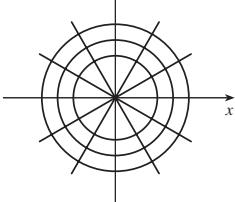


Eight; $x \approx 0.42, 1.58$

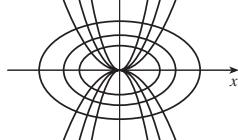
(b) $y = -x + 1; y = \frac{1}{3}x + 2$ (c) $1 \pm \frac{1}{3}\sqrt{3}$

45. $(\pm\frac{5}{4}\sqrt{3}, \pm\frac{5}{4})$ 47. $(x_0x/a^2) - (y_0y/b^2) = 1$

51.



53.



57. (a) $\frac{V^3(nb - V)}{PV^3 - n^2aV + 2n^3ab}$ (b) $\approx -4.04 \text{ L/atm}$

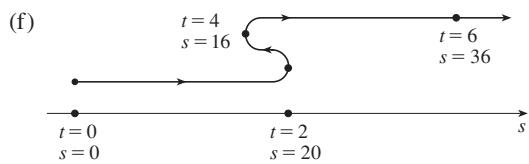
59. $(\pm\sqrt{3}, 0)$ 61. $(-1, -1), (1, 1)$

63. $y' = \frac{y}{x + 2y^3}; y' = \frac{1}{3y^2 + 1}$

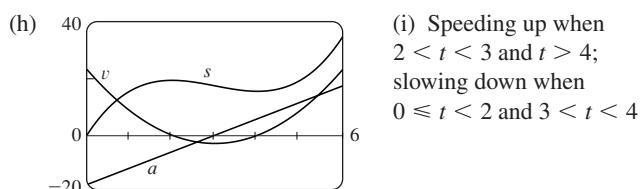
65. 2 units

EXERCISES 2.7 ■ PAGE 181

1. (a) $3t^2 - 18t + 24$ (b) 9 m/s (c) $t = 2, 4$
(d) $0 \leq t < 2, t > 4$ (e) 44 m



(g) $6t - 18; -12 \text{ m/s}^2$



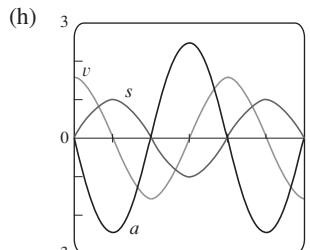
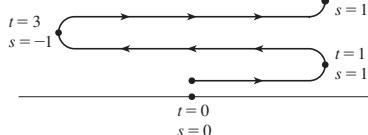
3. (a) $(\pi/2) \cos(\pi t/2)$ (b) 0 m/s

(c) $t = 2n + 1, n$ a nonnegative integer

(d) $0 < t < 1, 3 < t < 5, 7 < t < 9$, and so on (e) 6 m

(f)

(g) $(-\pi^2/4) \sin(\pi t/2); -\pi^2/4 \text{ m/s}^2$



(i) Speeding up when $1 < t < 2, 3 < t < 4$, and $5 < t < 6$; slowing down when $0 < t < 1, 2 < t < 3$, and $4 < t < 5$

5. (a) Speeding up when $0 < t < 1$ and $2 < t < 3$; slowing down when $1 < t < 2$

(b) Speeding up when $1 < t < 2$ and $3 < t < 4$; slowing down when $0 < t < 1$ and $2 < t < 3$

7. Traveling forward when $0 < t < 5$; traveling backward when $7 < t < 8$; not moving

- 9.** (a) 4.9 m/s; -14.7 m/s (b) After 2.5 s (c) $32\frac{5}{8} \text{ m}$
 (d) $\approx 5.08 \text{ s}$ (e) $\approx -25.3 \text{ m/s}$

- 11.** (a) 7.56 m/s (b) $\approx 6.24 \text{ m/s}; \approx -6.24 \text{ m/s}$

- 13.** (a) $30 \text{ mm}^2/\text{mm}$; the rate at which the area is increasing with respect to side length as x reaches 15 mm
 (b) $\Delta A \approx 2x \Delta x$

- 15.** (a) (i) 5π (ii) 4.5π (iii) 4.1π
 (b) 4π (c) $\Delta A \approx 2\pi r \Delta r$

- 17.** (a) $160\pi \text{ cm}^2/\text{cm}$ (b) $320\pi \text{ cm}^2/\text{cm}$ (c) $480\pi \text{ cm}^2/\text{cm}$
 The rate increases as the radius increases.

- 19.** (a) 6 kg/m (b) 12 kg/m (c) 18 kg/m

At the right end; at the left end

- 21.** (a) 4.75 A (b) $5 \text{ A}; t = \frac{2}{3} \text{ s}$

- 25.** (a) $dV/dP = -C/P^2$ (b) At the beginning

- 27.** (a) 16 million/year; 78.5 million/year
 (b) $P(t) = at^3 + bt^2 + ct + d$, where $a \approx -0.0002849$,
 $b \approx 0.5224331$, $c \approx -6.395641$, $d \approx 1720.586$
 (c) $P'(t) = 3at^2 + 2bt + c$
 (d) 14.16 million/year (smaller); 71.72 million/year (smaller)
 (e) $P'(85) \approx 76.24 \text{ million/year}$

- 29.** (a) $0.926 \text{ cm/s}; 0.694 \text{ cm/s}; 0$

- (b) 0 ; -92.6 (cm/s)/cm ; -185.2 (cm/s)/cm

- (c) At the center; at the edge

- 31.** (a) $C'(x) = 3 + 0.02x + 0.0006x^2$

- (b) \$11/pair; the rate at which the cost is changing as the 100th pair of jeans is being produced; the cost of the 101st pair
 (c) \$11.07

- 33.** (a) $[xp'(x) - p(x)]/x^2$; the average productivity increases as new workers are added.

- 35.** $\approx -0.2436 \text{ K/min}$

- 37.** (a) 0 and 0 (b) $C = 0$

- (c) $(0, 0)$, $(500, 50)$; it is possible for the species to coexist.

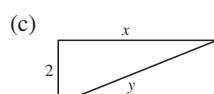
EXERCISES 2.8 ■ PAGE 189

- 1.** (a) $dV/dt = 3x^2 dx/dt$ (b) $2700 \text{ cm}^3/\text{s}$ (c) $48 \text{ cm}^2/\text{s}$

- 5.** $128\pi \text{ cm}^2/\text{min}$ (d) $3/(25\pi) \text{ m/min}$

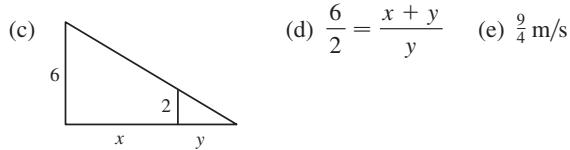
- 9.** (a) $-\frac{3}{8}$ (b) $\frac{8}{3}$ (c) **11.** -3.41 N/s

- 13.** (a) The plane's altitude is 2 km and its speed is 800 km/h.
 (b) The rate at which the distance from the plane to the station is increasing when the plane is 3 km from the station



- (d) $y^2 = x^2 + 4$
 (e) $800/3\sqrt{5} \text{ km/h}$

- 15.** (a) The height of the pole (6 m), the height of the man (2 m), and the speed of the man (1.5 m/s)
 (b) The rate at which the tip of the man's shadow is moving when he is 10 m from the pole



(d) $\frac{6}{2} = \frac{x+y}{y}$ (e) $\frac{9}{4} \text{ m/s}$

17. 78 km/h (f) $8064/\sqrt{8,334,400} \approx 2.79 \text{ m/s}$

21. -1.6 cm/min (g) 9.8 m/s

25. $(10,000 + 800,000\pi/9) \approx 2.89 \times 10^5 \text{ cm}^3/\text{min}$

27. $\frac{10}{3} \text{ cm/min}$ (h) $4/(3\pi) \approx 0.42 \text{ m/min}$

31. $150\sqrt{3} \text{ cm}^2/\text{min}$ (i) $\approx 20.3 \text{ m/s}$ (j) $-\frac{1}{2} \text{ rad/s}$

37. $80 \text{ cm}^3/\text{min}$ (k) $\frac{107}{810} \approx 0.132 \Omega/\text{s}$ (l) $\approx 87.2 \text{ km/h}$

43. $\sqrt{7}\pi/21 \approx 0.396 \text{ m/min}$

45. (a) 120 ms/s (b) $\approx 0.107 \text{ rad/s}$

47. $\frac{10}{9}\pi \text{ km/min}$ (m) $1650/\sqrt{31} \approx 296 \text{ km/h}$

51. $\frac{7}{4}\sqrt{15} \approx 6.78 \text{ m/s}$

EXERCISES 2.9 ■ PAGE 196

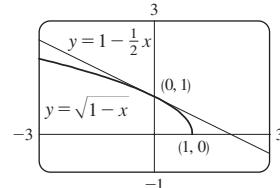
1. $L(x) = 16x + 23$

3. $L(x) = \frac{1}{12}x + \frac{4}{3}$

5. $\sqrt{1-x} \approx 1 - \frac{1}{2}x$

$\sqrt{0.9} \approx 0.95$,

$\sqrt{0.99} \approx 0.995$



7. $-0.368 < x < 0.677$

9. $-0.045 < x < 0.055$ (n) $dy = -\frac{4x}{(x^2 - 3)^3} dx$

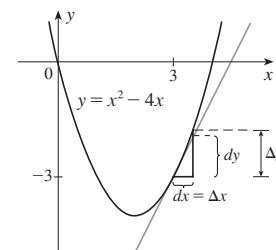
13. $dy = \frac{-1}{(1+3u)^2} du$

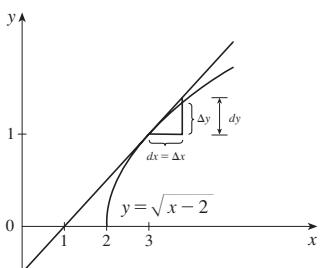
15. $dy = \frac{3-2x}{(x^2-3x)^2} dx$ (o) $dy = \frac{1+\sin t}{2\sqrt{t-\cos t}} dt$

19. (a) $dy = \sec^2 x dx$ (b) -0.2

21. (a) $dy = \frac{x}{\sqrt{3+x^2}} dx$ (b) -0.05

23. $\Delta y = 1.25$, $dy = 1$



25. $\Delta y \approx 0.34, dy = 0.4$ 27. $\Delta y \approx 0.1655, dy = 0.15; \Delta y \approx 0.0306, dy = 0.03$; yes29. $\Delta y \approx -0.012539, dy = -0.0125;$ $\Delta y \approx -0.002502, dy = -0.0025$; yes31. 15.968 33. 10.003 35. $\pi/90 \approx 0.0349$ 39. (a) $270 \text{ cm}^3, 0.01, 1\%$ (b) $36 \text{ cm}^2, 0.006, 0.6\%$ 41. (a) $84/\pi \approx 27 \text{ cm}^2; \frac{1}{84} \approx 0.012 = 1.2\%$ (b) $1764/\pi^2 \approx 179 \text{ cm}^3; \frac{1}{56} \approx 0.018 = 1.8\%$ 43. (a) $2\pi rh \Delta r$ (b) $\pi(\Delta r)^2 h$

49. (a) 4.8, 5.2 (b) Too large

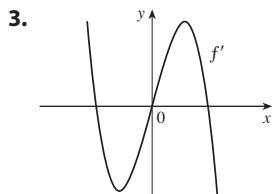
CHAPTER 2 REVIEW ■ PAGE 200

True-False Quiz

1. False 3. False 5. True 7. False 9. True
 11. False 13. True 15. False

Exercises

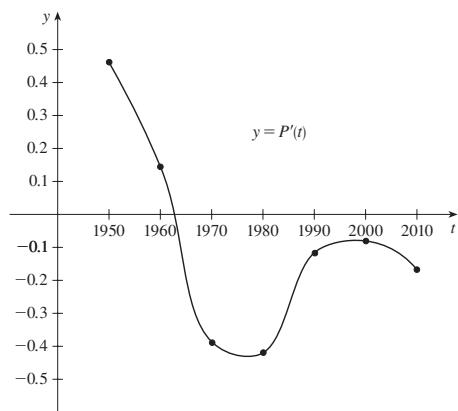
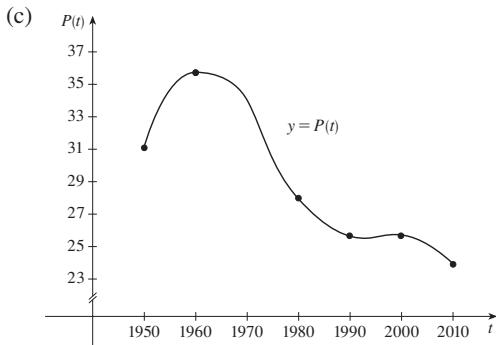
1. (a) (i) 3 m/s (ii) 2.75 m/s (iii) 2.625 m/s
 (iv) 2.525 m/s (b) 2.5 m/s



5. The graphs of f , f' , and f'' are a , c , and b , respectively.
 7. (a) The rate at which the cost changes with respect to the interest rate; dollars/(percent per year)
 (b) As the interest rate increases past 10%, the cost is increasing at a rate of \$1200/(percent per year).
 (c) Always positive
 9. (a) $P'(t)$ is the rate at which the percentage of Americans under the age of 18 is changing with respect to time. Its units are percent per year (%/year).

(b)

t	$P'(t)$
1950	0.460
1960	0.145
1970	-0.385
1980	-0.415
1990	-0.115
2000	-0.085
2010	-0.170



(d) By obtaining data for the mid-decade years

11. $f'(x) = 3x^2 + 5$

13. $4x^7(x+1)^3(3x+2)$

15. $\frac{3}{2}\sqrt{x} - \frac{1}{2\sqrt{x}} - \frac{1}{\sqrt{x^3}}$

17. $x(\pi x \cos \pi x + 2 \sin \pi x)$

19. $\frac{8t^3}{(t^4 + 1)^2}$ 21. $-\frac{\sec^2 \sqrt{1-x}}{2\sqrt{1-x}}$

23. $\frac{1-y^4-2xy}{4xy^3+x^2-3}$ 25. $\frac{2 \sec 2\theta (\tan 2\theta - 1)}{(1+\tan 2\theta)^2}$

27. $-(x-1)^{-2}$ 29. $\frac{2x-y \cos(xy)}{x \cos(xy)+1}$

31. $-6x \csc^2(3x^2+5)$ 33. $\frac{\cos \sqrt{x} - \sqrt{x} \sin \sqrt{x}}{2\sqrt{x}}$

35. $2 \cos \theta \tan(\sin \theta) \sec^2(\sin \theta)$

37. $\frac{1}{5}(x \tan x)^{-4/5}(\tan x + x \sec^2 x)$

39. $\cos(\tan \sqrt{1+x^3})(\sec^2 \sqrt{1+x^3}) \frac{3x^2}{2\sqrt{1+x^3}}$

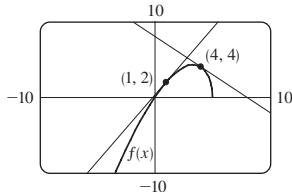
41. $-\frac{4}{27}$ 43. $-5x^4/y^{11}$ 45. 1

47. $y = 2\sqrt{3}x + 1 - \pi\sqrt{3}/3$

49. $y = 2x + 1, y = -\frac{1}{2}x + 1$

51. (a) $\frac{10 - 3x}{2\sqrt{5-x}}$ (b) $y = \frac{7}{4}x + \frac{1}{4}$, $y = -x + 8$

(c)



53. $(\pi/4, \sqrt{2}), (5\pi/4, -\sqrt{2})$ 55. $y = -\frac{2}{3}x^2 + \frac{14}{3}x$

59. (a) 4 (b) 6 (c) $\frac{7}{9}$ (d) 12

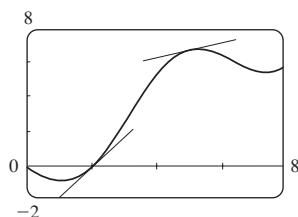
61. $x^2g'(x) + 2xg(x)$

63. $2g(x)g'(x)$ 65. $g'(g(x))g'(x)$

67. $g'(\sin x) \cdot \cos x$

69. $\frac{f'(x)[g(x)]^2 + g'(x)[f(x)]^2}{[f(x) + g(x)]^2}$

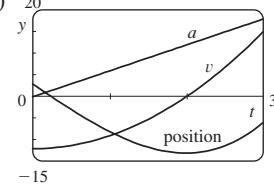
(a)



(b) $[2, 3]$ (c) $x = 2$

73. (a) $v(t) = 3t^2 - 12$; $a(t) = 6t$ (b) $t > 2$; $0 \leq t < 2$

(c) 23 (d) 20



(e) $t > 2$; $0 < t < 2$

75. 4 kg/m 77. $\frac{4}{3}$ cm²/min

79. $117/\sqrt{666} \approx 4.53$ m/s 81. 400 m/h

83. (a) $L(x) = 1 + x$; $\sqrt[3]{1+3x} \approx 1 + x$; $\sqrt[3]{1.03} \approx 1.01$

(b) $-0.235 < x < 0.401$

85. $12 + \frac{3}{2}\pi \approx 16.7$ cm²

87. $\left[\frac{d}{dx} \sqrt[4]{x} \right]_{x=16} = \frac{1}{32}$

89. $\frac{1}{4}$ 91. $\frac{1}{8}x^2$

PROBLEMS PLUS ■ PAGE 204

1. $(\pm\sqrt{3}/2, \frac{1}{4})$ 5. $3\sqrt{2}$ 9. $(0, \frac{5}{4})$

11. 3 lines; $(0, 2)$, $(\frac{4}{3}\sqrt{2}, \frac{2}{3})$ and $(\frac{2}{3}\sqrt{2}, \frac{10}{3})$, $(-\frac{4}{3}\sqrt{2}, \frac{2}{3})$ and $(-\frac{2}{3}\sqrt{2}, \frac{10}{3})$

13. (a) $4\pi\sqrt{3}/\sqrt{11}$ rad/s (b) $40(\cos\theta + \sqrt{8 + \cos^2\theta})$ cm

(c) $-480\pi \sin\theta(1 + (\cos\theta)/\sqrt{8 + \cos^2\theta})$ cm/s

15. $x_T \in (3, \infty)$, $y_T \in (2, \infty)$, $x_N \in (0, \frac{5}{3})$, $y_N \in (-\frac{5}{2}, 0)$

17. (b) (i) 53° (or 127°) (ii) 63° (or 117°)

19. R approaches the midpoint of the radius AO .

21. $-\sin a$ 23. $(1, -2)$, $(-1, 0)$

25. $\sqrt{29}/58$ 27. $2 + \frac{375}{128}\pi \approx 11.204$ cm³/min

CHAPTER 3

EXERCISES 3.1 ■ PAGE 216

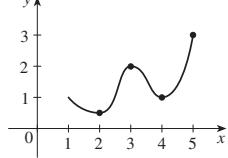
Abbreviations: abs, absolute; loc, local; max, maximum; min, minimum

1. Abs min: smallest function value on the entire domain of the function; loc min at c : smallest function value when x is near c

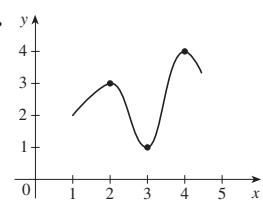
3. Abs max at s , abs min at r , loc max at c , loc min at b and r , neither a max nor a min at a and d

5. Abs max $f(4) = 5$, loc max $f(4) = 5$ and $f(6) = 4$, loc min $f(2) = 2$ and $f(1) = f(5) = 3$

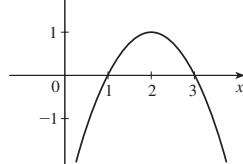
7.



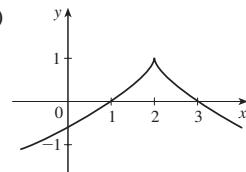
9.



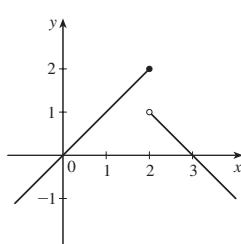
11. (a)



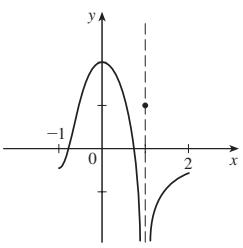
(b)



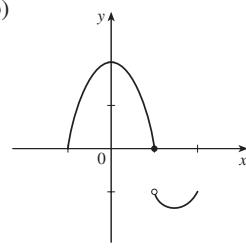
(c)



13. (a)



(b)



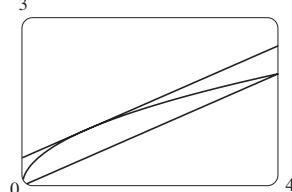
15. Abs max $f(-1) = 5$

17. Abs max $f(1) = 1$

- 19.** Abs min $f(0) = 0$
21. Abs max $f(\pi/2) = 1$; abs min $f(-\pi/2) = -1$
23. Abs min $f(-1) = 1$; loc min $f(-1) = 1$
25. Abs max $f(0) = 1$
27. Abs min $f(1) = -1$; loc min $f(0) = 0$ **29.** $-\frac{1}{6}$
31. $-4, 0, 2$ **33.** None **35.** $0, 2$ **37.** $-1, 2$
39. $0, \frac{4}{9}$ **41.** $0, \frac{8}{7}, 4$ **43.** $0, \frac{4}{3}, 4$
45. $n\pi$ (n an integer) **47.** 10
49. $f(2) = 16, f(5) = 7$ **51.** $f(-1) = 8, f(2) = -19$
53. $f(-2) = 33, f(2) = -31$ **55.** $f(0.2) = 5.2, f(1) = 2$
57. $f(4) = 4 - \sqrt[3]{4}, f(\sqrt{3}/9) = -2\sqrt{3}/9$
59. $f(\pi/6) = \frac{3}{2}\sqrt{3}, f(\pi/2) = 0$
61. $f\left(\frac{a}{a+b}\right) = \frac{a^ab^b}{(a+b)^{a+b}}$
63. (a) 2.19, 1.81 (b) $\frac{6}{25}\sqrt{\frac{3}{5}} + 2, -\frac{6}{25}\sqrt{\frac{3}{5}} + 2$
65. (a) 0.32, 0.00 (b) $\frac{3}{16}\sqrt{3}, 0$ **67.** $\approx 3.9665^\circ\text{C}$
69. About 4.1 months after Jan. 1
71. (a) $r = \frac{2}{3}r_0$ (b) $v = \frac{4}{27}kr_0^3$
(c)
-

EXERCISES 3.2 ■ PAGE 225

- 1.** 1, 5
3. (a) g is continuous on $[0, 8]$ and differentiable on $(0, 8)$.
(b) 2.2, 6.4 (c) 3.7, 5.5
5. No **7.** Yes; ≈ 3.8
9. 1 **11.** π
13. f is not differentiable on $(-1, 1)$ **15.** 1
17. $\sqrt{3}/9$ **19.** 1; yes 3

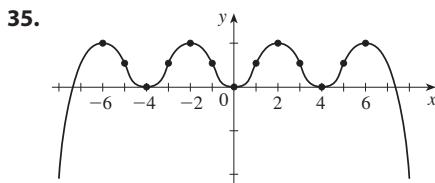
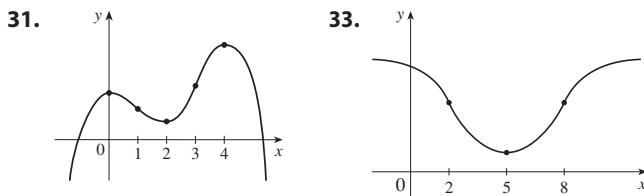
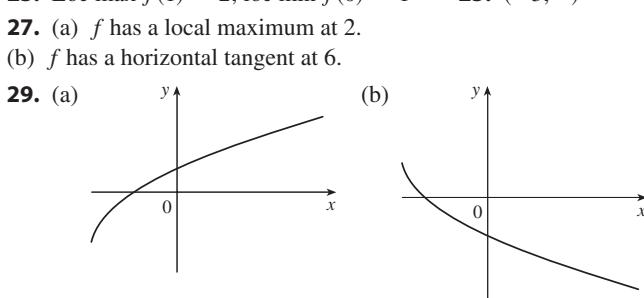


- 21.** f is not continuous at 3 **29.** 16 **31.** No **37.** No

EXERCISES 3.3 ■ PAGE 234

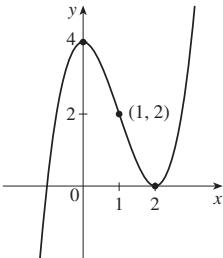
- Abbreviations:* CD, concave downward; CU, concave upward;
dec, decreasing; inc, increasing; HA, horizontal asymptote;
IP, inflection point; VA, vertical asymptote
- 1.** (a) $(1, 3), (4, 6)$ (b) $(0, 1), (3, 4)$ (c) $(0, 2)$
(d) $(2, 4), (4, 6)$ (e) $(2, 3)$
3. (a) I/D Test (b) Concavity Test
(c) Find points at which the concavity changes.

- 5.** (a) Inc on $(0, 1), (3, 5)$; dec on $(1, 3), (5, 6)$
(b) Loc max at $x = 1, x = 5$; loc min at $x = 3$
7. (a) 3, 5 (b) 2, 4, 6 (c) 1, 7
9. Inc on $(-\infty, 1), (4, \infty)$; dec on $(1, 4)$; loc max $f(1) = 6$;
loc min $f(4) = -21$
11. Inc on $(2, \infty)$; dec on $(-\infty, 2)$; loc min $f(2) = -31$
13. Inc on $(-\infty, 4), (6, \infty)$; dec on $(4, 5), (5, 6)$;
loc max $f(4) = 8$; loc min $f(6) = 12$
15. CU on $(1, \infty)$; CD on $(-\infty, 1)$; IP $(1, -7)$
17. CU on $(0, \pi/4), (3\pi/4, \pi)$; CD on $(\pi/4, 3\pi/4)$;
IP $(\pi/4, \frac{1}{2}), (3\pi/4, \frac{1}{2})$
19. (a) Inc on $(-1, 0), (1, \infty)$; dec on $(-\infty, -1), (0, 1)$
(b) Loc max $f(0) = 3$; loc min $f(\pm 1) = 2$
(c) CU on $(-\infty, -\sqrt{3}/3), (\sqrt{3}/3, \infty)$;
CD on $(-\sqrt{3}/3, \sqrt{3}/3)$; IP $(\pm\sqrt{3}/3, \frac{22}{9})$
21. (a) Inc on $(0, \pi/4), (5\pi/4, 2\pi)$; dec on $(\pi/4, 5\pi/4)$
(b) Loc max $f(\pi/4) = \sqrt{2}$; loc min $f(5\pi/4) = -\sqrt{2}$
(c) CU on $(3\pi/4, 7\pi/4)$; CD on $(0, 3\pi/4), (7\pi/4, 2\pi)$;
IP $(3\pi/4, 0), (7\pi/4, 0)$
23. Loc max $f(1) = 2$; loc min $f(0) = 1$ **25.** $(-3, \infty)$
27. (a) f has a local maximum at 2.
(b) f has a horizontal tangent at 6.



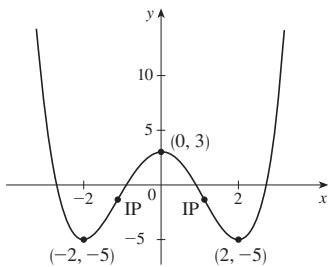
- 37.** (a) Inc on $(0, 2), (4, 6), (8, \infty)$;
dec on $(2, 4), (6, 8)$
(b) Loc max at $x = 2, 6$;
loc min at $x = 4, 8$
(c) CU on $(3, 6), (6, \infty)$;
CD on $(0, 3)$ (d) 3
(e) See graph at right.
-

- 39.** (a) Inc on $(-\infty, 0), (2, \infty)$; dec on $(0, 2)$
 (b) Loc max $f(0) = 4$; loc min $f(2) = 0$
 (c) CU on $(1, \infty)$; CD on $(-\infty, 1)$; IP $(1, 2)$
 (d) See graph at right.

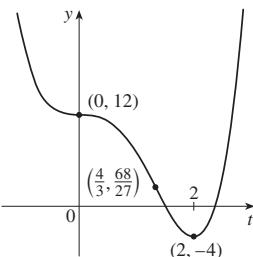


- 41.** (a) Inc on $(-2, 0), (2, \infty)$; dec on $(-\infty, -2), (0, 2)$
 (b) Loc max $f(0) = 3$; loc min $f(\pm 2) = -5$
 (c) CU on $\left(-\infty, -\frac{2}{\sqrt{3}}\right), \left(\frac{2}{\sqrt{3}}, \infty\right)$; CD on $\left(-\frac{2}{\sqrt{3}}, \frac{2}{\sqrt{3}}\right)$; IPs $\left(\pm\frac{2}{\sqrt{3}}, -\frac{13}{9}\right)$

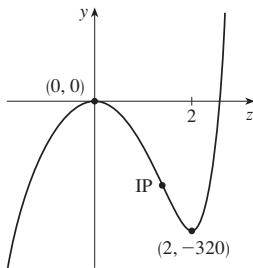
(d)



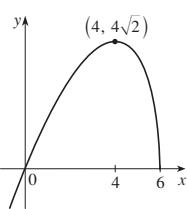
- 43.** (a) Inc on $(2, \infty)$; dec on $(-\infty, 2)$
 (b) Loc min $g(2) = -4$
 (c) CU on $(-\infty, 0), \left(\frac{4}{3}, \infty\right)$; CD on $(0, \frac{4}{3})$; IPs $(0, 12), \left(\frac{4}{3}, \frac{68}{27}\right)$
 (d) See graph at right.



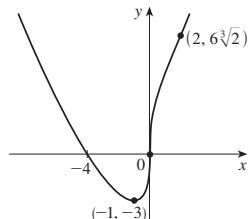
- 45.** (a) Inc on $(-\infty, 0), (2, \infty)$; dec on $(0, 2)$
 (b) Loc max $f(0) = 0$; loc min $f(2) = -320$
 (c) CU on $\left(\sqrt{\frac{16}{3}}, \infty\right)$; CD on $(-\infty, \sqrt{\frac{16}{3}})$; IP $\left(\sqrt{\frac{16}{3}}, -\frac{320}{3}\right) \approx (1.398, -208.4)$
 (d) See graph at right.



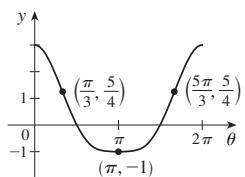
- 47.** (a) Inc on $(-\infty, 4)$; dec on $(4, 6)$
 (b) Loc max $F(4) = 4\sqrt{2}$
 (c) CD on $(-\infty, 6)$; No IP
 (d) See graph at right.



- 49.** (a) Inc on $(-1, \infty)$; dec on $(-\infty, -1)$
 (b) Loc min $C(-1) = -3$
 (c) CU on $(-\infty, 0), (2, \infty)$; CD on $(0, 2)$; IPs $(0, 0), (2, 6\sqrt[3]{2})$
 (d) See graph at right.



- 51.** (a) Inc on $(\pi, 2\pi)$; dec on $(0, \pi)$
 (b) Loc min $f(\pi) = -1$
 (c) CU on $(\pi/3, 5\pi/3)$; CD on $(0, \pi/3), (5\pi/3, 2\pi)$; IPs $(\pi/3, \frac{5}{4}), (5\pi/3, \frac{5}{4})$
 (d) See graph at right.



- 53.** f is CU on $(-\infty, \infty)$ for all $c > 0$. As c increases, the minimum point gets farther away from the origin.

55. (a) Loc and abs max $f(1) = \sqrt{2}$, no min (b) $\frac{1}{4}(3 - \sqrt{17})$

- 57.** (b) CD on $(0, 0.85), (1.57, 2.29)$; CU on $(0.85, 1.57), (2.29, \pi)$; IPs $(0.85, 0.74), (1.57, 0), (2.29, -0.74)$

- 59.** CU on $(-\infty, -0.6), (0.0, \infty)$; CD on $(-0.6, 0.0)$

- 61.** (a) The rate of increase is initially very small, increases to a maximum at $t \approx 8$ h, then decreases toward 0.

- (b) When $t = 8$ (c) CU on $(0, 8)$; CD on $(8, 18)$
 (d) $(8, 350)$

- 63.** If $D(t)$ is the size of the deficit as a function of time, then at the time of the speech $D'(t) > 0$, but $D''(t) < 0$.

- 65.** $K(3) - K(2)$; CD

67. $f(x) = \frac{1}{9}(2x^3 + 3x^2 - 12x + 7)$

EXERCISES 3.4 ■ PAGE 247

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

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

5. 0 **7.** $\frac{2}{5}$ **9.** $\frac{4}{5}$ **11.** 0 **13.** $-\frac{1}{3}$ **15.** -1

17. $\frac{\sqrt{3}}{4}$ **19.** -2 **21.** $-\infty$ **23.** Does not exist

25. 0 **27.** $\frac{1}{2}(a - b)$ **29.** $-\infty$ **31.** 1

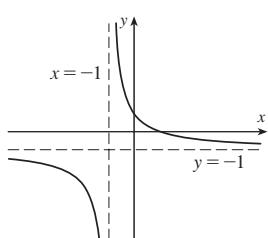
33. (a), (b) $-\frac{1}{2}$ **35.** $y = 4, x = -3$

37. $y = 2; x = -2, x = 1$ **39.** $x = 5$ **41.** $y = 3$

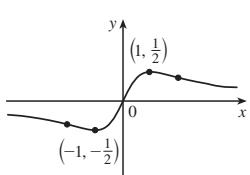
43. (a) 0 (b) $\pm\infty$

45. $f(x) = \frac{2-x}{x^2(x-3)}$ **47.** (a) $\frac{5}{4}$ (b) 5

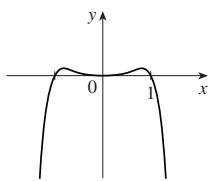
49. $y = -1$



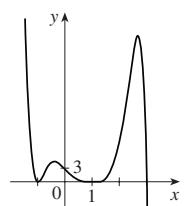
51. $y = 0$



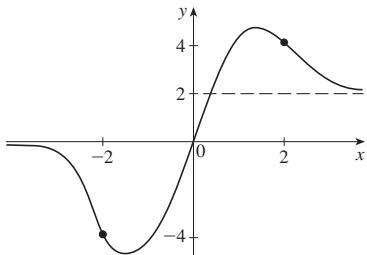
53. $-\infty, -\infty$



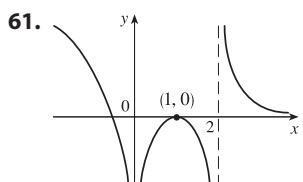
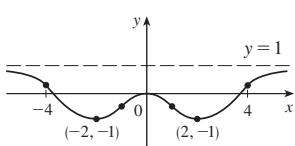
55. $-\infty, \infty$



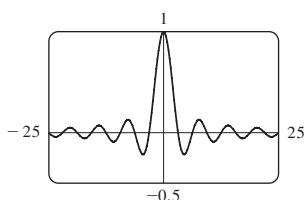
57.



59.



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



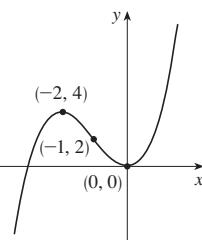
65. 4 67. $N \geq 15$ 69. $N \leq -9, N \leq -19$

71. (a) $x > 100$ 75. (b) 0

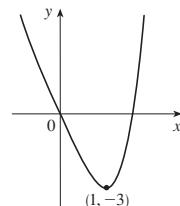
EXERCISES 3.5 ■ PAGE 256

Abbreviations: int, intercept; SA, slant asymptote

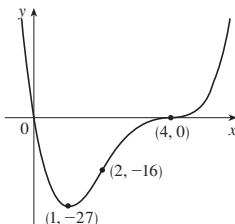
1. A. \mathbb{R} B. y-int 0; x-int $-3, 0$
 C. None D. None
 E. Inc on $(-\infty, -2), (0, \infty)$;
 dec on $(-2, 0)$
 F. Loc max $f(-2) = 4$;
 loc min $f(0) = 0$
 G. CU on $(-1, \infty)$; CD on $(-\infty, -1)$;
 IP $(-1, 2)$
 H. See graph at right.



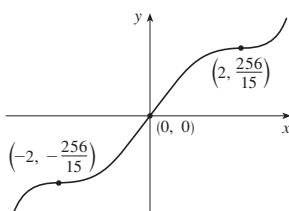
3. A. \mathbb{R} B. y-int 0; x-int $0, \sqrt[3]{4}$
 C. None D. None
 E. Inc on $(1, \infty)$; dec on $(-\infty, 1)$
 F. Loc min $f(1) = -3$
 G. CU on $(-\infty, \infty)$
 H. See graph at right.



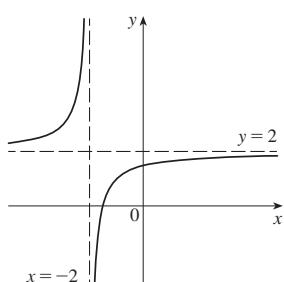
5. A. \mathbb{R} B. y-int 0; x-int $0, 4$
 C. None D. None
 E. Inc on $(1, \infty)$; dec on $(-\infty, 1)$
 F. Loc min $f(1) = -27$
 G. CU on $(-\infty, 2), (4, \infty)$;
 CD on $(2, 4)$;
 IPs $(2, -16), (4, 0)$
 H. See graph at right.



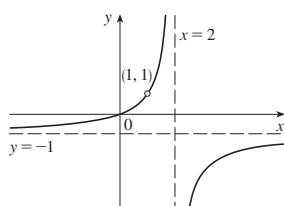
7. A. \mathbb{R} B. y-int 0; x-int 0
 C. About $(0, 0)$ D. None
 E. Inc on $(-\infty, \infty)$
 F. None
 G. CU on $(-2, 0), (2, \infty)$;
 CD on $(-\infty, -2), (0, 2)$;
 IPs $(-2, -\frac{256}{15}), (0, 0), (2, \frac{256}{15})$
 H. See graph at right.



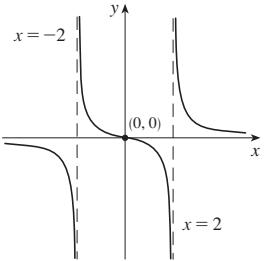
9. A. $(-\infty, -2) \cup (-2, \infty)$
 B. y-int $\frac{3}{2}$; x-int $-\frac{3}{2}$
 C. None D. VA $x = -2$,
 HA $y = 2$
 E. Inc on $(-\infty, -2), (-2, \infty)$
 F. None
 G. CU on $(-\infty, -2)$;
 CD on $(-2, \infty)$
 H. See graph at right.



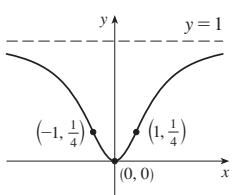
11. A. $(-\infty, 1) \cup (1, 2) \cup (2, \infty)$
 B. y-int 0; x-int 0 C. None
 D. VA $x = 2$; HA $y = -1$
 E. Inc on $(-\infty, 1), (1, 2), (2, \infty)$
 F. None
 G. CU on $(-\infty, 1), (1, 2)$;
 CD on $(2, \infty)$
 H. See graph at right.



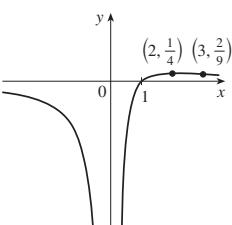
- 13.** A. $(-\infty, -2) \cup (-2, 2) \cup (2, \infty)$ B. y-int 0; x-int 0
 C. About $(0, 0)$ D. VA $x = \pm 2$; HA $y = 0$
 E. Dec on $(-\infty, -2), (-2, 2), (2, \infty)$
 F. No local extrema
 G. CU on $(-2, 0), (2, \infty)$;
 CD on $(-\infty, -2), (0, 2)$; IP $(0, 0)$
 H. See graph at right.



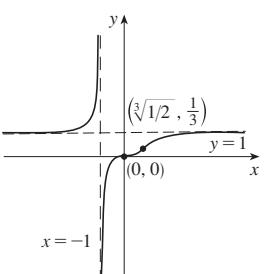
- 15.** A. \mathbb{R} B. y-int 0; x-int 0
 C. About y-axis D. HA $y = 1$
 E. Inc on $(0, \infty)$; dec on $(-\infty, 0)$
 F. Loc min $f(0) = 0$
 G. CU on $(-1, 1)$;
 CD on $(-\infty, -1), (1, \infty)$; IPs $(\pm 1, \frac{1}{4})$
 H. See graph at right.



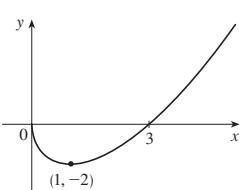
- 17.** A. $(-\infty, 0) \cup (0, \infty)$ B. x-int 1
 C. None D. VA $x = 0$; HA $y = 0$
 E. Inc on $(0, 2)$;
 dec on $(-\infty, 0), (2, \infty)$
 F. Loc max $f(2) = \frac{1}{4}$
 G. CU on $(3, \infty)$;
 CD on $(-\infty, 0), (0, 3)$; IP $(3, \frac{2}{9})$
 H. See graph at right.



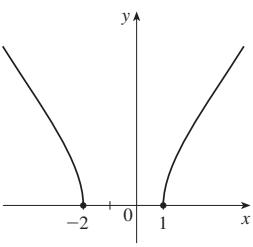
- 19.** A. $(-\infty, -1) \cup (-1, \infty)$
 B. y-int 0; x-int 0 C. None
 D. VA $x = -1$; HA $y = 1$
 E. Inc on $(-\infty, -1), (-1, \infty)$;
 F. None
 G. CU on $(-\infty, -1), (0, \sqrt[3]{\frac{1}{2}})$;
 CD on $(-1, 0), (\sqrt[3]{\frac{1}{2}}, \infty)$;
 IPs $(0, 0), (\sqrt[3]{\frac{1}{2}}, \frac{1}{3})$
 H. See graph at right.



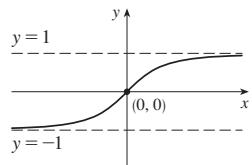
- 21.** A. $[0, \infty)$ B. y-int 0; x-int 0, 3
 C. None D. None
 E. Inc on $(1, \infty)$; dec on $(0, 1)$
 F. Loc min $f(1) = -2$
 G. CU on $(0, \infty)$
 H. See graph at right.



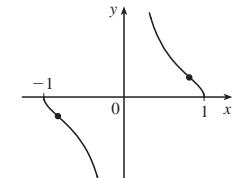
- 23.** A. $(-\infty, -2] \cup [1, \infty)$
 B. x-int $-2, 1$ C. None
 D. None
 E. Inc on $(1, \infty)$; dec on $(-\infty, -2)$
 F. None
 G. CD on $(-\infty, -2), (1, \infty)$
 H. See graph at right.



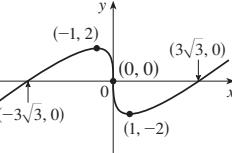
- 25.** A. \mathbb{R} B. y-int 0; x-int 0
 C. About $(0, 0)$ D. HA $y = \pm 1$
 E. Inc on $(-\infty, \infty)$ F. None
 G. CU on $(-\infty, 0)$;
 CD on $(0, \infty)$; IP $(0, 0)$
 H. See graph at right.



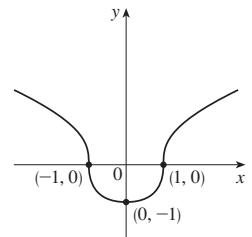
- 27.** A. $[-1, 0) \cup (0, 1]$ B. x-int ± 1 C. About $(0, 0)$
 D. VA $x = 0$
 E. Dec on $(-1, 0), (0, 1)$
 F. None
 G. CU on $(-1, -\sqrt{2}/3), (0, \sqrt{2}/3)$;
 CD on $(-\sqrt{2}/3, 0), (\sqrt{2}/3, 1)$;
 IPs $(\pm \sqrt{2}/3, \pm 1/\sqrt{2})$
 H. See graph at right.



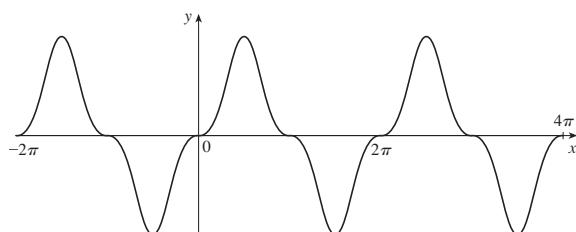
- 29.** A. \mathbb{R} B. y-int 0; x-int $\pm 3\sqrt{3}, 0$ C. About $(0, 0)$
 D. None E. Inc on $(-\infty, -1), (1, \infty)$; dec on $(-1, 1)$
 F. Loc max $f(-1) = 2$;
 loc min $f(1) = -2$
 G. CU on $(0, \infty)$;
 CD on $(-\infty, 0)$; IP $(0, 0)$
 H. See graph at right.



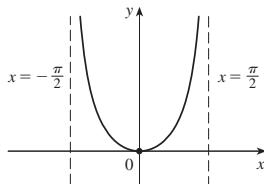
- 31.** A. \mathbb{R} B. y-int -1 ; x-int ± 1
 C. About the y-axis D. None
 E. Inc on $(0, \infty)$; dec on $(-\infty, 0)$
 F. Loc min $f(0) = -1$
 G. CU on $(-1, 1)$;
 CD on $(-\infty, -1), (1, \infty)$; IPs $(\pm 1, 0)$
 H. See graph at right.



- 33.** A. \mathbb{R} B. y-int 0; x-int $n\pi$ (n an integer)
 C. About $(0, 0)$, period 2π D. None
 E-G answers for $0 \leq x \leq \pi$:
 E. Inc on $(0, \pi/2)$; dec on $(\pi/2, \pi)$ F. Loc max $f(\pi/2) = 1$
 G. Let $\alpha = \sin^{-1}\sqrt{2}/3$; CU on $(0, \alpha), (\pi - \alpha, \pi)$;
 CD on $(\alpha, \pi - \alpha)$; IPs at $x = 0, \pi, \alpha, \pi - \alpha$
 H.



- 35.** A. $(-\pi/2, \pi/2)$ B. y-int 0; x-int 0 C. About y-axis
 D. VA $x = \pm \pi/2$
 E. Inc on $(0, \pi/2)$;
 dec on $(-\pi/2, 0)$
 F. Loc min $f(0) = 0$
 G. CU on $(-\pi/2, \pi/2)$
 H. See graph at right.



37. A. $[-2\pi, 2\pi]$

B. y -int $\sqrt{3}$; x -int $-4\pi/3, -\pi/3, 2\pi/3, 5\pi/3$

C. Period 2π D. None

E. Inc on $(-\pi, -11\pi/6), (-5\pi/6, \pi/6), (\pi/6, 2\pi)$; dec on $(-\pi, -5\pi/6), (\pi/6, 7\pi/6)$

F. Loc max $f(-11\pi/6) = f(\pi/6) = 2$;

loc min $f(-5\pi/6) = f(7\pi/6) = -2$

G. CU on $(-\pi/3, -\pi/3)$,

$(2\pi/3, 5\pi/3)$;

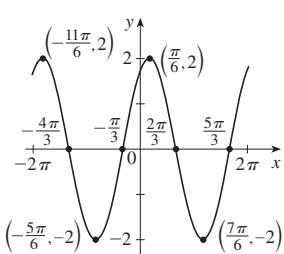
CD on $(-\pi, -4\pi/3)$,

$(-\pi/3, 2\pi/3), (5\pi/3, 2\pi)$;

IPs $(-4\pi/3, 0), (-\pi/3, 0)$,

$(2\pi/3, 0), (5\pi/3, 0)$

H. See graph at right.



39. A. All reals except $(2n + 1)\pi$ (n an integer)

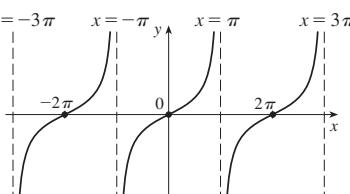
B. y -int 0; x -int $2n\pi$ C. About the origin, period 2π

D. VA $x = (2n + 1)\pi$ E. Inc on $((2n - 1)\pi, (2n + 1)\pi)$

F. None G. CU on $(2n\pi, (2n + 1)\pi)$;

CD on $((2n - 1)\pi, 2n\pi)$; IPs $(2n\pi, 0)$

H. See graph at right.



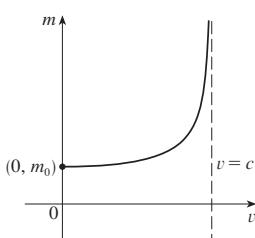
41. (a) $(-\infty, 7]$; $(-\infty, 3) \cup (3, 7)$ (b) 3, 5

(c) $-1/\sqrt{3} \approx -0.58$ (d) HA $y = \sqrt{2}$

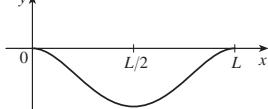
43. (a) $\mathbb{R}; (-\infty, 3) \cup (3, 7) \cup (7, \infty)$ (b) 3, 5, 7, 9

(c) -2 (d) HA $y = 1, y = 2$

45.



47.



49. $y = x - 1$

51. $y = 2x - 3$

53. A. $(-\infty, 1) \cup (1, \infty)$

B. y -int 0; x -int 0

C. None

D. VA $x = 1$; SA $y = x + 1$

E. Inc on $(-\infty, 0), (2, \infty)$;

dec on $(0, 1), (1, 2)$

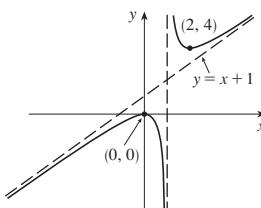
F. Loc max $f(0) = 0$;

loc min $f(2) = 4$

G. CU on $(1, \infty)$; CD on

$(-\infty, 1)$

H. See graph at right.



55. A. $(-\infty, 0) \cup (0, \infty)$

B. x -int $-\sqrt[3]{4}$ C. None

D. VA $x = 0$; SA $y = x$

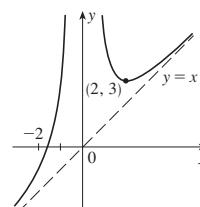
E. Inc on $(-\infty, 0), (2, \infty)$;

dec on $(0, 2)$

F. Loc min $f(2) = 3$

G. CU on $(-\infty, 0), (0, \infty)$

H. See graph at right.



57. A. \mathbb{R} B. y -int 1; x -int -1

C. None D. SA $y = 2x + 1$

E. Inc on $(-\infty, \infty)$ F. None

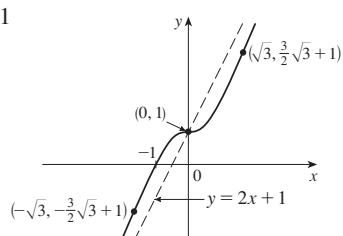
G. CU on $(-\infty, -\sqrt{3}),$

$(0, \sqrt{3})$;

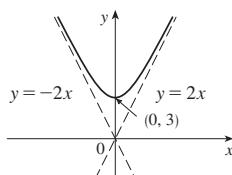
CD on $(-\sqrt{3}, 0), (\sqrt{3}, \infty)$;

IP $(\pm\sqrt{3}, 1 \pm \frac{3}{2}\sqrt{3})$, $(0, 1)$

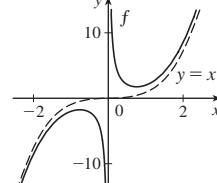
H. See graph at right.



59.



63. VA $x = 0$, asymptotic to $y = x^3$



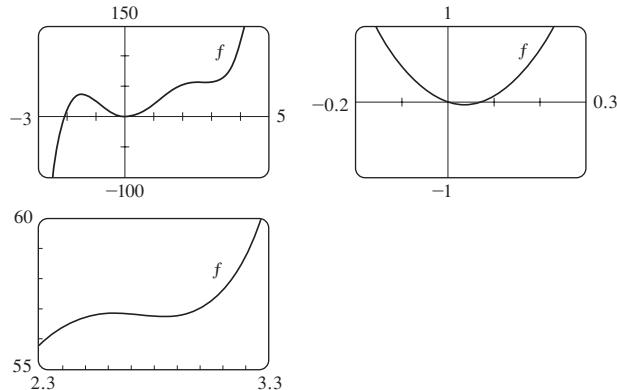
EXERCISES 3.6 ■ PAGE 263

1. Inc on $(-\infty, -1.50), (0.04, 2.62), (2.84, \infty)$; dec on

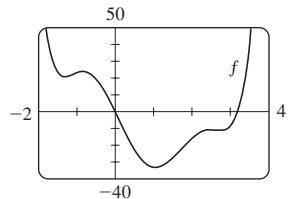
$(-1.50, 0.04), (2.62, 2.84)$; loc max $f(-1.50) \approx 36.47$,

$f(2.62) \approx 56.83$; loc min $f(0.04) \approx -0.04, f(2.84) \approx 56.73$

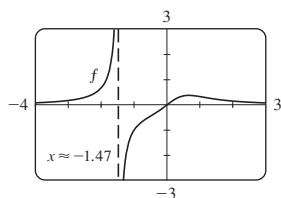
CU on $(-0.89, 1.15), (2.74, \infty)$; CD on $(-\infty, -0.89), (1.15, 2.74)$;
IPs $(-0.89, 20.90), (1.15, 26.57), (2.74, 56.78)$



- 3.** Inc on $(-1.31, -0.84), (1.06, 2.50), (2.75, \infty)$;
dec on $(-\infty, -1.31), (-0.84, 1.06), (2.50, 2.75)$;
loc max $f(-0.84) \approx 23.71, f(2.50) \approx -11.02$; loc min
 $f(-1.31) \approx 20.72, f(1.06) \approx -33.12, f(2.75) \approx -11.33$;
CU on $(-\infty, -1.10), (0.08, 1.72), (2.64, \infty)$;
CD on $(-1.10, 0.08), (1.72, 2.64)$;
IPs $(-1.10, 22.09), (0.08, -3.88), (1.72, -22.53), (2.64, -11.18)$

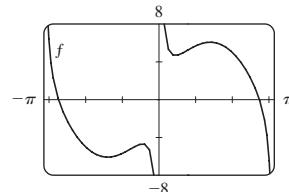


- 5.** Inc on $(-\infty, -1.47), (-1.47, 0.66)$; dec on $(0.66, \infty)$;
loc max $f(0.66) \approx 0.38$; CU on $(-\infty, -1.47), (-0.49, 0), (1.10, \infty)$;
CD on $(-1.47, -0.49), (0, 1.10)$;
IPs $(-0.49, -0.44), (1.10, 0.31), (0, 0)$

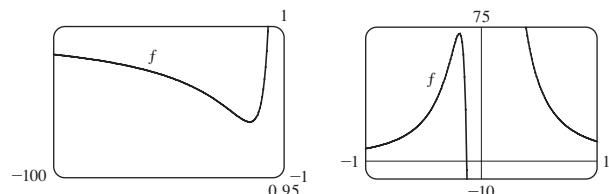


- 7.** Inc on $(-1.40, -0.44), (0.44, 1.40)$; dec on $(-\pi, -1.40), (-0.44, 0), (0, 0.44), (1.40, \pi)$;
loc max $f(-0.44) \approx -4.68, f(1.40) \approx 6.09$; loc min $f(-1.40) \approx -6.09, f(0.44) \approx 4.68$;

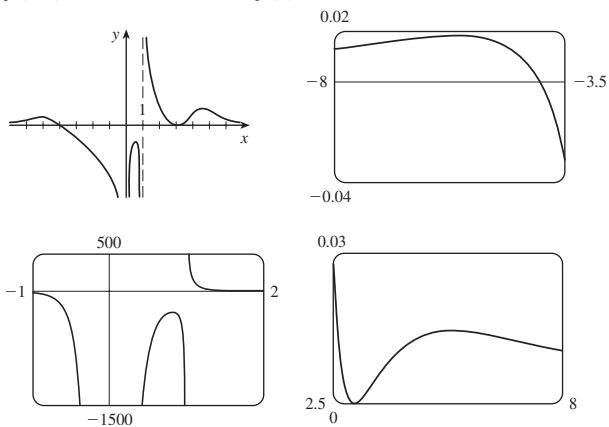
CU on $(-\pi, -0.77), (0, 0.77)$; CD on $(-0.77, 0), (0.77, \pi)$;
IPs $(-0.77, -5.22), (0.77, 5.22)$



- 9.** Inc on $(-8 - \sqrt{61}, -8 + \sqrt{61})$; dec on $(-\infty, -8 - \sqrt{61}), (-8 + \sqrt{61}, 0), (0, \infty)$; CU on $(-12 - \sqrt{138}, -12 + \sqrt{138}), (0, \infty)$; CD on $(-\infty, -12 - \sqrt{138}), (-12 + \sqrt{138}, 0)$



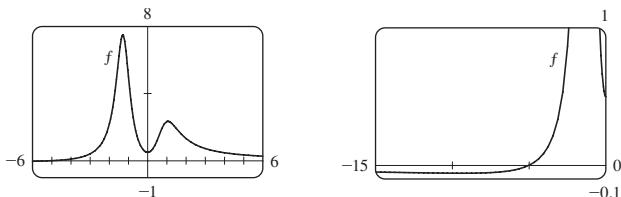
- 11.** Loc max $f(-5.6) \approx 0.018, f(0.82) \approx -281.5, f(5.2) \approx 0.0145$; loc min $f(3) = 0$



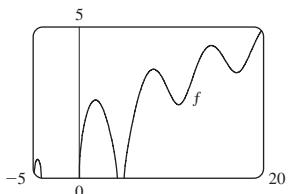
$$\begin{aligned} \mathbf{13.} \quad &f'(x) = -\frac{x(x+1)^2(x^3 + 18x^2 - 44x - 16)}{(x-2)^3(x-4)^5} \\ &f''(x) = 2 \frac{(x+1)(x^6 + 36x^5 + 6x^4 - 628x^3 + 684x^2 + 672x + 64)}{(x-2)^4(x-4)^6} \end{aligned}$$

- CU on $(-35.3, -5.0), (-1, -0.5), (-0.1, 2), (2, 4), (4, \infty)$;
CD on $(-\infty, -35.3), (-5.0, -1), (-0.5, -0.1)$;
IPs $(-35.3, -0.015), (-5.0, -0.005), (-1, 0), (-0.5, 0.00001), (-0.1, 0.0000066)$

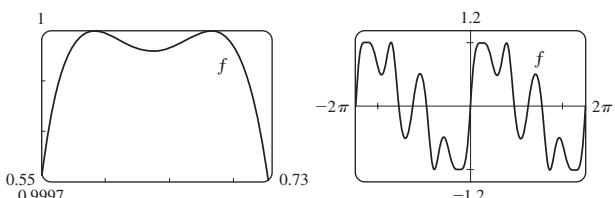
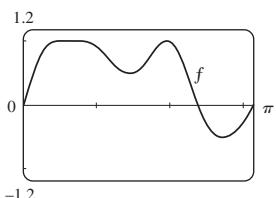
- 15.** Inc on $(-9.41, -1.29), (0, 1.05)$;
 dec on $(-\infty, -9.41), (-1.29, 0), (1.05, \infty)$;
 loc max $f(-1.29) \approx 7.49, f(1.05) \approx 2.35$;
 loc min $f(-9.41) \approx -0.056, f(0) = 0.5$;
 CU on $(-13.81, -1.55), (-1.03, 0.60), (1.48, \infty)$;
 CD on $(-\infty, -13.81), (-1.55, -1.03), (0.60, 1.48)$;
 IPs $(-13.81, -0.05), (-1.55, 5.64), (-1.03, 5.39), (0.60, 1.52), (1.48, 1.93)$



- 17.** Inc on $(-4.91, -4.51), (0, 1.77), (4.91, 8.06), (10.79, 14.34), (17.08, 20)$;
 dec on $(-4.51, -4.10), (1.77, 4.10), (8.06, 10.79), (14.34, 17.08)$;
 loc max $f(-4.51) \approx 0.62, f(1.77) \approx 2.58, f(8.06) \approx 3.60, f(14.34) \approx 4.39$;
 loc min $f(10.79) \approx 2.43, f(17.08) \approx 3.49$;
 CU on $(9.60, 12.25), (15.81, 18.65)$;
 CD on $(-4.91, -4.10), (0, 4.10), (4.91, 9.60), (12.25, 15.81), (18.65, 20)$;
 IPs $(9.60, 2.95), (12.25, 3.27), (15.81, 3.91), (18.65, 4.20)$



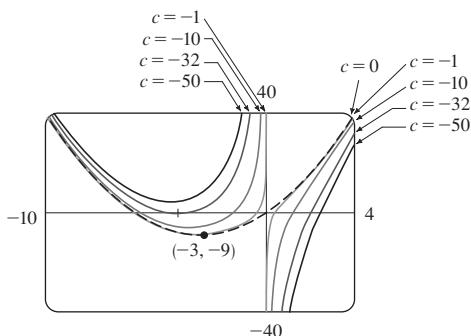
- 19.** Max $f(0.59) \approx 1, f(0.68) \approx 1, f(1.96) \approx 1$;
 min $f(0.64) \approx 0.99996, f(1.46) \approx 0.49, f(2.73) \approx -0.51$;
 IPs $(0.61, 0.99998), (0.66, 0.99998), (1.17, 0.72), (1.75, 0.77), (2.28, 0.34)$



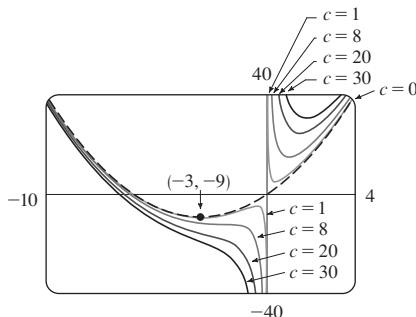
- 21.** For $c < 0$, there is a loc min that moves toward $(-3, -9)$ as c increases. For $0 < c < 8$, there is a loc min that moves toward

$(-3, -9)$ and a loc max that moves toward the origin as c decreases. For all $c > 0$, there is a first-quadrant loc min that moves toward the origin as c decreases. $c = 0$ is a transitional value that gives the graph of a parabola. For all nonzero c , the y -axis is a VA and there is an IP that moves toward the origin as $|c| \rightarrow 0$.

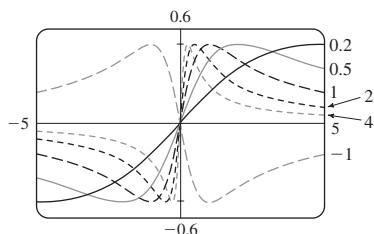
$c \leq 0$:



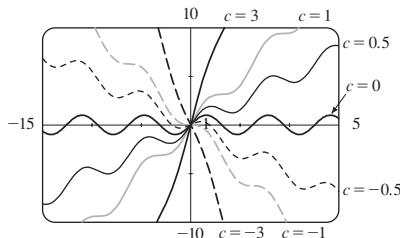
$c \geq 0$:



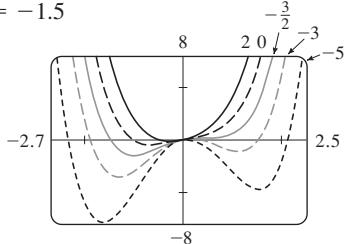
- 23.** For $c > 0$, the maximum and minimum values are always $\pm \frac{1}{2}$, but the extreme points and IPs move closer to the y -axis as c increases. $c = 0$ is a transitional value: when c is replaced by $-c$, the curve is reflected in the x -axis.



- 25.** For $|c| < 1$, the graph has loc max and min values; for $|c| \geq 1$, it does not. The function increases for $c \geq 1$ and decreases for $c \leq -1$. As c changes, the IPs move vertically but not horizontally.



27. $c = 0; c = -1.5$



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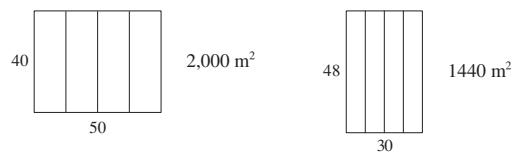
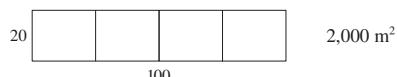
1. (a) 11, 12 (b) 11.5, 11.5

7. 25 m by 25 m

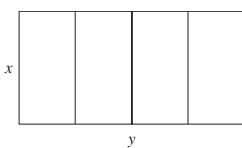
3. 10, 10

5. $\frac{9}{4}$

11. (a)



(b)



(c) $A = xy$ (d) $5x + 2y = 300$ (e) $A(x) = 150x - \frac{5}{2}x^2$
(f) 2250 m^2

13. 100 m by 150 m, middle fence parallel to short side

15. 20 m by 600 m **19.** 4000 cm^3 **21.** $\approx \$163.54$

23. 45 cm by 45 cm by 90 cm.

25. $(-\frac{6}{5}, \frac{3}{5})$ **27.** $(-\frac{1}{3}, \pm\frac{4}{3}\sqrt{2})$ **29.** Square, side $\sqrt{2}r$

31. $L/2, \sqrt{3}L/4$ **33.** Base $\sqrt{3}r$, height $3r/2$

37. $4\pi r^3/(3\sqrt{3})$ **39.** $\pi r^2(1 + \sqrt{5})$

41. 24 cm by 36 cm

43. (a) Use all of the wire for the square

(b) $40\sqrt{3}/(9 + 4\sqrt{3})$ m for the square

45. 30 cm **47.** $V = 2\pi R^3/(9\sqrt{3})$ **51.** $E^2/(4r)$

53. (a) $\frac{3}{2}s^2 \csc \theta (\csc \theta - \sqrt{3} \cot \theta)$ (b) $\cos^{-1}(1/\sqrt{3}) \approx 55^\circ$

(c) $6s[h + s/(2\sqrt{2})]$

55. Row directly to B **57.** ≈ 4.85 km east of the refinery

59. $10\sqrt[3]{3}/(1 + \sqrt[3]{3}) \approx 5.91$ m from the stronger source

61. $(a^{2/3} + b^{2/3})^{3/2}$ **63.** $2\sqrt{6}$

65. (b) (i) \$342,491; \$342.49/unit; \$389.74/unit

(ii) 400 (iii) \$320/unit

67. (a) $p(x) = 19 - \frac{1}{3000}x$ (b) \$9.50

69. (a) $p(x) = 500 - \frac{1}{8}x$ (b) \$250 (c) \$310

75. 9.35 m **79.** $x = 15$ cm **81.** $\pi/6$ **83.** $\frac{1}{2}(L + W)^2$

85. (a) About 5.1 km from B (b) C is close to B ; C is close to D ; $W/L = \sqrt{25 + x^2}/x$, where $x = |BC|$

(c) ≈ 1.07 ; no such value (d) $\sqrt{41}/4 \approx 1.6$

EXERCISES 3.8 ■ PAGE 283

1. (a) $x_2 \approx 7.3, x_3 \approx 6.8$ (b) Yes

3. $\frac{9}{2}$ **5.** a, b, c **7.** 1.5215 **9.** -1.25

11. 2.94283096 **13.** (b) 2.630020 **15.** -1.914021

17. 1.934563 **19.** -0.549700, 2.629658 **21.** 0.865474

23. -1.69312029, -0.74466668, 1.26587094

25. 0.76682579 **27.** (b) 31.622777

33. (a) -1.293227, -0.441731, 0.507854 (b) -2.0212

35. (1.519855, 2.306964) **37.** (0.410245, 0.347810)

39. 0.76286%

EXERCISES 3.9 ■ PAGE 290

1. (a) $F(x) = 6x$ (b) $G(t) = t^3$

3. (a) $H(q) = \sin q$ (b) $F(x) = \sec x$

5. $F(x) = 2x^2 + 7x + C$ **7.** $F(x) = \frac{1}{2}x^4 - \frac{2}{9}x^3 + \frac{5}{2}x^2 + C$

9. $F(x) = 4x^3 + 4x^2 + C$ **11.** $G(x) = 12x^{1/3} - \frac{3}{4}x^{8/3} + C$

13. $F(x) = 2x^{3/2} - \frac{3}{2}x^{4/3} + C$

15. $F(t) = \frac{4}{3}t^{3/2} - 8\sqrt{t} + 3t + C$

17. $F(x) = \begin{cases} -5/(4x^8) + C_1 & \text{if } x < 0 \\ -5/(4x^8) + C_2 & \text{if } x > 0 \end{cases}$

19. $F(\theta) = -2 \cos \theta - 3 \sec \theta + C$

21. $H(\theta) = -2 \cos \theta - \tan \theta + C_n$ on $(n\pi - \pi/2, n\pi + \pi/2)$,
 n an integer

23. $G(v) = \frac{3}{5}v^{5/3} - 2 \tan v + C_n$ on $(n\pi - \pi/2, n\pi + \pi/2)$,
 n an integer

25. $F(x) = x^5 - \frac{1}{3}x^6 + 4$

27. $f(x) = 4x^3 + Cx + D$

29. $f(x) = \frac{1}{5}x^5 + 4x^3 - \frac{1}{2}x^2 + Cx + D$

31. $f(x) = 2x^2 - \frac{9}{28}x^{7/3} + Cx + D$

33. $f(t) = 2t^3 + \cos t + Ct^2 + Dt + E$

35. $f(x) = x^5 - x^3 + 4x + 6$

37. $f(x) = 3x^{5/3} - 75$

39. $f(t) = \tan t + \sec t - 2 - \sqrt{2}$

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

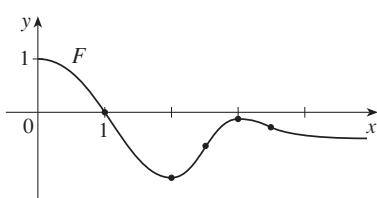
43. $f(\theta) = -\sin \theta - \cos \theta + 5\theta + 4$

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

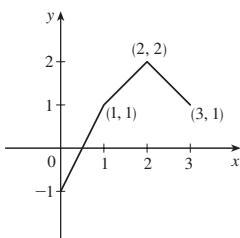
47. $f(t) = \frac{9}{28}t^{7/3} + \cos t + (\frac{19}{28} - \cos 1)t + 1$

49. 8 **51.** *b*

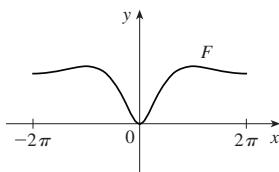
53.



55.



57.



59. $s(t) = 2 \sin t - 4 \cos t + 7$

61. $s(t) = \frac{1}{3}t^3 + \frac{1}{2}t^2 - 2t + 3$

63. $s(t) = -\sin t + \cos t + \frac{8}{\pi}t - 1$

65. (a) $s(t) = 450 - 4.9t^2$ (b) $\sqrt{450/4.9} \approx 9.58$ s

(c) $-9.8\sqrt{450/4.9} \approx -93.9$ m/s (d) About 9.09 s

69. 81.6 m 71. \$742.08 73. $\frac{130}{11} \approx 11.8$ s

75. 1.79 m/s² 77. $62,500 \text{ km/h}^2 \approx 4.82 \text{ m/s}^2$

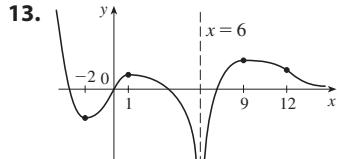
79. (a) 101.0 km (b) 87.7 km (c) 21 min 50 s
(d) 172 km

CHAPTER 3 REVIEW ■ PAGE 293**True-False Quiz**

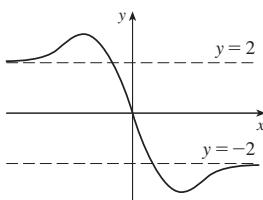
1. False 3. False 5. True 7. False 9. True
 11. True 13. False 15. True 17. True
 19. True

Exercises

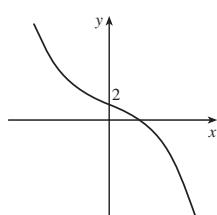
1. Abs max $f(2) = f(5) = 18$, abs min $f(0) = -2$,
 loc max $f(2) = 18$, loc min $f(4) = 14$
 3. Abs max $f(2) = \frac{2}{5}$, abs and loc min $f(-\frac{1}{3}) = -\frac{9}{2}$
 5. Abs and loc max $f(\pi/6) = \pi/6 + \sqrt{3}$,
 abs min $f(-\pi) = -\pi - 2$, loc min $f(5\pi/6) = 5\pi/6 - \sqrt{3}$
 7. $\frac{1}{2}$ 9. $-\frac{2}{3}$ 11. $\frac{3}{4}$



15.



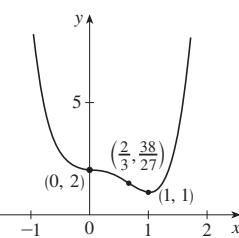
17. A. \mathbb{R} B. y-int 2
 C. None D. None
 E. Dec on $(-\infty, \infty)$ F. None
 G. CU on $(-\infty, 0)$; CD on $(0, \infty)$; IP $(0, 2)$
 H. See graph at right.

19. A. \mathbb{R} B. y-int 2

C. None D. None

E. Inc on $(1, \infty)$; dec on $(-\infty, 1)$ F. Loc min $f(1) = 1$ G. CU on $(-\infty, 0)$, $(\frac{2}{3}, \infty)$;CD on $(0, \frac{2}{3})$; IPs $(0, 2)$, $(\frac{2}{3}, \frac{38}{27})$

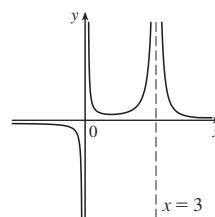
H. See graph at right.

21. A. $(-\infty, 0) \cup (0, 3) \cup (3, \infty)$

B. None C. None

D. HA $y = 0$; VA $x = 0, x = 3$ E. Inc on $(1, 3)$;
dec on $(-\infty, 0)$, $(0, 1)$, $(3, \infty)$ F. Loc min $f(1) = \frac{1}{4}$ G. CU on $(0, 3)$, $(3, \infty)$;CD on $(-\infty, 0)$

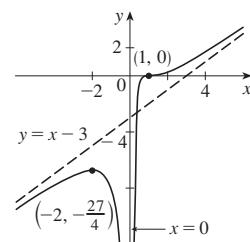
H. See graph at right.

23. A. $(-\infty, 0) \cup (0, \infty)$

B. x-int 1 C. None

D. VA $x = 0$; SA $y = x - 3$ E. Inc on $(-\infty, -2)$, $(0, \infty)$;
dec on $(-2, 0)$ F. Loc max $f(-2) = -\frac{27}{4}$ G. CU on $(1, \infty)$; CD on $(-\infty, 0)$,
 $(0, 1)$; IP $(1, 0)$

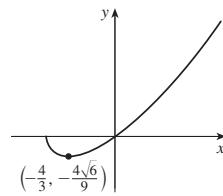
H. See graph at right.

25. A. $[-2, \infty)$ B. y-int 0; x-int $-2, 0$

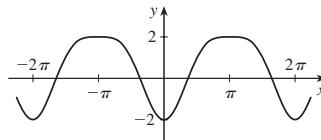
C. None D. None

E. Inc on $(-\frac{4}{3}, \infty)$, dec on $(-2, -\frac{4}{3})$ F. Loc min $f(-\frac{4}{3}) = -\frac{4}{9}\sqrt{6}$ G. CU on $(-2, \infty)$

H. See graph at right.

27. A. \mathbb{R} B. y-int -2 C. About y-axis, period 2π D. None E. Inc on $(2n\pi, (2n+1)\pi)$, n an integer;
dec on $((2n-1)\pi, 2n\pi)$ F. Loc max $f((2n+1)\pi) = 2$; loc min $f(2n\pi) = -2$ G. CU on $(2n\pi - (\pi/3), 2n\pi + (\pi/3))$;CD on $(2n\pi + (\pi/3), 2n\pi + (5\pi/3))$; IP $(2n\pi \pm (\pi/3), -\frac{1}{4})$

H.



29. Inc on $(-\sqrt{3}, 0), (0, \sqrt{3})$;
dec on $(-\infty, -\sqrt{3}), (\sqrt{3}, \infty)$;

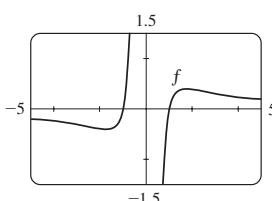
$$\text{loc max } f(\sqrt{3}) = \frac{2}{9}\sqrt{3},$$

$$\text{loc min } f(-\sqrt{3}) = -\frac{2}{9}\sqrt{3};$$

CU on $(-\sqrt{6}, 0), (\sqrt{6}, \infty)$;

CD on $(-\infty, -\sqrt{6}), (0, \sqrt{6})$;

$$\text{IPs } (\sqrt{6}, \frac{5}{36}\sqrt{6}), (-\sqrt{6}, -\frac{5}{36}\sqrt{6})$$

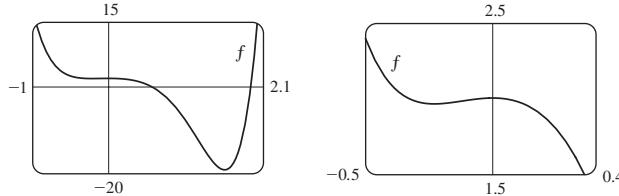


31. Inc on $(-0.23, 0), (1.62, \infty)$; dec on $(-\infty, -0.23), (0, 1.62)$;

$$\text{loc max } f(0) = 2; \text{ loc min } f(-0.23) \approx 1.96, f(1.62) \approx -19.2;$$

CU on $(-\infty, -0.12), (1.24, \infty)$;

CD on $(-0.12, 1.24)$; IPs $(-0.12, 1.98), (1.24, -12.1)$



37. (a) 0 (b) CU on \mathbb{R} **41.** $3\sqrt{3}r^2$

43. $4/\sqrt{3}$ cm from D

45. $L = C$

47. \$11.50

49. 1.297383 **51.** 1.16718557

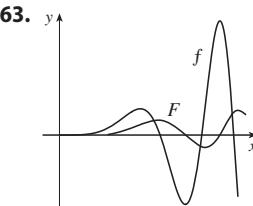
53. $F(x) = \frac{8}{3}x^{3/2} - 2x^3 + 3x + C$

55. $H(t) = \begin{cases} -\frac{1}{2}t^{-2} - 5 \cos t + C_1 & \text{if } t < 0 \\ -\frac{1}{2}t^{-2} - 5 \cos t + C_2 & \text{if } t > 0 \end{cases}$

57. $f(t) = t^2 + 3 \cos t + 2$

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

61. $s(t) = t^2 + \cos t + 2$



65. No

67. (b) About 25.44 cm by 5.96 cm (c) $2\sqrt{300}$ cm by $2\sqrt{600}$ cm

69. $\tan^{-1}\left(-\frac{2}{\pi}\right) + 180^\circ \approx 147.5^\circ$

71. (a) $10\sqrt{2} \approx 14$ m

(b) $\frac{dI}{dt} = \frac{-60k(h-1)}{[(h-1)^2 + 400]^{-5/2}}$, where k is the constant of proportionality

PROBLEMS PLUS ■ PAGE 298

5. $(-2, 4), (2, -4)$ **11.** $(m/2, m^2/4)$

13. $-3.5 < a < -2.5$

15. (a) $x/(x^2 + 1)$ (b) $\frac{1}{2}$

17. (a) $\frac{d\theta}{dt} = -\tan \theta \left[\frac{1}{c} \frac{dc}{dt} + \frac{1}{b} \frac{db}{dt} \right]$

(b) $\frac{da}{dt} = \frac{b \frac{db}{dt} + c \frac{dc}{dt} - \left(b \frac{dc}{dt} + c \frac{db}{dt} \right) \sec \theta}{\sqrt{b^2 + c^2 - 2bc \cos \theta}}$

19. (a) $T_1 = D/c_1, T_2 = (2h \sec \theta)/c_1 + (D - 2h \tan \theta)/c_2, T_3 = \sqrt{4h^2 + D^2}/c_1$

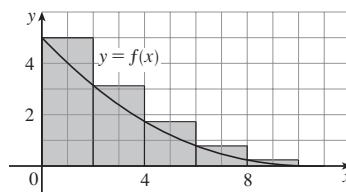
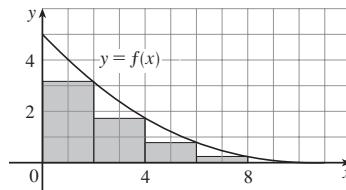
(c) $c_1 \approx 3.85$ km/s, $c_2 \approx 7.66$ km/s, $h \approx 0.42$ km

23. $3/(\sqrt[3]{2} - 1) \approx 11\frac{1}{2}$ h

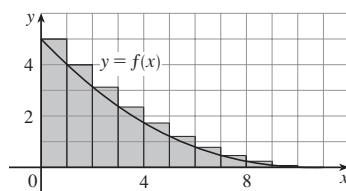
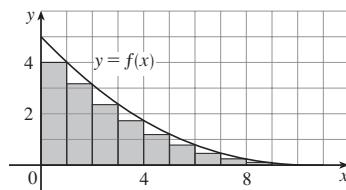
CHAPTER 4

EXERCISES 4.1 ■ PAGE 311

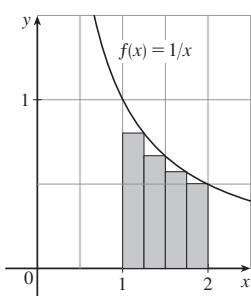
1. (a) Lower ≈ 12 , upper ≈ 22



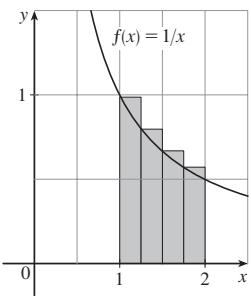
(b) Lower ≈ 14.4 , upper ≈ 19.4



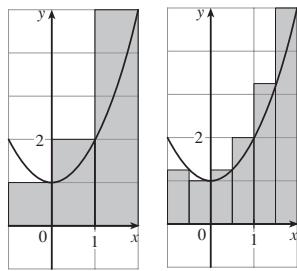
3. (a) 0.6345, underestimate



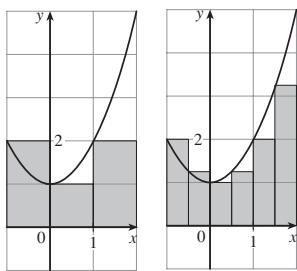
(b) 0.7595, overestimate



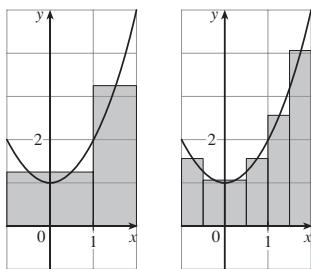
5. (a) 8, 6.875



(b) 5, 5.375

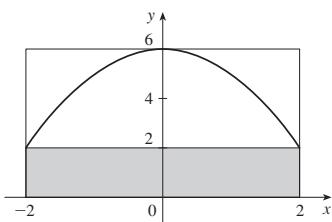


(c) 5.75, 5.9375

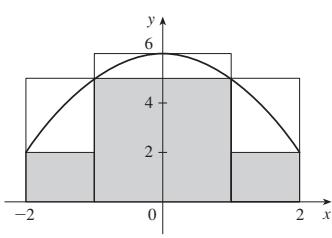


(d) M_6

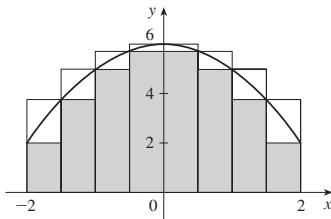
7. $n = 2$: upper = 24, lower = 8



$n = 4$: upper = 22, lower = 14



$n = 8$: upper = 20.5, lower = 16.5



9. 10.55 m, 13.65 m

11. 63.2 L, 70 L

13. 39 m

15. 7840

$$\lim_{n \rightarrow \infty} \sum_{i=1}^n [2 + \sin^2(\pi i/n)] \cdot \frac{\pi}{n}$$

$$\lim_{n \rightarrow \infty} \sum_{i=1}^n (1 + 4i/n)\sqrt{(1 + 4i/n)^3 + 8} \cdot \frac{4}{n}$$

21. The region under the graph of $y = \frac{1}{1+x}$ from 0 to 2

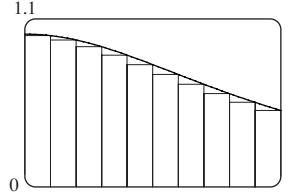
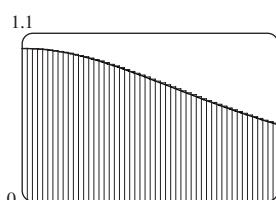
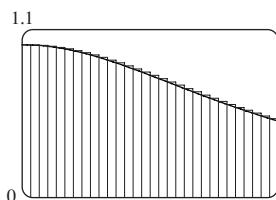
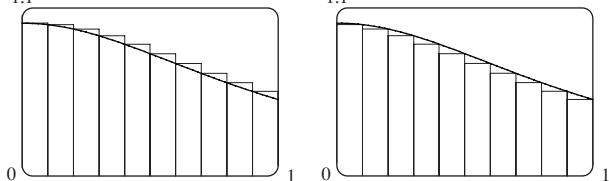
23. The region under the graph of $y = \tan x$ from 0 to $\pi/4$

25. (a) $L_n < A < R_n$

27. 0.2533, 0.2170, 0.2101, 0.2050; 0.2

29. (a) Left: 0.8100, 0.7937, 0.7904;
right: 0.7600, 0.7770, 0.7804

(b)



31. (a) $\lim_{n \rightarrow \infty} \frac{64}{n^6} \sum_{i=1}^n i^5$ (b) $\frac{n^2(n+1)^2(2n^2+2n-1)}{12}$

(c) $\frac{32}{3}$

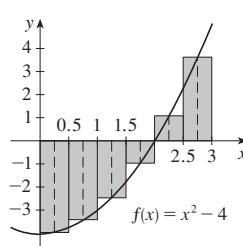
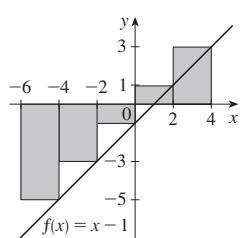
33. $\sin b, 1$

EXERCISES 4.2 ■ PAGE 324**1.** -10

The Riemann sum represents the sum of the areas of the two rectangles above the x -axis minus the sum of the areas of the three rectangles below the x -axis; that is, the *net area* of the rectangles with respect to the x -axis.

3. $-\frac{49}{16}$

The Riemann sum represents the sum of the areas of the two rectangles above the x -axis minus the sum of the areas of the four rectangles below the x -axis.

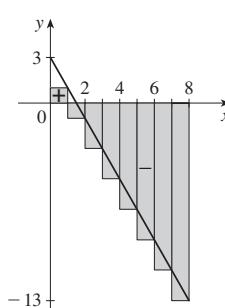
**5.** (a) 4 (b) 2 (c) 6**7.** Lower = -64 ; upper = 16 **11.** 6.1820**13.** 0.3186**15.** 0.3181, 0.3180**17.**

n	R_n
5	1.933766
10	1.983524
50	1.999342
100	1.999836

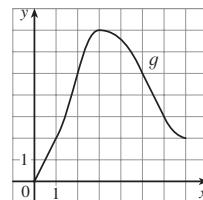
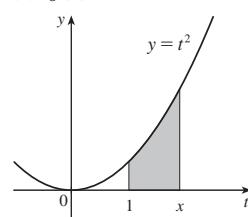
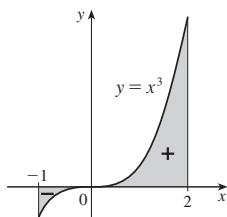
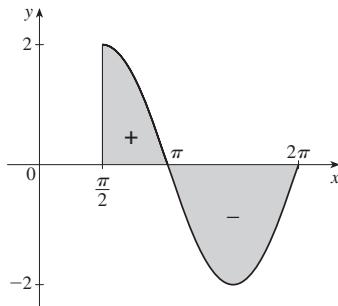
The values of R_n appear to be approaching 2.

19. $\int_0^\pi \frac{\sin x}{1+x} dx$ **21.** $\int_2^7 (5x^3 - 4x) dx$ **23.** $-\frac{40}{3}$ **25.** $\lim_{n \rightarrow \infty} \sum_{i=1}^n \sqrt{4 + (1 + 2i/n)} \cdot \frac{2}{n}$ **27.** 6**29.** $\frac{57}{2}$ **31.** 208**33.** $-\frac{3}{4}$ **35.** (a) 4**37.** (a) 18**39.** (a) -48**(b)**

(c) -40

**41.** $\frac{35}{2}$ **43.** $\frac{25}{4}$ **45.** $3 + \frac{9}{4}\pi$ **49.** $\lim_{n \rightarrow \infty} \sum_{i=1}^n \left(\sin \frac{5\pi i}{n} \right) \frac{\pi}{n} = \frac{2}{5}$ **51.** 0**53.** 3**55.** 22.5**57.** $\int_{-1}^5 f(x) dx$ **59.** 122**61.** B < E < A < D < C**63.** 15**69.** $0 \leq \int_0^1 x^3 dx \leq 1$ **71.** $\frac{\pi}{12} \leq \int_{\pi/4}^{\pi/3} \tan x dx \leq \frac{\pi}{12} \sqrt{3}$ **73.** $2 \leq \int_{-1}^1 \sqrt{1+x^4} dx \leq 2\sqrt{2}$ **77.** $\int_1^2 \sqrt{x} dx$ **83.** $\int_0^1 x^4 dx$ **85.** $\frac{1}{2}$ **EXERCISES 4.3 ■ PAGE 335**

1. One process undoes what the other one does. See the Fundamental Theorem of Calculus.

3. (a) 0, 2, 5, 7, 3 (d)**(b)** (0, 3)**(c)** $x = 3$ **5.** (a) $g(x) = 3x$ **7.**(a), (b) x^2 **9.** $g'(x) = \sqrt{x + x^3}$ **11.** $g'(w) = \sin(1 + w^3)$ **13.** $F'(x) = -\sqrt{1 + \sec x}$ **15.** $h'(x) = -\sin^4(1/x)/x^2$ **17.** $y' = \frac{3(3x+2)}{1+(3x+2)^3}$ **19.** $y' = -\frac{1}{2} \tan \sqrt{x}$ **21.** 3.75**23.** -2**25.** $\frac{26}{3}$ **27.** 2**29.** $\frac{52}{3}$ **31.** $\frac{512}{15}$ **33.** -1**35.** $-\frac{37}{6}$ **37.** $\frac{82}{5}$ **39.** $\frac{17}{6}$ **41.** 1**43.** $\frac{15}{4}$ **45.** 0**47.** $\frac{16}{3}$ **49.** $\frac{32}{3}$ **51.** $\frac{243}{4}$ **53.** 2

55. The function $f(x) = x^{-4}$ is not continuous on the interval $[-2, 1]$, so FTC2 cannot be applied.

57. The function $f(\theta) = \sec \theta \tan \theta$ is not continuous on the interval $[\pi/3, \pi]$, so FTC2 cannot be applied.

59. $g'(x) = \frac{-2(4x^2 - 1)}{4x^2 + 1} + \frac{3(9x^2 - 1)}{9x^2 + 1}$

61. $h'(x) = -\frac{1}{2\sqrt{x}} \cos x + 3x^2 \cos(x^6)$

63. $y = -\frac{1}{\pi}x + 1$

65. $(-4, 0)$ **67.** 29

69. (a) $-2\sqrt{n}, \sqrt{4n - 2}$, n an integer > 0

(b) $(0, 1), (-\sqrt{4n - 1}, -\sqrt{4n - 3})$, and $(\sqrt{4n - 1}, \sqrt{4n + 1})$, n an integer > 0 (c) 0.74

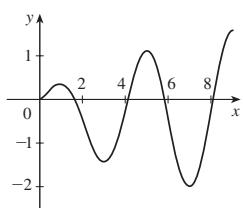
71. (a) Loc max at 1 and 5;

loc min at 3 and 7

(b) $x = 9$

(c) $(\frac{1}{2}, 2), (4, 6), (8, 9)$

(d) See graph at right.



73. $\frac{7}{10}$ **81.** $f(x) = x^{3/2}$, $a = 9$

83. (b) Average expenditure over $[0, t]$; to minimize average expenditure

85. $\ln 3$ **87.** $\pi/3$ **89.** $e^2 - 1$

EXERCISES 4.4 ■ PAGE 345

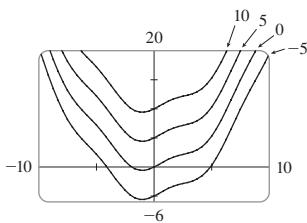
5. $x^3 + 2x^2 + x + C$ **7.** $\frac{1}{2}x^2 + \sin x + C$

9. $\frac{1}{23}x^{2.3} + 2x^{3.5} + C$ **11.** $5x + \frac{2}{9}x^3 + \frac{3}{16}x^4 + C$

13. $\frac{2}{3}u^3 + \frac{9}{2}u^2 + 4u + C$ **15.** $2\sqrt{x} + x + \frac{2}{3}x^{3/2} + C$

17. $\theta + \tan \theta + C$ **19.** $-3 \cot t + C$

21. $\sin x + \frac{1}{4}x^2 + C$



23. $-\frac{10}{3}$ **25.** 505.5 **27.** -2 **29.** 8

31. 36 **33.** $8/\sqrt{3}$ **35.** $\frac{55}{63}$ **37.** $2\sqrt{5}$

39. $1 + \pi/4$ **41.** 659,456/55

43. $\frac{5}{2}$ **45.** -3.5 **47.** ≈ 1.36 **49.** $\frac{4}{3}$

51. The increase in the child's weight (in kilograms) between the ages of 5 and 10

53. Number of liters of oil leaked in the first 2 hours (120 minutes)

55. Increase in revenue when production is increased from 1000 to 5000 units

57. Total number of heart beats during the first 30 min of exercise

59. Newton-meters (or joules) **61.** (a) $-\frac{3}{2}m$ (b) $\frac{41}{6}m$

63. (a) $v(t) = \frac{1}{2}t^2 + 4t + 5$ m/s (b) $416\frac{2}{3}$ m

65. $46\frac{2}{3}$ kg **67.** 2.3 km **69.** 83,462,400 m³

71. 12.1 m/s **73.** 332.6 gigawatt-hours

75. $-\cos x + \cosh x + C$ **77.** $\frac{1}{3}x^3 + x + \tan^{-1}x + C$

79. $\pi/6$

EXERCISES 4.5 ■ PAGE 355

1. $\frac{1}{2}\sin 2x + C$ **3.** $\frac{2}{9}(x^3 + 1)^{3/2} + C$

5. $-\frac{1}{4(x^4 - 5)} + C$ **7.** $2 \sin \sqrt{t} + C$

9. $-\frac{1}{3}(1 - x^2)^{3/2} + C$ **11.** $\frac{1}{3}\sin(x^3) + C$

13. $-(3/\pi)\cos(\pi t/3) + C$ **15.** $\frac{1}{3}\sec 3t + C$

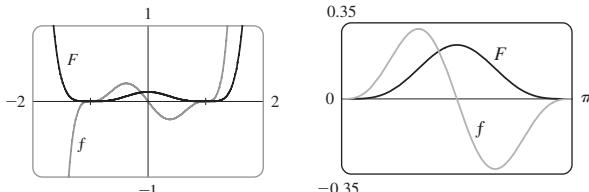
17. $\frac{1}{5}\sin(1 + 5t) + C$ **19.** $-\frac{1}{4}\cos^4 \theta + C$

21. $\frac{1}{12}\left(x^2 + \frac{2}{x}\right)^6 + C$ **23.** $\frac{2}{3}\sqrt{3ax + bx^3} + C$

25. $\frac{1}{2}(1 + z^3)^{2/3} + C$ **27.** $-\frac{2}{3}(\cot x)^{3/2} + C$

29. $\frac{1}{3}\sec^3 x + C$ **31.** $\frac{1}{40}(2x + 5)^{10} - \frac{5}{36}(2x + 5)^9 + C$

33. $\frac{1}{8}(x^2 - 1)^4 + C$ **35.** $\frac{1}{4}\sin^4 x + C$



37. $2/\pi$ **39.** $\frac{45}{28}$ **41.** $2/\sqrt{3} - 1$

43. 0 **45.** 3 **47.** $\frac{1}{3}(2\sqrt{2} - 1)a^3$ **49.** $\frac{16}{15}$

51. $\frac{1}{2}(\sin 4 - \sin 1)$ **53.** $\sqrt{3} - \frac{1}{3}$ **55.** 6π

57. $\frac{5}{4\pi}\left(1 - \cos \frac{2\pi t}{5}\right)L$

59. 5 **67.** $\frac{1}{4}\ln|4x + 7| + C$ **69.** $\frac{1}{3}(\ln x)^3 + C$

71. $\frac{2}{15}(2 + 3e^r)^{5/2} + C$ **73.** $\frac{1}{3}(\arctan x)^3 + C$

75. $\tan^{-1}x + \frac{1}{2}\ln(1 + x^2) + C$ **77.** $-\ln(1 + \cos^2 x) + C$

79. $\ln|\sin x| + C$ **81.** 2 **83.** $\ln(e + 1)$ **85.** $\pi^2/4$

CHAPTER 4 REVIEW ■ PAGE 357

True-False Quiz

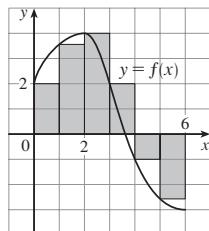
1. True 3. True 5. False 7. True 9. False

11. True 13. False 15. True 17. False

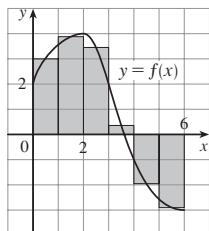
19. False

Exercises

1. (a) 8



(b) 5.7



3. $\frac{1}{2} + \pi/4$ 5. 3 7. f is c , f' is b , $\int_0^x f(t) dt$ is a .
 9. 3, 0 11. $-\frac{13}{6}$ 13. $\frac{9}{10}$ 15. -76 17. $\frac{21}{4}$
 19. Does not exist 21. $\frac{1}{3} \sin 1$ 23. 0
 25. $[1/(2\pi)] \sin^2 \pi t + C$ 27. $\frac{1}{2}\sqrt{2} - \frac{1}{2}$
 29. $-\frac{3}{5}(1-x)^{5/3} + \frac{3}{8}(1-x)^{8/3} + C$
 31. $\frac{23}{3}$ 33. $2\sqrt{1+\sin x} + C$ 35. $\frac{64}{5}$ 37. $\frac{124}{3}$
 39. (a) 2 (b) 6 41. $F'(x) = x^2/(1+x^3)$
 43. $g'(x) = 4x^3 \cos(x^8)$ 45. $y' = \frac{2 \cos x - \cos \sqrt{x}}{2x}$
 47. $4 \leq \int_1^3 \sqrt{x^2 + 3} dx \leq 4\sqrt{3}$ 51. 0.2810
 53. Number of barrels of oil consumed from Jan. 1, 2015, through Jan. 1, 2020
 55. 72,400 57. 3 59. $(1+x^2)(x \cos x + \sin x)/x^2$

PROBLEMS PLUS ■ PAGE 361

1. $\pi/2$ 3. $f(x) = \frac{1}{2}x$ 5. -1 7. $[-1, 2]$
 9. (a) $\frac{1}{2}(n-1)n$
 (b) $\frac{1}{2}\llbracket b \rrbracket(2b - \llbracket b \rrbracket - 1) - \frac{1}{2}\llbracket a \rrbracket(2a - \llbracket a \rrbracket - 1)$
 15. $y = -\frac{2b}{a^2}x^2 + \frac{3b}{a}x$ 17. $2(\sqrt{2} - 1)$

CHAPTER 5**EXERCISES 5.1 ■ PAGE 370**

1. (a) $\int_0^2 (2x - x^2) dx$ (b) $\frac{4}{3}$
 3. (a) $\int_0^1 (\sqrt{y} - y^2 + 1) dy$ (b) $\frac{4}{3}$
 5. 8 7. $\int_1^2 \left(\frac{1}{x} - \frac{1}{x^2}\right) dx$ 9. $\int_1^2 (-x^2 + 3x - 2) dx$
 11. $\frac{23}{6}$ 13. $\frac{9}{2}$ 15. $\frac{4}{3}$ 17. $\frac{8}{3}$ 19. 72
 21. $\frac{32}{3}$ 23. 4 25. 9 27. $\frac{1}{2}$ 29. $6\sqrt{3}$
 31. $\frac{13}{5}$ 33. $(4/\pi) - \frac{1}{2}$
 35. (a) 39 (b) 15 37. $\frac{4}{3}$ 39. $\frac{5}{2}$
 41. $\frac{3}{2}\sqrt{3} - 1$ 43. 0, 0.896; 0.037
 45. $-1.11, 1.25, 2.86; 8.38$ 47. 2.80123 49. 0.25142
 51. $12\sqrt{6} - 9$ 53. 36 m 55. 4232 cm²

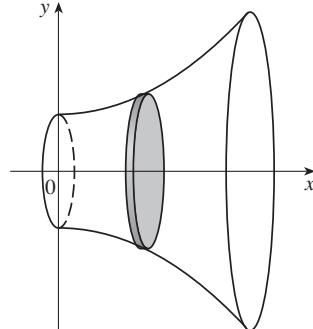
57. (a) Day 12 ($t \approx 11.26$) (b) Day 18 ($t \approx 17.18$)
 (c) 706 (cells/mL) · days

59. (a) Car A (b) The distance by which car A is ahead of car B after 1 minute

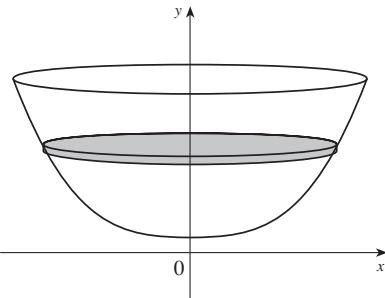
- (c) Car A (d) $t \approx 2.2$ min
 61. $\frac{24}{5}\sqrt{3}$ 63. $4^{2/3}$ 65. ± 6 67. $\frac{32}{27}$
 69. $2 - 2 \ln 2$ 71. $\ln 2$

EXERCISES 5.2 ■ PAGE 384

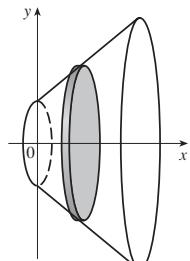
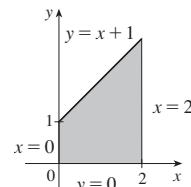
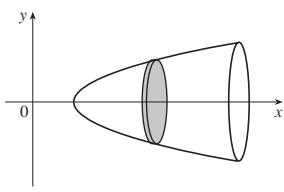
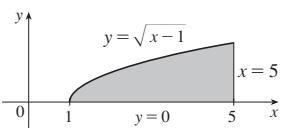
1.

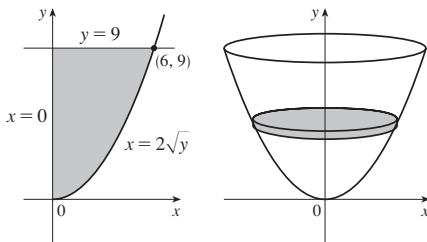
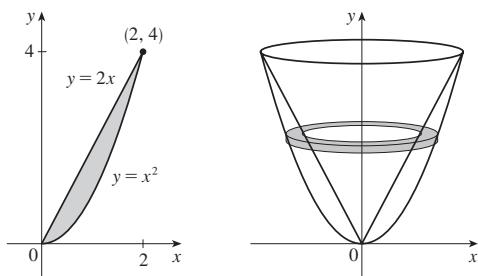
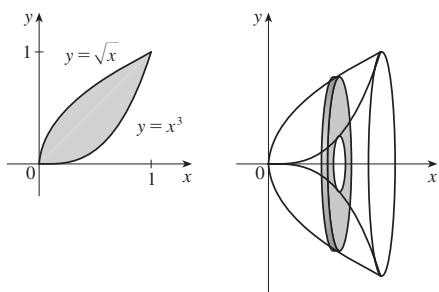
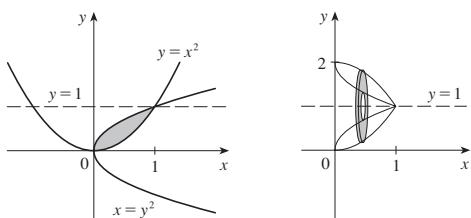
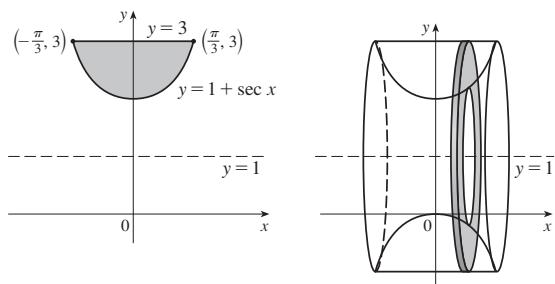
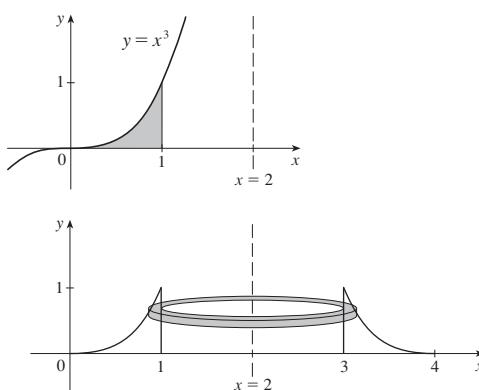
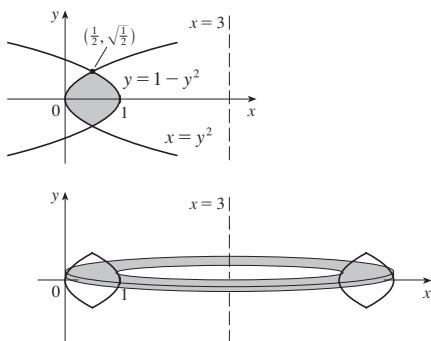
(b) $\int_0^3 \pi(x^4 + 10x^2 + 25) dx$ (c) $1068\pi/5$

3.

(b) $\int_1^9 \pi(y-1)^{2/3} dy$ (c) $96\pi/5$

5. $\int_1^3 \pi \left(1 - \frac{1}{x}\right)^2 dx$ 7. $\int_0^2 \pi(8y - y^4) dy$

9. $\int_0^\pi \pi[(2 + \sin x)^2 - 4] dx$ 11. $26\pi/3$ 13. 8π 

15. 162π

 17. $8\pi/3$

 19. $5\pi/14$

 21. $11\pi/30$

 23. $2\pi(\frac{4}{3}\pi - \sqrt{3})$

 25. $3\pi/5$

 27. $10\sqrt{2}\pi/3$

 29. $\pi/3$ 31. $\pi/3$ 33. $\pi/3$

 35. $13\pi/45$ 37. $\pi/3$ 39. $17\pi/45$

 41. (a) $\pi \int_0^{\pi/4} \tan^2 x \, dx \approx 0.67419$

 (b) $\pi \int_0^{\pi/4} (\tan^2 x + 2 \tan x) \, dx \approx 2.85178$

 43. (a) $2\pi \int_0^2 8\sqrt{1 - x^2/4} \, dx \approx 78.95684$

 (b) $2\pi \int_0^1 8\sqrt{4 - 4y^2} \, dy \approx 78.95684$

 45. $-1, 0.857; 9.756$ 47. $\frac{11}{8}\pi^2$

 49. Solid obtained by rotating the region $0 \leq x \leq \pi/2$, $0 \leq y \leq \sin x$ about the x -axis

 51. Solid obtained by rotating the region $0 \leq x \leq 1$, $x^3 \leq y \leq x^2$ about the x -axis

 53. Solid obtained by rotating the region $0 \leq y \leq 4$, $0 \leq x \leq \sqrt{y}$ about the y -axis

 55. 1110 cm^3 57. (a) 196 (b) 838

 59. $\frac{1}{3}\pi r^2 h$ 61. $\pi h^2(r - \frac{1}{3}h)$ 63. $\frac{2}{3}b^2 h$

 65. 10 cm^3 67. 24 69. $\frac{1}{3}$ 71. $\frac{8}{15}$ 73. $4\pi/15$

 75. (a) $8\pi R \int_0^r \sqrt{r^2 - y^2} \, dy$ (b) $2\pi r^2 R$

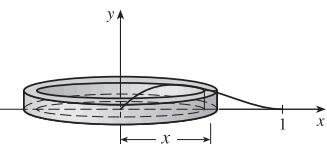
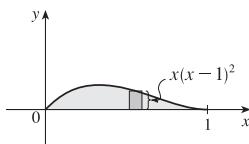
 77. $\int_0^4 \frac{2}{\sqrt{3}} y \sqrt{16 - y^2} \, dy = \frac{128}{3\sqrt{3}}$ 81. $\frac{5}{12}\pi r^3$

 83. $8 \int_0^r \sqrt{R^2 - y^2} \sqrt{r^2 - y^2} \, dy$

 87. (a) $93\pi/5$ (d) $\sqrt[3]{25,000/(93\pi)} \approx 4.41$

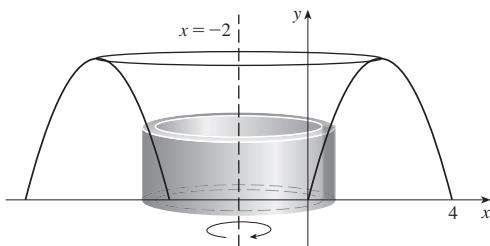
EXERCISES 5.3 ■ PAGE 392

1. Circumference = $2\pi x$, height = $x(x - 1)^2$; $\pi/15$



3. (a) $\int_0^{\sqrt{\pi/2}} 2\pi x \cos(x^2) dx$ (b) π 5. $\int_0^2 2\pi x \sqrt[4]{x} dx$
 7. $\int_0^2 2\pi(3 - y)(4 - y^2) dy$ 9. $128\pi/5$ 11. 6π
 13. $\frac{2}{3}\pi(27 - 5\sqrt{5})$ 15. 4π 17. 192π 19. $16\pi/3$
 21. $384\pi/5$

23. (a)



- (b) $\int_0^4 2\pi(x + 2)(4x - x^2) dx$ (c) $256\pi/3$

25. $264\pi/5$ 27. $8\pi/3$ 29. $13\pi/3$

31. (a) $\int_{2\pi}^{3\pi} 2\pi x \sin x dx$ (b) 98.69604

33. (a) $4\pi \int_{-\pi/2}^{\pi/2} (\pi - x) \cos^4 x dx$ (b) 46.50942

35. (a) $\int_0^\pi 2\pi(4 - y)\sqrt{\sin y} dy$ (b) 36.57476 37. 3.68

39. Solid obtained by rotating the region $0 \leq y \leq x^4$, $0 \leq x \leq 3$ about the y-axis

41. Solid obtained (using shells) by rotating the region $0 \leq x \leq 1/y^2$, $1 \leq y \leq 4$ about the line $y = -2$

43. 0, 2.175; 14.450 45. $\frac{1}{32}\pi^3$

47. (a) $\int_0^1 2\pi x \left(2 - \sqrt[3]{x} - x\right) dx$ (b) $10\pi/21$

49. (a) $\int_0^\pi \pi \sin x dx$ (b) 2π

51. (a) $\int_0^{1/2} 2\pi(x + 2)(x^2 - x^3) dx$ (b) $59\pi/480$

53. 8π 55. $4\sqrt{3}\pi$ 57. $4\pi/3$

59. $117\pi/5$ 61. $\frac{4}{3}\pi r^3$ 63. $\frac{1}{3}\pi r^2 h$

EXERCISES 5.4 ■ PAGE 398

1. 980 J 3. 4.5 J 5. 180 J 7. $\frac{81}{16}\text{ J}$

9. (a) $\frac{25}{24} \approx 1.04\text{ J}$ (b) 10.8 cm 11. $W_2 = 3W_1$

13. (a) $\frac{6615}{8}\text{ J}$ (b) $\approx 620\text{ J}$ 15. $845,250\text{ J}$

17. 73.5 J 19. $\approx 3857\text{ J}$ 21. 2450 J

23. $\approx 1.06 \times 10^6\text{ J}$ 25. $\approx 176,000\text{ J}$

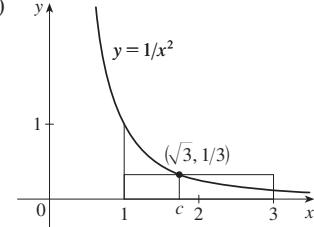
27. $\approx 2.0\text{ m}$ 33. $\approx 32.14\text{ m/s}$

35. (a) $Gm_1m_2 \left(\frac{1}{a} - \frac{1}{b} \right)$ (b) $\approx 8.50 \times 10^9\text{ J}$

EXERCISES 5.5 ■ PAGE 403

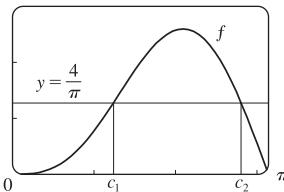
1. 7 3. $6/\pi$ 5. $29,524/15$ 7. $2/(5\pi)$

9. (a) $\frac{1}{3}$ (b) $\sqrt{3}$ (c)



11. (a) $4/\pi$ (b) $\approx 1.24, 2.81$

- (c) 3



15. $\frac{9}{8}$ 17. $(10 + 8/\pi)^\circ\text{C} \approx 12.5^\circ\text{C}$ 19. 6 kg/m

21. $5/(4\pi) \approx 0.40\text{ L}$

CHAPTER 5 REVIEW ■ PAGE 406**True-False Quiz**

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

Exercises

1. $\frac{64}{3}$ 3. $\frac{7}{12}$ 5. $\frac{4}{3} + 4/\pi$ 7. $64\pi/15$ 9. $1656\pi/5$

11. $\frac{4}{3}\pi(2ah + h^2)^{3/2}$

13. $\int_{-\pi/3}^{\pi/3} 2\pi(\pi/2 - x)(\cos^2 x - \frac{1}{4}) dx$

15. $189\pi/5$ 17. (a) $2\pi/15$ (b) $\pi/6$ (c) $8\pi/15$

19. (a) 0.38 (b) 0.87

21. Solid obtained by rotating the region $0 \leq y \leq \cos x$, $0 \leq x \leq \pi/2$ about the y-axis

23. Solid obtained by rotating the region $0 \leq y \leq 2 - \sin x$, $0 \leq x \leq \pi$ about the x-axis

25. 36 27. $\frac{125}{3}\sqrt{3}\text{ m}^3$ 29. 3.2 J

31. (a) $10,640\text{ J}$ (b) 0.7 m

33. $4/\pi$ 35. (a) No (b) Yes (c) No (d) Yes

PROBLEMS PLUS ■ PAGE 408

1. $f(x) = \sqrt{2x/\pi}$ 3. $y = \frac{32}{9}x^2$ 7. $2/\sqrt{5}$

9. (a) $V = \int_0^h \pi[f(y)]^2 dy$

- (c) $f(y) = \sqrt{kA/(\pi C)}y^{1/4}$. Advantage: the markings on the container are equally spaced.

11. $b = 2a$ 13. $B = 16A$

CHAPTER 6**EXERCISES 6.1 ■ PAGE 418**

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

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

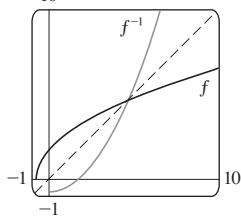
13. No 15. No 17. (a) 6 (b) 3 19. 4

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

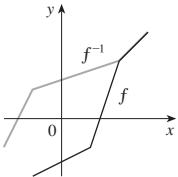
$$23. f^{-1}(x) = \frac{5}{4} - \frac{1}{4}x \quad 25. f^{-1}(x) = \sqrt{1-x}$$

$$27. g^{-1}(x) = (x-2)^2 - 1, x \geq 2 \quad 29. y = (\sqrt[5]{x} - 2)^3$$

$$31. f^{-1}(x) = \frac{1}{4}(x^2 - 3), x \geq 0$$



33.



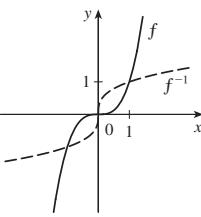
35. (a) $f^{-1}(x) = \sqrt{1-x^2}, 0 \leq x \leq 1$; f^{-1} and f are the same function. (b) Quarter-circle in the first quadrant

37. (b) $\frac{1}{12}$

(c) $f^{-1}(x) = \sqrt[3]{x}$,

domain = \mathbb{R} = range

(e)

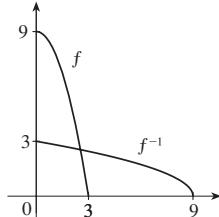


39. (b) $-\frac{1}{2}$

(c) $f^{-1}(x) = \sqrt{9-x}$,

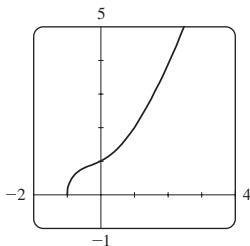
domain = $[0, 9]$, range = $[0, 3]$

(e)



41. $\frac{1}{6}$ 43. $2/\pi$ 45. $\frac{3}{2}$ 47. $1/\sqrt{28}$

49. The graph passes the Horizontal Line Test.



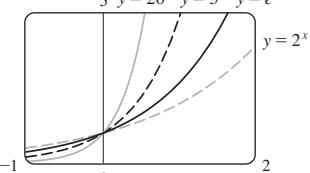
$$f^{-1}(x) = -\frac{1}{6}\sqrt[3]{4}(\sqrt[3]{D - 27x^2 + 20} - \sqrt[3]{D + 27x^2 - 20} + \sqrt[3]{2}),$$

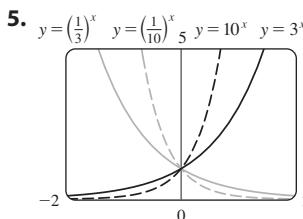
where $D = 3\sqrt{3}\sqrt{27x^4 - 40x^2 + 16}$; two of the expressions are complex.

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

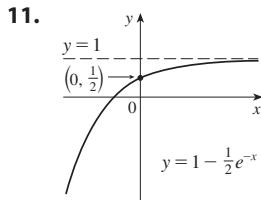
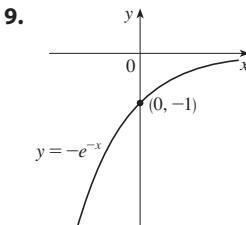
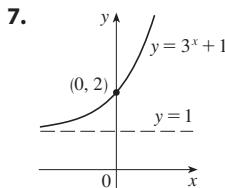
EXERCISES 6.2 ■ PAGE 429

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

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



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



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

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

17. $f(x) = 3 \cdot 2^x$ 21. At $x \approx 35.8$ 23. ∞

25. 1 27. 0 29. 0 31. $f'(t) = -2e^t$

33. $f'(x) = e^x(3x^2 + x - 5)$ 35. $y' = 3ax^2 e^{ax^3}$

37. $y' = (\sec^2 \theta) e^{\tan \theta}$ 39. $f'(x) = \frac{x e^x (x^3 + 2e^x)}{(x^2 + e^x)^2}$

41. $y' = x e^{-3x}(2 - 3x)$ 43. $f'(t) = e^{at}(b \cos bt + a \sin bt)$

45. $F'(t) = e^{t \sin 2t}(2t \cos 2t + \sin 2t)$

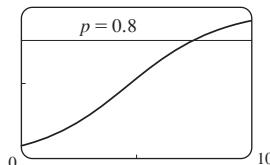
47. $g'(u) = ue^{\sqrt{\sec u^2}} \sqrt{\sec u^2} \tan u^2$

49. $g'(x) = \frac{e^x}{(1+e^x)^2} \cos\left(\frac{e^x}{1+e^x}\right)$ 51. $y = 2x + 1$

53. $y' = \frac{y(y - e^{x/y})}{y^2 - xe^{x/y}}$ 57. $-4, -2$

59. $f^{(n)}(x) = 2^n e^{2x}$ 61. (b) -0.567143 63. 3.5 days

65. (a) 1 (b) $kae^{-kt}/(1+ae^{-kt})^2$
 (c) 1 $t \approx 7.4$ h



67. $f(3) = e^3/10, f(0) = 1$ 69. -1

71. (a) Inc on $(-\frac{1}{2}, \infty)$; dec on $(-\infty, -\frac{1}{2})$

(b) CU on $(-1, \infty)$; CD on $(-\infty, -1)$ (c) $\left(-1, -\frac{1}{e^2}\right)$

73. A. $\{x | x \neq -1\}$

B. y-int $1/e$ C. None

D. HA $y = 1$; VA $x = -1$

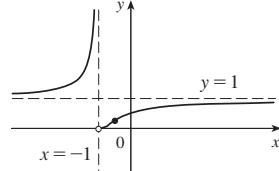
E. Inc on $(-\infty, -1), (-1, \infty)$

F. None

G. CU on $(-\infty, -1), (-1, -\frac{1}{2})$

CD on $(-\frac{1}{2}, \infty)$; IP $(-\frac{1}{2}, 1/e^2)$

H. See graph at right.



75. A. \mathbb{R} B. y-int $\frac{1}{2}$ C. None

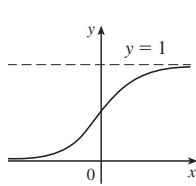
D. HA $y = 0, y = 1$

E. Inc on \mathbb{R} F. None

G. CU on $(-\infty, 0)$;

CD on $(0, \infty)$; IP $(0, \frac{1}{2})$

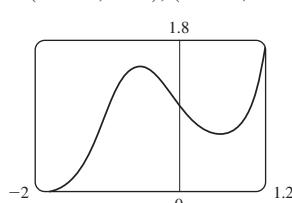
H. See graph at right.



77. Loc max $f(-1/\sqrt{3}) = e^{2\sqrt{3}/9} \approx 1.5$;

loc min $f(1/\sqrt{3}) = e^{-2\sqrt{3}/9} \approx 0.7$;

IP $(-0.15, 1.15), (-1.09, 0.82)$



79. 0.0177 g/dL; 21.4 min

81. $\frac{1}{e+1} + e - 1$ 83. $\frac{1}{\pi}(1 - e^{-2\pi})$

85. $\frac{2}{3}(1 + e^x)^{3/2} + C$ 87. $\frac{1}{2}e^{2x} + 2x - \frac{1}{2}e^{-2x} + C$

89. $\frac{1}{1-e^u} + C$ 91. $e - \sqrt{e}$ 93. $\frac{1}{2}(1 - e^{-4})$

95. 4.644 97. $\pi(e^2 - 1)/2$

99. All three areas are equal. 101. ≈ 4512 L

103. $C_0(1 - e^{-30r/V})$; the total amount of urea removed from the blood in the first 30 minutes of dialysis treatment

105. $\frac{1}{2}$

EXERCISES 6.3 ■ PAGE 438

1. (a) It's defined as the inverse of the exponential function with base b , that is, $\log_b x = y \iff b^y = x$.

(b) $(0, \infty)$ (c) \mathbb{R} (d) See Figure 1.

3. (a) 4 (b) -4 (c) $\frac{1}{2}$

5. (a) 1 (b) -2 (c) -4

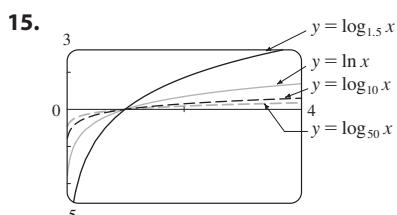
7. (a) $2 \log_{10} x + 3 \log_{10} y + \log_{10} z$

(b) $4 \ln x - \frac{1}{2} \ln(x+2) - \frac{1}{2} \ln(x-2)$

9. (a) $\log_{10} 2$ (b) $\ln \frac{ac^3}{b^2}$

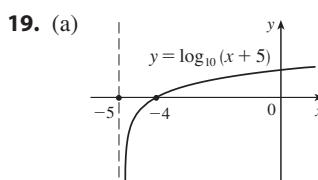
11. (a) $\ln[(x-2)^2(x-3)]$ (b) $\log_a \left(\frac{x^c z}{y^d} \right)$

13. (a) 2.261860 (b) 0.721057

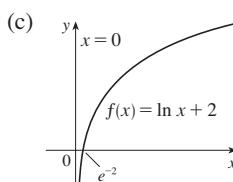


All graphs approach $-\infty$ as $x \rightarrow 0^+$, all pass through $(1, 0)$, and all are increasing. The larger the base, the slower the rate of increase.

17. About 335,544 km



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



23. (a) $\frac{1}{4}(e^3 - 2) \approx 4.521$ (b) $\frac{1}{2}(3 + \ln 12) \approx 2.742$

25. (a) $\frac{1}{2}(1 + \sqrt{5}) \approx 1.618$ (b) $\frac{1}{2} - \frac{\ln 9}{2 \ln 5} \approx -0.183$

27. (a) 0 or $\ln 2$ (b) $\ln \ln 10$

29. (a) 3.7704 (b) 0.3285

31. (a) $0 < x < 1$ (b) $x > \ln 5$ 33. 8.3

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

37. $-\infty$ 39. 0 41. ∞ 43. $(-2, 2)$

45. (a) $(-\infty, \frac{1}{2} \ln 3]$ (b) $f^{-1}(x) = \frac{1}{2} \ln(3 - x^2), [0, \sqrt{3}]$

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

49. $y = e^{x/3} + 2$ 51. $y = 1 - \ln x$

53. $y = 2 + \frac{1}{2} \log_3 x$ 55. $(-\frac{1}{2} \ln 3, \infty)$

57. (b) $f^{-1}(x) = \frac{1}{2}(e^x - e^{-x})$

59. f is a constant function.

63. $-1 \leq x < 1 - \sqrt{3}$ or $1 + \sqrt{3} < x \leq 3$

EXERCISES 6.4 ■ PAGE 448

1. The differentiation formula is simplest.

3. $f'(x) = \frac{2x+3}{x^2+3x+5}$ 5. $f'(x) = \frac{\cos(\ln x)}{x}$

7. $f'(x) = -\frac{1}{x}$ 9. $g'(x) = \frac{1}{x} - 2$

11. $F'(t) = \ln t \left(\ln t \cos t + \frac{2 \sin t}{t} \right)$

13. $y' = \frac{2x+3}{(x^2+3x)\ln 8}$ 15. $f'(u) = \frac{1+\ln 2}{u[1+\ln(2u)]^2}$

17. $f'(x) = 5x^4 + 5^x \ln 5$

19. $T'(z) = 2^z \left(\frac{1}{z \ln 2} + \ln z \right)$

21. $g'(t) = \frac{1}{t} + \frac{8t}{t^2+1} - \frac{2}{3(2t-1)}$ 23. $y' = \frac{-10x^4}{3-2x^5}$

25. $y' = \sec^2[\ln(ax+b)] \frac{a}{ax+b}$

27. $G'(x) = -C(\ln 4) \frac{4^{Cx}}{x^2}$

31. $y' = (2 + \ln x)/(2\sqrt{x}); y'' = -\ln x/(4x\sqrt{x})$

33. $y' = \tan x; y'' = \sec^2 x$

35. $f'(x) = \frac{2x-1-(x-1)\ln(x-1)}{(x-1)[1-\ln(x-1)]^2}; (1, 1+e) \cup (1+e, \infty)$

37. $f'(x) = \frac{2(x-1)}{x(x-2)}; (-\infty, 0) \cup (2, \infty)$ 39. 2

41. $y = 3x - 9$ 43. $\cos x + 1/x$ 45. 7

47. $y' = (x^2+2)^2(x^4+4)^4 \left(\frac{4x}{x^2+2} + \frac{16x^3}{x^4+4} \right)$

49. $y' = \sqrt{\frac{x-1}{x^4+1}} \left(\frac{1}{2x-2} - \frac{2x^3}{x^4+1} \right)$

51. $y' = x^x(1 + \ln x)$

53. $y' = x^{\sin x} \left(\frac{\sin x}{x} + \ln x \cos x \right)$

55. $y' = (\cos x)^x(-x \tan x + \ln \cos x)$

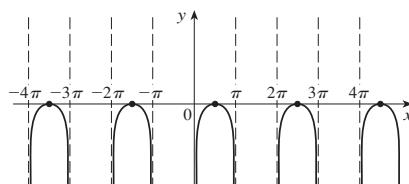
57. $y' = \frac{(2x^{\ln x})\ln x}{x}$ 59. $y' = \frac{2x}{x^2+y^2-2y}$

61. $f^{(n)}(x) = \frac{(-1)^{n-1}(n-1)!}{(x-1)^n}$

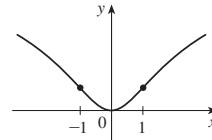
63. CU on $(e^{8/3}, \infty)$, CD on $(0, e^{8/3})$, IP $(e^{8/3}, \frac{8}{3}e^{-4/3})$

65. A. All x in $(2n\pi, (2n+1)\pi)$ (n an integer)B. x -int $\pi/2 + 2n\pi$ C. Period 2π D. VA $x = n\pi$ E. Inc on $(2n\pi, \pi/2 + 2n\pi)$; dec on $(\pi/2 + 2n\pi, (2n+1)\pi)$ F. Loc max $f(\pi/2 + 2n\pi) = 0$ G. CD on $(2n\pi, (2n+1)\pi)$

H.

67. A. \mathbb{R} B. y-int 0; x -int 0

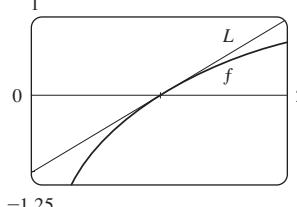
C. About y-axis D. None

E. Inc on $(0, \infty)$; dec on $(-\infty, 0)$ F. Loc min $f(0) = 0$ G. CU on $(-1, 1)$; CD on $(-\infty, -1), (1, \infty)$ IP $(\pm 1, \ln 2)$ H. See graph at right.69. Inc on $(0, 2.7), (4.5, 8.2), (10.9, 14.3)$ IP $(3.8, 1.7), (5.7, 2.1), (10.0, 2.7), (12.0, 2.9)$

71. 2.958516, 5.290718

73. (a) $\ln x \approx x - 1$

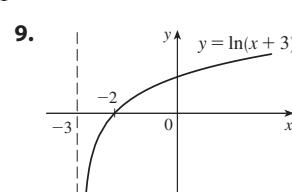
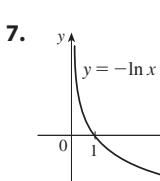
(b)

73. (c) Approximately $0.62 \leq x \leq 1.51$ 75. $3 \ln 2$ 77. $\frac{1}{3} \ln \frac{5}{2}$ 79. $20 + \ln 3$ 81. $\frac{1}{3}(\ln x)^3 + C$ 83. $-\ln(1 + \cos^2 x) + C$ 85. $\frac{15}{\ln 2}$ 89. $\pi \ln 2$ 91. 45,974 J 93. $\frac{1}{3}$ 95. $0 < m < 1; m - 1 - \ln m$ **EXERCISES 6.2* ■ PAGE 458**

1. (a) $\frac{1}{2} \ln a + \frac{1}{2} \ln b$ (b) $4 \ln x - \frac{1}{2} \ln(x+2) - \frac{1}{2} \ln(x-2)$

3. (a) $\ln \frac{ac^3}{b^2}$ (b) $\ln \frac{4a}{\sqrt[3]{a+1}}$

5. (a) $\ln 6$ (b) $\ln \frac{\sqrt{x}}{x+1}$



11. 0 13. ∞ 15. $f'(x) = x^2 + 3x^2 \ln x$

17. $f'(x) = \frac{2x+3}{x^2+3x+5}$ 19. $f'(x) = \frac{\cos(\ln x)}{x}$

21. $f'(x) = -\frac{1}{x}$ 23. $f'(x) = \frac{\sin x}{x} + \cos x \ln(5x)$

25. $F'(t) = \ln t \cos t + \frac{2 \sin t}{t}$

27. $y' = \frac{2 \ln \tan x}{\sin x \cos x}$ 29. $f'(u) = \frac{1 + \ln 2}{u[1 + \ln(2u)]^2}$

31. $g'(t) = \frac{1}{t} + \frac{8t}{t^2 + 1} - \frac{2}{3(2t - 1)}$

33. $y' = \frac{-10x^4}{3 - 2x^5}$

37. $y' = (2 + \ln x)/(2\sqrt{x})$; $y'' = -\ln x/(4x\sqrt{x})$

39. $y' = \tan x$; $y'' = \sec^2 x$

41. $f'(x) = \frac{2x - 1 - (x - 1) \ln(x - 1)}{(x - 1)[1 - \ln(x - 1)]^2}$,
 $(1, 1 + e) \cup (1 + e, \infty)$

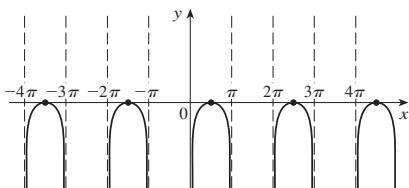
43. $f'(x) = \frac{2(x - 1)}{x(x - 2)}$; $(-\infty, 0) \cup (2, \infty)$ 45. 2

47. $\cos x + 1/x$

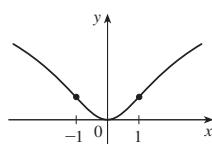
49. $y = 2x - 2$ 51. $y' = \frac{2x}{x^2 + y^2 - 2y}$

53. $f^{(n)}(x) = \frac{(-1)^{n-1}(n-1)!}{(x-1)^n}$

55. A. All x in $(2n\pi, (2n+1)\pi)$ (n an integer)
 B. x -int $\pi/2 + 2n\pi$ C. Period 2π D. VA $x = n\pi$
 E. Inc on $(2n\pi, \pi/2 + 2n\pi)$; dec on $(\pi/2 + 2n\pi, (2n+1)\pi)$
 F. Loc max $f(\pi/2 + 2n\pi) = 0$ G. CD on $(2n\pi, (2n+1)\pi)$
 H.



57. A. \mathbb{R} B. y-int 0; x -int 0
 C. About y -axis D. None
 E. Inc on $(0, \infty)$; dec on $(-\infty, 0)$
 F. Loc min $f(0) = 0$
 G. CU on $(-1, 1)$;
 CD on $(-\infty, -1), (1, \infty)$;
 IP $(\pm 1, \ln 2)$ H. See graph at right.



59. Inc on $(0, 2.7), (4.5, 8.2), (10.9, 14.3)$;
 IP $(3.8, 1.7), (5.7, 2.1), (10.0, 2.7), (12.0, 2.9)$

61. 2.958516, 5.290718

63. $y' = (x^2 + 2)^2(x^4 + 4)^4 \left(\frac{4x}{x^2 + 2} + \frac{16x^3}{x^4 + 4} \right)$

65. $y' = \sqrt{\frac{x-1}{x^4+1}} \left(\frac{1}{2x-2} - \frac{2x^3}{x^4+1} \right)$

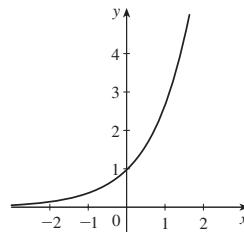
67. $3 \ln 2$ 69. $\frac{1}{3} \ln \frac{5}{2}$ 71. $20 + \ln 3$

73. $\frac{1}{3}(\ln x)^3 + C$ 75. $-\ln(1 + \cos^2 x) + C$

79. $\pi \ln 2$ 81. 45,974 J 83. $\frac{1}{3}$ 85. (b) 0.405
 89. $0 < m < 1$; $m - 1 - \ln m$

EXERCISES 6.3* ■ PAGE 465

1.



If $f(x) = e^x$, then $f'(0) = 1$.

3. (a) -2 (b) $\frac{1}{2}$ (c) $\sin x$

5. (a) $\frac{1}{4}(e^3 - 2) \approx 4.521$ (b) $\frac{1}{2}(3 + \ln 12) \approx 2.742$

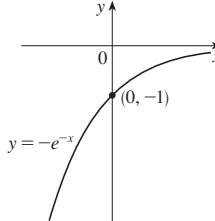
7. (a) $\frac{1}{2}(1 + \sqrt{5}) \approx 1.618$ (b) $-\frac{1}{2} \ln(e - 1) \approx -0.271$

9. (a) 0 or $\ln 2$ (b) $\ln \ln 10$

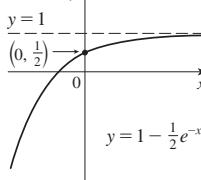
11. (a) 3.7704 (b) 0.3285

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

15.



17.



19. (a) $(-\infty, \frac{1}{2} \ln 3]$ (b) $f^{-1}(x) = \frac{1}{2} \ln(3 - x^2), [0, \sqrt{3}]$

21. $y = e^{x/3} + 2$ 23. $y = 1 - \ln x$

25. 1 27. 0 29. 0

31. $f'(t) = -2e^t$

33. $f'(x) = e^x(3x^2 + x - 5)$

35. $y' = 3ax^2 e^{ax^3}$

37. $y' = (\sec^2 \theta) e^{\tan \theta}$ 39. $f'(x) = \frac{xe^x(x^3 + 2e^x)}{(x^2 + e^x)^2}$

41. $y' = xe^{-3x}(2 - 3x)$ 43. $f'(t) = e^{at}(b \cos bt + a \sin bt)$

45. $F'(t) = e^{t \sin 2t}(2t \cos 2t + \sin 2t)$

47. $g'(u) = ue^{\sqrt{\sec u^2}} \sqrt{\sec u^2} \tan u^2$

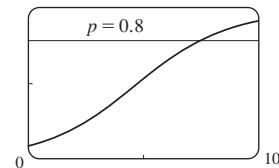
49. $g'(x) = \frac{e^x}{(1 + e^x)^2} \cos \left(\frac{e^x}{1 + e^x} \right)$ 51. $y = 2x + 1$

53. $y' = \frac{y(y - e^{x/y})}{y^2 - xe^{x/y}}$ 57. $-4, -2$

59. $f^{(n)}(x) = 2^n e^{2x}$ 61. (b) -0.567143

63. (a) 1 (b) $kae^{-kt}/(1 + ae^{-kt})^2$

- (c) 1 $t \approx 7.4$ h



65. $f(3) = e^3/10, f(0) = 1$ 67. -1

69. (a) Inc on $(-\frac{1}{2}, \infty)$; dec on $(-\infty, -\frac{1}{2})$ (b) CU on $(-1, \infty)$; CD on $(-\infty, -1)$ (c) $\left(-1, -\frac{1}{e^2}\right)$

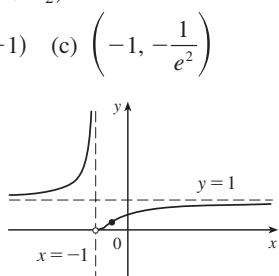
71. A. $\{x | x \neq -1\}$

B. y -int $1/e$ C. NoneD. HA $y = 1$; VA $x = -1$ E. Inc on $(-\infty, -1), (-1, \infty)$

F. None

G. CU on $(-\infty, -1), (-1, -\frac{1}{2})$ CD on $(-\frac{1}{2}, \infty)$; IP $(-\frac{1}{2}, 1/e^2)$

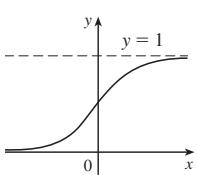
H. See graph at right.



73. A. \mathbb{R} B. y -int $\frac{1}{2}$ C. None

D. HA $y = 0, y = 1$ E. Inc on \mathbb{R} F. NoneG. CU on $(-\infty, 0)$ CD on $(0, \infty)$; IP $(0, \frac{1}{2})$

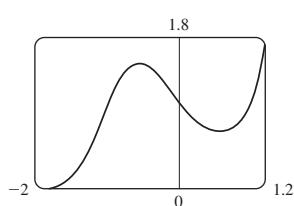
H. See graph at right.



75. Loc max $f(-1/\sqrt{3}) = e^{2\sqrt{3}/9} \approx 1.5$;

loc min $f(1/\sqrt{3}) = e^{-2\sqrt{3}/9} \approx 0.7$;

IP $(-0.15, 1.15), (-1.09, 0.82)$



77. $0.0177 \text{ g/dL}; 21.4 \text{ min}$

79. $\frac{1}{e+1} + e - 1$ 81. $\frac{1}{\pi}(1 - e^{-2\pi})$

83. $\frac{2}{3}(1 + e^x)^{3/2} + C$ 85. $\frac{1}{2}e^{2x} + 2x - \frac{1}{2}e^{-2x} + C$

87. $\frac{1}{1 - e^u} + C$ 89. $e - \sqrt{e}$ 91. $\frac{1}{2}(1 - e^{-4})$

93. 4.644 95. $\pi(e^2 - 1)/2$

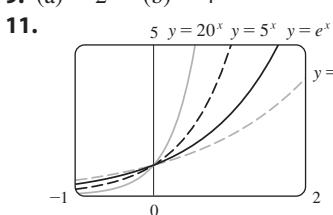
97. All three areas are equal. 99. $\approx 4512 \text{ L}$ 101. $C_0(1 - e^{-30r/V})$; the total amount of urea removed from the blood in the first 30 minutes of dialysis treatment**EXERCISES 6.4* ■ PAGE 476**

1. (a) $b^x = e^{x \ln b}$ (b) $(-\infty, \infty)$ (c) $(0, \infty)$

(d) See Figures 1, 3, and 2.

3. $e^{-\pi \ln 4}$ 5. $e^{x^2 \ln 10}$ 7. (a) 4 (b) -4 (c) $\frac{1}{2}$

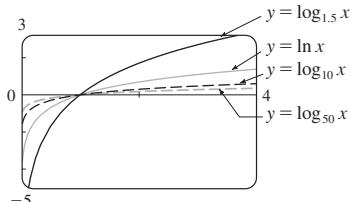
9. (a) -2 (b) -4



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

13. (a) 1.430677 (b) 2.261860 (c) 0.721057

15.



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

17. $f(x) = 3 \cdot 2^x$ 19. (b) About 335,544 km

21. ∞ 23. 0 25. $f'(x) = 5x^4 + 5^x \ln 5$

27. $G'(x) = -C(\ln 4) \frac{4^{C/x}}{x^2}$

29. $L'(v) = 2v \ln 4 \sec^2(4^{v^2}) \cdot 4^{v^2}$ 31. $y' = \frac{2x+3}{(x^2+3x)\ln 8}$

33. $y' = \frac{x \cot x}{\ln 4} + \log_4 \sin x$ 35. $y' = x^x(1 + \ln x)$

37. $y' = x^{\sin x} \left(\frac{\sin x}{x} + \ln x \cos x \right)$

39. $y' = (\cos x)^x(-x \tan x + \ln \cos x)$ 41. $y' = \frac{(2x^{\ln x})\ln x}{x}$

43. $y = (10 \ln 10)x + 10(1 - \ln 10)$ 45. $\frac{15}{\ln 2}$

47. $(\ln x)^2/(2 \ln 10) + C$ [or $\frac{1}{2}(\ln 10)(\log_{10} x)^2 + C$]

49. $3^{\sin \theta} / \ln 3 + C$ 51. $16/(5 \ln 5) - 1/(2 \ln 2)$

53. 0.600967 55. $g^{-1}(x) = \sqrt[3]{4^x - 2}$ 57. 8.3

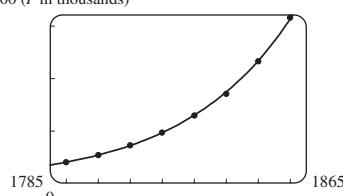
59. $10^8 / \ln 10 \text{ dB/(watt/m}^2\text{)}$

61. (a) $\frac{1}{D \ln 2}$; decreases

(b) $-\frac{1}{W \ln 2}$; difficulty decreases with increasing width; increases

63. 3.5 days

65. (a) 32,000 (P in thousands)



The fit appears
to be very good.

(b) 165,550 people/year; 719,000 people/year

(c) 156,850 people/year; 686,070 people/year; these estimates are somewhat less

(d) 41,946,560; likely due to the Civil War

EXERCISES 6.5 ■ PAGE 484

1. About 8.7 million

3. (a) $50e^{1.9803t}$ (b) $\approx 19,014$

(c) $\approx 37,653 \text{ cells/h}$ (d) $\approx 4.30 \text{ h}$

5. (a) 1508 million, 1871 million (b) 2161 million
 (c) 3972 million; wars in the first half of century, increased life expectancy in second half
 7. (a) $Ce^{-0.0005t}$ (b) $-2000 \ln 0.9 \approx 211$ s
 9. (a) $100 \times 2^{-t/30}$ mg (b) ≈ 9.92 mg (c) ≈ 199.3 years
 11. ≈ 2500 years 13. Yes; 12.5 billion years
 15. (a) $\approx 58^\circ\text{C}$ (b) ≈ 89 min
 17. (a) 13.3°C (b) ≈ 67.74 min
 19. (a) ≈ 64.5 kPa (b) ≈ 39.9 kPa
 21. (a) (i) \$4362.47 (ii) \$4364.11 (iii) \$4365.49
 (iv) \$4365.70 (v) \$4365.76 (vi) \$4365.77
 (b) $dA/dt = 0.0175A$, $A(0) = 4000$

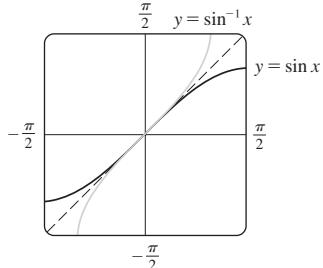
EXERCISES 6.6 ■ PAGE 493

1. (a) $\pi/6$ (b) π 3. (a) $\pi/4$ (b) $\pi/6$

5. (a) 10 (b) $-\pi/4$ 7. $2/\sqrt{5}$

9. $\frac{119}{169}$ 13. $x/\sqrt{1+x^2}$

15.



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

23. $f'(x) = \frac{5}{\sqrt{1-25x^2}}$

25. $y' = \frac{2 \tan^{-1} x}{1+x^2}$ 27. $y' = \frac{1}{2x\sqrt{x-1}}$

29. $y' = -\frac{\sin \theta}{1+\cos^2 \theta}$ 31. $f'(z) = \frac{2ze^{\arcsin(z^2)}}{\sqrt{1-z^4}}$

33. $h'(t) = 0$ 35. $y' = \sin^{-1} x$

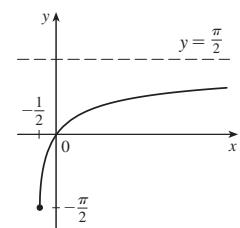
37. $y' = \frac{a}{x^2+a^2} + \frac{a}{x^2-a^2}$

39. $g'(x) = \frac{2}{\sqrt{1-(3-2x)^2}}$; [1, 2], (1, 2) 41. $\pi/6$

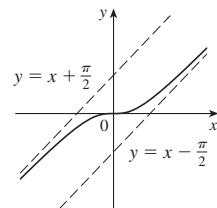
43. $1 - \frac{x \arcsin x}{\sqrt{1-x^2}}$ 45. $-\pi/2$ 47. $\pi/2$

49. At a distance $5 - 2\sqrt{5}$ from A 51. $-\frac{1}{2}$ rad/s

53. A. $[-\frac{1}{2}, \infty)$
 B. y-int 0; x-int 0
 C. None
 D. HA $y = \pi/2$
 E. Inc on $(-\frac{1}{2}, \infty)$
 F. None
 G. CD on $(-\frac{1}{2}, \infty)$
 H. See graph at right.

55. A. \mathbb{R}

- B. y-int 0; x-int 0
 C. About (0, 0)
 D. SA $y = x \pm \pi/2$
 E. Inc on \mathbb{R} F. None
 G. CU on $(0, \infty)$; CD on $(-\infty, 0)$; IP (0, 0)
 H. See graph at right.

57. Max at $x = 0$, min at $x \approx \pm 0.87$, IP at $x \approx \pm 0.52$

59. $F(x) = 2x + 3 \tan^{-1} x + C$ 61. $4\pi/3$ 63. $\pi^2/72$

65. $\tan^{-1} x + \frac{1}{2} \ln(1+x^2) + C$ 67. $\frac{1}{3}(\arctan x)^3 + C$

69. $e^{\arcsin x} + C$ 71. $\frac{1}{3} \sin^{-1}(t^3) + C$

73. $2 \tan^{-1} \sqrt{x} + C$ 77. $\pi/2 - 1$

EXERCISES 6.7 ■ PAGE 501

1. (a) 0 (b) 1 3. (a) $\frac{13}{5}$ (b) $\frac{1}{2}(e^5 + e^{-5}) \approx 74.20995$

5. (a) 1 (b) 0 7. $\frac{13}{2}e^x - \frac{3}{2}e^{-x}$ 9. $\frac{x^2 - 1}{2x}$

25. $\operatorname{sech} x = \frac{3}{5}$, $\sinh x = \frac{4}{3}$, $\operatorname{csch} x = \frac{3}{4}$, $\tanh x = \frac{4}{5}$, $\coth x = \frac{5}{4}$

27. (a) 1 (b) -1 (c) ∞ (d) $-\infty$ (e) 0 (f) 1
 (g) ∞ (h) $-\infty$ (i) 0 (j) $\frac{1}{2}$

35. $f'(x) = 3 \sinh 3x$ 37. $h'(x) = 2x \cosh(x^2)$

39. $G'(t) = \frac{t^2+1}{2t^2}$ 41. $f'(x) = \frac{\operatorname{sech}^2 \sqrt{x}}{2\sqrt{x}}$

43. $y' = \operatorname{sech}^3 x - \operatorname{sech} x \tanh^2 x$

45. $g'(t) = \coth \sqrt{t^2+1} - \frac{t^2}{\sqrt{t^2+1}} \operatorname{csch}^2 \sqrt{t^2+1}$

47. $f'(x) = \frac{-2}{\sqrt{1+4x^2}}$ 49. $y' = \sec \theta$

51. $G'(u) = \frac{1}{\sqrt{1+u^2}}$ 53. $y' = \sinh^{-1}(x/3)$

59. (a) 0.3572 (b) 70.34°

61. (a) 1176 N; 164.50 m (b) 120 m; 164.13 m

63. (b) $y = 2 \sinh 3x - 4 \cosh 3x$ 65. $(\ln(1+\sqrt{2}), \sqrt{2})$

67. $\frac{1}{3} \cosh^3 x + C$ 69. $2 \cosh \sqrt{x} + C$ 71. $-\operatorname{csch} x + C$

73. $\ln\left(\frac{6+3\sqrt{3}}{4+\sqrt{7}}\right)$ 75. $\tanh^{-1} e^x + C$

77. (a) 0, 0.48 (b) 0.04

EXERCISES 6.8 ■ PAGE 511

1. (a) Indeterminate (b) 0 (c) 0
 (d) $\infty, -\infty$, or does not exist (e) Indeterminate

3. (a) $-\infty$ (b) Indeterminate (c) ∞

5. $\frac{9}{4}$ 7. 1 9. 6 11. $\frac{7}{3}$ 13. $\sqrt{2}/2$ 15. 2

17. $\frac{1}{4}$ 19. 0 21. $-\infty$ 23. $-\frac{1}{3}$ 25. 3 27. 2

29. 1 31. 1 33. $1/\ln 3$ 35. 0 37. 0

39. a/b 41. $\frac{1}{24}$ 43. π 45. $\frac{5}{3}$ 47. 0

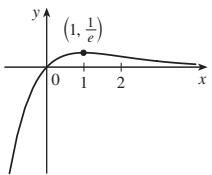
49. $-2/\pi$ 51. $\frac{1}{2}$ 53. $\frac{1}{2}$ 55. 0 57. 1 59. e^{-2}

61. $1/e$ 63. 1 65. e^4 67. e^3 69. 0

71. e^2 73. $\frac{1}{4}$ 77. 1

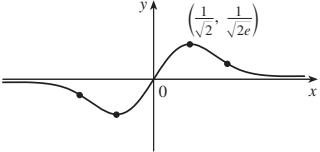
- 79.** A. \mathbb{R} B. y -int 0; x -int 0
 C. None D. HA $y = 0$
 E. Inc on $(-\infty, 1)$, dec on $(1, \infty)$
 F. Loc max $f(1) = 1/e$
 G. CU on $(2, \infty)$; CD on $(-\infty, 2)$
 IP $(2, 2/e^2)$

H. See graph at right.

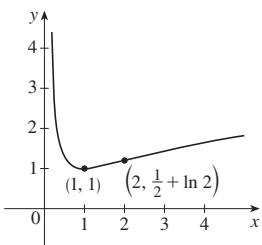


- 81.** A. \mathbb{R} B. y -int 0; x -int 0 C. About $(0, 0)$ D. HA $y = 0$
 E. Inc on $(-1/\sqrt{2}, 1/\sqrt{2})$; dec on $(-\infty, -1/\sqrt{2}), (1/\sqrt{2}, \infty)$
 F. Loc min $f(-1/\sqrt{2}) = -1/\sqrt{2}e$; loc max $f(1/\sqrt{2}) = 1/\sqrt{2}e$
 G. CU on $(-\sqrt{3}/2, 0), (\sqrt{3}/2, \infty)$
 CD on $(-\infty, -\sqrt{3}/2), (0, \sqrt{3}/2)$; IP $(\pm\sqrt{3}/2, \pm\sqrt{3}/2e^{-3/2})$, $(0, 0)$

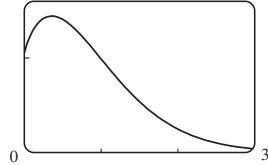
H.



- 83.** A. $(0, \infty)$ B. None
 C. None D. VA $x = 0$
 E. Inc on $(1, \infty)$; dec on $(0, 1)$
 F. Loc min $f(1) = 1$
 G. CU on $(0, 2)$; CD on $(2, \infty)$
 IP $(2, \frac{1}{2} + \ln 2)$
 H. See graph at right.

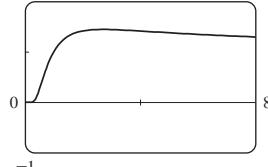


- 85.** (a) 1.6



- (c) Max value $f(1/e) = e^{1/e} \approx 1.44$ (d) 1.0

- 87.** (a) 2



- (b) $\lim_{x \rightarrow 0^+} x^{1/x} = 0$, $\lim_{x \rightarrow \infty} x^{1/x} = 1$
 (c) Loc max $f(e) = e^{1/e}$ (d) IPs at $x \approx 0.58, 4.37$

89. f has an absolute minimum for $c > 0$. As c increases, the minimum points get farther away from the origin.

- 93.** (a) M ; the population should approach its maximum size as time increases (b) $P_0 e^{kt}$; exponential

95. 1 **97.** $\pi/6$ **99.** $\frac{16}{9}a$ **101.** $\frac{1}{2}$

- 103.** (a) One possibility: $f(x) = 7/x^2$, $g(x) = 1/x^2$

- (b) One possibility: $f(x) = 7 + (1/x^2)$, $g(x) = 1/x^2$

- 105.** (a) 0

CHAPTER 6 REVIEW ■ PAGE 516

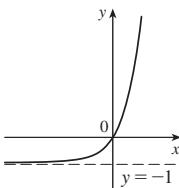
True-False Quiz

1. True 3. False 5. True 7. True 9. False
 11. False 13. False 15. True 17. True
 19. False

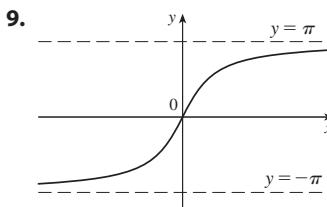
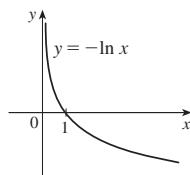
Exercises

1. No 3. (a) 7 (b) $\frac{1}{8}$

- 5.



- 7.



11. (a) 25 (b) 3 (c) $\frac{4}{3}$ **13.** $\frac{1}{2} \ln 3 \approx 0.549$

15. $\ln(\ln 10) \approx 0.834$ **17.** $\pm 1/\sqrt{3} \approx \pm 0.577$

19. $\frac{5}{e^3 - 1} \approx 0.262$ **21.** $f'(t) = t + 2t \ln t$

23. $h'(\theta) = 2 \sec^2(2\theta) e^{\tan 2\theta}$ **25.** $y' = 5 \sec 5x$

27. $y' = 2 \tan x$ **29.** $y' = -\frac{e^{1/x}(1+2x)}{x^4}$

31. $y' = \frac{-5}{x^2 + 1}$ **33.** $y' = 3^{x \ln x} (\ln 3)(1 + \ln x)$

35. $y' = \tan^{-1} x$ **37.** $y' = 2x^2 \cosh(x^2) + \sinh(x^2)$

39. $y' = \frac{2x}{(\arcsin x^2)\sqrt{1-x^4}}$

41. $y' = -(1/x)[1 + 1/(\ln x)^2]$

43. $y' = 3 \tanh 3x$ **45.** $y' = \frac{\cosh x}{\sqrt{\sinh^2 x - 1}}$

47. $y' = \frac{-3 \sin(e^{\sqrt{\tan 3x}}) e^{\sqrt{\tan 3x}} \sec^2(3x)}{2\sqrt{\tan 3x}}$ **49.** $e^{g(x)} g'(x)$

51. $g'(x)/g(x)$ **53.** $2^x (\ln 2)^n$ **57.** $y = -x + 2$

59. $(-3, 0)$ **61.** (a) $y = \frac{1}{4}x + \frac{1}{4}(\ln 4 + 1)$ (b) $y = ex$

63. 0 **65.** 0 **67.** 0 **69.** -1

71. 1 **73.** 4 **75.** 0 **77.** $\frac{1}{2}$

- 79.** A. $[-\pi, \pi]$ B. y -int 0; x -int $-\pi, 0, \pi$

- C. None D. None

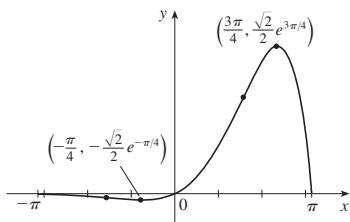
- E. Inc on $(-\pi/4, 3\pi/4)$; dec on $(-\pi, -\pi/4), (3\pi/4, \pi)$

- F. Loc max $f(3\pi/4) = \frac{1}{2}\sqrt{2}e^{3\pi/4}$,

- loc min $f(-\pi/4) = -\frac{1}{2}\sqrt{2}e^{-\pi/4}$

G. CU on $(-\pi/2, \pi/2)$; CD on $(-\pi, -\pi/2), (\pi/2, \pi)$;
IPs $(-\pi/2, -e^{-\pi/2}), (\pi/2, e^{\pi/2})$

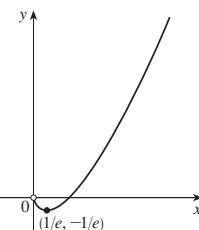
H.

81. A. $(0, \infty)$ B. x -int 1

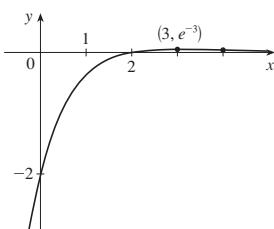
C. None D. None

E. Inc on $(1/e, \infty)$; dec on $(0, 1/e)$ F. Loc min $f(1/e) = -1/e$ G. CU on $(0, \infty)$

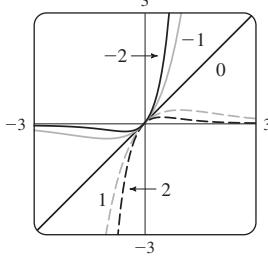
H. See graph at right.

83. A. \mathbb{R} B. y-int -2 ; x -int 2C. None D. HA $y = 0$ E. Inc on $(-\infty, 3)$; dec on $(3, \infty)$ F. Loc max $f(3) = e^{-3}$ G. CU on $(4, \infty)$;CD on $(-\infty, 4)$;IP $(4, 2e^{-4})$

H. See graph at right.



85.

For $c > 0$, $\lim_{x \rightarrow \infty} f(x) = 0$ and $\lim_{x \rightarrow -\infty} f(x) = -\infty$.For $c < 0$, $\lim_{x \rightarrow \infty} f(x) = \infty$ and $\lim_{x \rightarrow -\infty} f(x) = 0$.As $|c|$ increases, the max and min points and the IPs get closer to the origin.

$$87. v(t) = -Ae^{-ct}[c \cos(\omega t + \delta) + \omega \sin(\omega t + \delta)], \\ a(t) = Ae^{-ct}[(c^2 - \omega^2) \cos(\omega t + \delta) + 2c\omega \sin(\omega t + \delta)]$$

$$89. (a) 200(3.24)^t \quad (b) \approx 22,040$$

$$(c) \approx 25,910 \text{ bacteria/h} \quad (d) (\ln 50)/(\ln 3.24) \approx 3.33 \text{ h}$$

$$91. \approx 4.32 \text{ days} \quad 93. \frac{1}{4}(1 - e^{-2}) \quad 95. \arctan e - \pi/4$$

$$97. 2e^{\sqrt{x}} + C \quad 99. \frac{1}{2}\ln|x^2 + 2x| + C$$

$$101. -\frac{1}{2}[\ln(\cos x)]^2 + C \quad 103. 2^{\tan \theta}/\ln 2 + C$$

$$105. -\frac{3}{2} - \ln 2 \quad 109. e^{\sqrt{x}}/(2x)$$

$$111. (a) \frac{1}{8}(\ln 5)^2 \quad (b) f(e) = 1/e, f(1) = 0$$

$$113. \pi^2/4 \quad 115. \frac{2}{3} \quad 117. 2/e$$

$$121. f(x) = e^{2x}(2x - 1)/(1 - e^{-x})$$

PROBLEMS PLUS ■ PAGE 521

$$3. x \in [-1, 1 - \sqrt{3}] \cup (1 + \sqrt{3}, 3]$$

$$5. \text{Abs max } f(-5) = e^{45}, \text{ no abs min}$$

$$13. a = \frac{1}{2} \quad 15. e^{-2} \quad 19. 2\sqrt{e} \quad 21. a \leq e^{1/e}$$

CHAPTER 7**EXERCISES 7.1 ■ PAGE 528**

$$1. \frac{1}{2}xe^{2x} - \frac{1}{4}e^{2x} + C \quad 3. \frac{1}{4}x \sin 4x + \frac{1}{16} \cos 4x + C$$

$$5. \frac{1}{2}te^{2t} - \frac{1}{4}e^{2t} + C \quad 7. -\frac{1}{10}x \cos 10x + \frac{1}{100} \sin 10x + C$$

$$9. \frac{1}{2}w^2 \ln w - \frac{1}{4}w^2 + C$$

$$11. (x^2 + 2x) \sin x + (2x + 2) \cos x - 2 \sin x + C$$

$$13. x \cos^{-1}x - \sqrt{1 - x^2} + C \quad 15. \frac{1}{5}t^5 \ln t - \frac{1}{25}t^5 + C$$

$$17. -t \cot t + \ln |\sin t| + C$$

$$19. x(\ln x)^2 - 2x \ln x + 2x + C$$

$$21. \frac{1}{10}e^{3x} \sin x + \frac{3}{10}e^{3x} \cos x + C$$

$$23. \frac{1}{13}e^{20}(2 \sin 3\theta - 3 \cos 3\theta) + C$$

$$25. z^3 e^z - 3z^2 e^z + 6ze^z - 6e^z + C$$

$$27. \frac{1}{3}x^2 e^{3x} - \frac{2}{9}xe^{3x} + \frac{11}{27}e^{3x} + C \quad 29. \frac{3}{\ln 3} - \frac{2}{(\ln 3)^2}$$

$$31. 2 \cosh 2 - \sinh 2 \quad 33. \frac{4}{5} - \frac{1}{5} \ln 5 \quad 35. -\pi/4$$

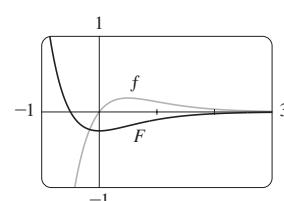
$$37. 2e^{-1} - 6e^{-5} \quad 39. \frac{1}{2} \ln 2 - \frac{1}{2}$$

$$41. -\frac{1}{2}(1 + \cosh \pi) = -\frac{1}{4}(2 + e^\pi + e^{-\pi})$$

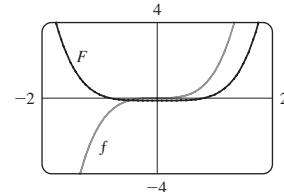
$$43. 2(\sqrt{x} - 1)e^{\sqrt{x}} + C \quad 45. -\frac{1}{2} - \pi/4$$

$$47. \frac{1}{2}(x^2 - 1) \ln(1 + x) - \frac{1}{4}x^2 + \frac{1}{2}x + \frac{3}{4} + C$$

$$49. -\frac{1}{2}xe^{-2x} - \frac{1}{4}e^{-2x} + C$$



$$51. \frac{1}{3}x^2(1 + x^2)^{3/2} - \frac{2}{15}(1 + x^2)^{5/2} + C$$



$$53. (b) -\frac{1}{4} \cos x \sin^3 x + \frac{3}{8}x - \frac{3}{16} \sin 2x + C$$

$$55. (b) \frac{2}{3}, \frac{8}{15}$$

$$56. x[(\ln x)^3 - 3(\ln x)^2 + 6 \ln x - 6] + C$$

$$58. \frac{16}{3} \ln 2 - \frac{29}{9} \quad 65. -1.75119, 1.17210; 3.99926$$

$$67. 4 - 8/\pi \quad 69. 2\pi e$$

$$71. (a) 2\pi(2 \ln 2 - \frac{3}{4}) \quad (b) 2\pi[(\ln 2)^2 - 2 \ln 2 + 1]$$

$$73. x S(x) + \frac{1}{\pi} \cos(\frac{1}{2}\pi x^2) + C$$

75. $2 - e^{-t}(t^2 + 2t + 2)$ m 77. 2

79. (b) $-\frac{\ln x}{x} - \frac{1}{x} + C$

EXERCISES 7.2 ■ PAGE 536

1. $\frac{1}{5}\cos^5 x - \frac{1}{3}\cos^3 x + C$ 3. $\frac{1}{210}$

5. $-\frac{1}{14}\cos^7(2t) + \frac{1}{5}\cos^5(2t) - \frac{1}{6}\cos^3(2t) + C$

7. $\pi/4$ 9. $3\pi/8$ 11. $\pi/16$

13. $\frac{2}{7}(\cos \theta)^{7/2} - \frac{2}{3}(\cos \theta)^{3/2} + C$ 15. $\frac{1}{4}\sec^4 x + C$

17. $\ln|\sin x| - \frac{1}{2}\sin^2 x + C$ 19. $\frac{1}{2}\sin^4 x + C$

21. $\frac{1}{3}\sec^3 x + C$ 23. $\tan x - x + C$

25. $\frac{1}{9}\tan^9 x + \frac{2}{7}\tan^7 x + \frac{1}{5}\tan^5 x + C$

27. $\frac{1}{3}\sec^3 x - \sec x + C$ 29. $\frac{1}{8}\tan^8 x + \frac{1}{3}\tan^6 x + \frac{1}{4}\tan^4 x + C$

31. $\frac{1}{4}\sec^4 x - \tan^2 x + \ln|\sec x| + C$ 33. $\frac{1}{2}\sin 2x + C$

35. $-\frac{1}{4} - \ln(\sqrt{2}/2)$ 37. $\sqrt{3} - \frac{1}{3}\pi$

39. $\frac{22}{105}\sqrt{2} - \frac{8}{105}$ 41. $\ln|\csc x - \cot x| + C$

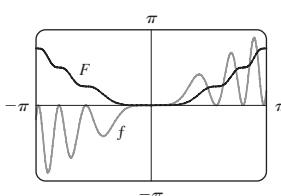
43. $-\frac{1}{6}\cos 3x - \frac{1}{26}\cos 13x + C$ 45. $\frac{1}{15}$

47. $-1/(2t) + \frac{1}{4}\sin(2/t) + C$ 49. $\frac{1}{2}\sqrt{2}$

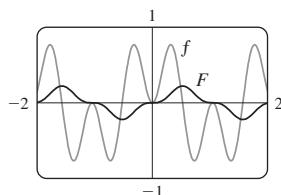
51. $\frac{1}{4}t^2 - \frac{1}{4}t \sin 2t - \frac{1}{8}\cos 2t + C$

53. $x \tan x - \ln|\sec x| - \frac{1}{2}x^2 + C$ 55. $\csc x + \cot x + C$

57. $\frac{1}{4}x^2 - \frac{1}{4}\sin(x^2)\cos(x^2) + C$



59. $\frac{1}{6}\sin 3x - \frac{1}{18}\sin 9x + C$



61. $\frac{1}{8}(\sqrt{2} - 7i)$ 63. 0 65. $\frac{1}{2}\pi - \frac{4}{3}$ 67. 0

69. $\pi^2/4$ 71. $\pi(2\sqrt{2} - \frac{5}{2})$ 73. $s = (1 - \cos^3 \omega t)/(3\omega)$

EXERCISES 7.3 ■ PAGE 543

1. (a) $x = \tan \theta$ (b) $\int \tan^3 \theta \sec \theta d\theta$

3. (a) $x = \sqrt{2} \sec \theta$ (b) $\int 2 \sec^3 \theta d\theta$

5. $-\sqrt{1-x^2} + \frac{1}{3}(1-x^2)^{3/2} + C$

7. $\sqrt{4x^2 - 25} - 5 \sec^{-1}(\frac{2}{5}x) + C$

9. $\frac{1}{15}(16+x^2)^{3/2}(3x^2 - 32) + C$

11. $\frac{1}{3} \frac{(x^2-1)^{3/2}}{x^3} + C$ 13. $\frac{1}{\sqrt{2}a^2}$

15. $\frac{2}{3}\sqrt{3} - \frac{3}{4}\sqrt{2}$

17. $\frac{1}{12}$

19. $\frac{1}{6}\sec^{-1}(x/3) - \sqrt{x^2 - 9}/(2x^2) + C$

21. $\frac{1}{16}\pi a^4$ 23. $\sqrt{x^2 - 7} + C$

25. $\ln|(\sqrt{1+x^2} - 1)/x| + \sqrt{1+x^2} + C$ 27. $\frac{9}{500}\pi$

29. $\ln|\sqrt{x^2+2x+5} + x+1| + C$

31. $4\sin^{-1}\left(\frac{x-1}{2}\right) + \frac{1}{4}(x-1)^3\sqrt{3+2x-x^2}$
$$- \frac{2}{3}(3+2x-x^2)^{3/2} + C$$

33. $\frac{1}{2}(x+1)\sqrt{x^2+2x} - \frac{1}{2}\ln|x+1+\sqrt{x^2+2x}| + C$

35. $\frac{1}{4}\sin^{-1}(x^2) + \frac{1}{4}x^2\sqrt{1-x^4} + C$

39. $\frac{1}{6}(\sqrt{48} - \sec^{-1} 7)$ 43. $\frac{3}{8}\pi^2 + \frac{3}{4}\pi$

47. $2\pi^2 Rr^2$ 49. $r\sqrt{R^2 - r^2} + \pi r^2/2 - R^2 \arcsin(r/R)$

EXERCISES 7.4 ■ PAGE 553

1. (a) $\frac{A}{x-3} + \frac{B}{x+5}$ (b) $\frac{A}{x-2} + \frac{B}{(x-2)^2} + \frac{Cx+D}{x^2+2}$

3. (a) $\frac{A}{x} + \frac{B}{x-1} + \frac{C}{x-2}$

(b) $\frac{A}{x} + \frac{B}{2x-1} + \frac{C}{(2x-1)^2} + \frac{Dx+E}{x^2+3} + \frac{Fx+G}{(x^2+3)^2}$

5. (a) $\frac{A}{x} + \frac{B}{x-1} + \frac{Cx+D}{x^2+1} + \frac{Ex+F}{(x^2+1)^2}$

(b) $1 + \frac{A}{x-2} + \frac{B}{x+3}$ 7. $\ln|x-1| - \ln|x+4| + C$

9. $\frac{1}{2}\ln|2x+1| + 2\ln|x-1| + C$ 11. $2\ln\frac{3}{2}$

13. $-\frac{1}{a}\ln|x| + \frac{1}{a}\ln|x-a| + C$

15. $\frac{1}{2}x^2 + x + \ln|x-1| + C$

17. $\frac{27}{5}\ln 2 - \frac{9}{5}\ln 3$ (or $\frac{9}{5}\ln\frac{8}{3}$)

19. $\frac{1}{2} - 5\ln 2 + 3\ln 3$ (or $\frac{1}{2} + \ln\frac{27}{32}$)

21. $\frac{1}{4}\left[\ln|t+1| - \frac{1}{t+1} - \ln|t-1| - \frac{1}{t-1}\right] + C$

23. $\ln|x-1| - \frac{1}{2}\ln(x^2+9) - \frac{1}{3}\tan^{-1}(x/3) + C$

25. $\frac{5}{2} - \ln 2 - \ln 3$ (or $\frac{5}{2} - \ln 6$)

27. $-2\ln|x+1| + \ln(x^2+1) + 2\tan^{-1}x + C$

29. $\frac{1}{2}\ln(x^2+1) + \tan^{-1}x - \frac{1}{2}\tan^{-1}(x/2) + C$

31. $\frac{1}{2}\ln(x^2+2x+5) + \frac{3}{2}\tan^{-1}\left(\frac{x+1}{2}\right) + C$

33. $\frac{1}{3}\ln|x-1| - \frac{1}{6}\ln(x^2+x+1) - \frac{1}{\sqrt{3}}\tan^{-1}\frac{2x+1}{\sqrt{3}} + C$

35. $\frac{1}{4}\ln\frac{8}{3}$

37. $2\ln|x| + \frac{3}{2}\ln(x^2+1) + \frac{1}{2}\tan^{-1}x + \frac{x}{2(x^2+1)} + C$

39. $\frac{7}{8}\sqrt{2}\tan^{-1}\left(\frac{x-2}{\sqrt{2}}\right) + \frac{3x-8}{4(x^2-4x+6)} + C$

41. $2 \tan^{-1} \sqrt{x-1} + C$

43. $-2 \ln \sqrt{x} - \frac{2}{\sqrt{x}} + 2 \ln(\sqrt{x} + 1) + C$

45. $\frac{3}{10}(x^2 + 1)^{5/3} - \frac{3}{4}(x^2 + 1)^{2/3} + C$

47. $2\sqrt{x} + 3\sqrt[3]{x} + 6\sqrt[4]{x} + 6 \ln |\sqrt[3]{x} - 1| + C$

49. $4 \ln |\sqrt{x} - 2| - 2 \ln |\sqrt{x} - 1| + C$

51. $\ln \frac{(e^x + 2)^2}{e^x + 1} + C$

53. $\ln |\tan t + 1| - \ln |\tan t + 2| + C$

55. $x - \ln(e^x + 1) + C$

57. $(x - \frac{1}{2}) \ln(x^2 - x + 2) - 2x + \sqrt{7} \tan^{-1} \left(\frac{2x - 1}{\sqrt{7}} \right) + C$

59. $-\frac{1}{2} \ln 3 \approx -0.55$

61. $\frac{1}{2} \ln \left| \frac{x-2}{x} \right| + C$ 65. $\frac{1}{5} \ln \left| \frac{2 \tan(x/2) - 1}{\tan(x/2) + 2} \right| + C$

67. $4 \ln \frac{2}{3} + 2$ 69. $-1 + \frac{11}{3} \ln 2$

71. $t = \ln \frac{10,000}{P} + 11 \ln \frac{P - 9000}{1000}$

73. (a) $\frac{24,110}{4879} \frac{1}{5x+2} - \frac{668}{323} \frac{1}{2x+1} - \frac{9438}{80,155} \frac{1}{3x-7}$
 $+ \frac{1}{260,015} \frac{22,098x + 48,935}{x^2 + x + 5}$

(b) $\frac{4822}{4879} \ln |5x+2| - \frac{334}{323} \ln |2x+1|$
 $- \frac{3146}{80,155} \ln |3x-7| + \frac{11,049}{260,015} \ln(x^2 + x + 5)$
 $+ \frac{75,772}{260,015\sqrt{19}} \tan^{-1} \frac{2x+1}{\sqrt{19}} + C$

The CAS omits the absolute value signs and the constant of integration.

77. $\frac{1}{a^n(x-a)} - \frac{1}{a^n x} - \frac{1}{a^{n-1} x^2} - \cdots - \frac{1}{a x^n}$

EXERCISES 7.5 ■ PAGE 559

1. (a) $\frac{1}{2} \ln(1+x^2) + C$ (b) $\tan^{-1} x + C$

(c) $\frac{1}{2} \ln |1+x| - \frac{1}{2} \ln |1-x| + C$

3. (a) $\frac{1}{2} (\ln x)^2 + C$ (b) $x \ln(2x) - x + C$

(c) $\frac{1}{2} x^2 \ln x - \frac{1}{4} x^2 + C$

5. (a) $\frac{1}{2} \ln |x-3| - \frac{1}{2} \ln |x-1| + C$ (b) $-\frac{1}{x-2} + C$

(c) $\tan^{-1}(x-2) + C$

7. (a) $\frac{1}{3} e^{x^3} + C$ (b) $e^x(x^2 - 2x + 2) + C$

(c) $\frac{1}{2} e^{x^2}(x^2 - 1) + C$

9. $-\ln(1 - \sin x) + C$ 11. $\frac{32}{3} \ln 2 - \frac{28}{9}$

13. $\ln y [\ln(\ln y) - 1] + C$ 15. $\frac{1}{6} \tan^{-1} \left(\frac{1}{3} x^2 \right) + C$

17. $\frac{4}{5} \ln 2 + \frac{1}{5} \ln 3$ (or $\frac{1}{5} \ln 48$) 19. $\frac{1}{2} \sec^{-1} x + \frac{\sqrt{x^2 - 1}}{2x^2} + C$

21. $-\frac{1}{4} \cos^4 x + C$ 23. $x \sec x - \ln |\sec x + \tan x| + C$

25. $\frac{1}{4} \pi^2$ 27. $e^{e^x} + C$ 29. $(x+1) \arctan \sqrt{x} - \sqrt{x} + C$

31. $\frac{4097}{45}$ 33. $4 - \ln 4$ 35. $x - \ln(1 + e^x) + C$

37. $x \ln(x + \sqrt{x^2 - 1}) - \sqrt{x^2 - 1} + C$

39. $\sin^{-1} x - \sqrt{1 - x^2} + C$

41. $2 \sin^{-1} \left(\frac{x+1}{2} \right) + \frac{x+1}{2} \sqrt{3 - 2x - x^2} + C$

43. 0 45. $\frac{1}{4}$ 47. $\ln |\sec \theta - 1| - \ln |\sec \theta| + C$

49. $\theta \tan \theta - \frac{1}{2} \theta^2 - \ln |\sec \theta| + C$ 51. $\frac{2}{3} \tan^{-1} (x^{3/2}) + C$

53. $\frac{2}{3} x^{3/2} - x + 2\sqrt{x} - 2 \ln(1 + \sqrt{x}) + C$

55. $\ln |x-1| - 3(x-1)^{-1} - \frac{3}{2}(x-1)^{-2} - \frac{1}{3}(x-1)^{-3} + C$

57. $\ln \left| \frac{\sqrt{4x+1} - 1}{\sqrt{4x+1} + 1} \right| + C$

59. $-\ln \left| \frac{\sqrt{4x^2+1} + 1}{2x} \right| + C$

61. $\frac{1}{m} x^2 \cosh mx - \frac{2}{m^2} x \sinh mx + \frac{2}{m^3} \cosh mx + C$

63. $2 \ln \sqrt{x} - 2 \ln(1 + \sqrt{x}) + C$

65. $\frac{3}{7}(x+c)^{7/3} - \frac{3}{4}c(x+c)^{4/3} + C$

67. $\frac{1}{32} \ln \left| \frac{x-2}{x+2} \right| - \frac{1}{16} \tan^{-1} \left(\frac{x}{2} \right) + C$

69. $\csc \theta - \cot \theta + C$ or $\tan(\theta/2) + C$

71. $2(x-2\sqrt{x}+2)e^{\sqrt{x}} + C$

73. $-\tan^{-1}(\cos^2 x) + C$ 75. $\frac{2}{3}[(x+1)^{3/2} - x^{3/2}] + C$

77. $\sqrt{2} - 2/\sqrt{3} + \ln(2 + \sqrt{3}) - \ln(1 + \sqrt{2})$

79. $e^x - \ln(1 + e^x) + C$

81. $-\sqrt{1-x^2} + \frac{1}{2}(\arcsin x)^2 + C$ 83. $\ln |\ln x - 1| + C$

85. $2(x-2)\sqrt{1+e^x} + 2 \ln \frac{\sqrt{1+e^x} + 1}{\sqrt{1+e^x} - 1} + C$

87. $\frac{1}{3} x \sin^3 x + \frac{1}{3} \cos x - \frac{1}{9} \cos^3 x + C$

89. $2\sqrt{1+\sin x} + C$ 91. $2\sqrt{2}$

93. $(3 - \sqrt{3})/2$ or $1 - \sqrt{1 - (\sqrt{3}/2)}$ 95. $xe^{x^2} + C$

EXERCISES 7.6 ■ PAGE 565

1. $-\frac{5}{21}$ 3. $\frac{1}{2} x^2 \sin^{-1}(x^2) + \frac{1}{2} \sqrt{1-x^4} + C$

5. $\frac{1}{4} y^2 \sqrt{4+y^4} - \ln(y^2 + \sqrt{4+y^4}) + C$

7. $\frac{\pi}{8} \arctan \frac{\pi}{4} - \frac{1}{4} \ln(1 + \frac{1}{16}\pi^2)$ 9. $\frac{1}{6} \ln \left| \frac{\sin x - 3}{\sin x + 3} \right| + C$

11. $-\frac{\sqrt{9x^2+4}}{x} + 3 \ln(3x + \sqrt{9x^2+4}) + C$

13. $5\pi/16$ 15. $2\sqrt{x} \arctan \sqrt{x} - \ln(1+x) + C$

17. $-\ln |\sinh(1/y)| + C$

19. $\frac{2y-1}{8}\sqrt{6+4y-4y^2} + \frac{7}{8}\sin^{-1}\left(\frac{2y-1}{\sqrt{7}}\right) - \frac{1}{12}(6+4y-4y^2)^{3/2} + C$

21. $\frac{1}{9}\sin^3 x [3 \ln(\sin x) - 1] + C$

23. $-\ln(\cos^2\theta + \sqrt{\cos^4\theta + 4}) + C$

25. $\frac{1}{8}e^{2x}(4x^3 - 6x^2 + 6x - 3) + C$

27. $\frac{1}{15}\sin y (3\cos^4 y + 4\cos^2 y + 8) + C$

29. $-\frac{1}{2}x^{-2}\cos^{-1}(x^{-2}) + \frac{1}{2}\sqrt{1-x^{-4}} + C$

31. $\sqrt{e^{2x}-1} - \cos^{-1}(e^{-x}) + C$

33. $\frac{1}{5}\ln|x^5 + \sqrt{x^{10}-2}| + C \quad 35. \frac{3}{8}\pi^2$

39. $\frac{1}{3}\tan x \sec^2 x + \frac{2}{3}\tan x + C$

41. $\frac{1}{4}x(x^2+2)\sqrt{x^2+4} - 2\ln(\sqrt{x^2+4} + x) + C$

43. $\frac{1}{4}\cos^3 x \sin x + \frac{3}{8}x + \frac{3}{8}\sin x \cos x + C$

45. $-\ln|\cos x| - \frac{1}{2}\tan^2 x + \frac{1}{4}\tan^4 x + C$

47. (a) $-\ln\left|\frac{1+\sqrt{1-x^2}}{x}\right| + C;$

both have domain $(-1, 0) \cup (0, 1)$

EXERCISES 7.7 ■ PAGE 577

1. (a) $L_2 = 6, R_2 = 12, M_2 \approx 9.6$

(b) L_2 is an underestimate, R_2 and M_2 are overestimates.

(c) $T_2 = 9 < I$ (d) $L_n < T_n < I < M_n < R_n$

3. (a) $T_4 \approx 0.895759$ (underestimate)

(b) $M_4 \approx 0.908907$ (overestimate);

$T_4 < I < M_4$

5. (a) $M_6 \approx 3.177769, E_M \approx -0.036176$

(b) $S_6 \approx 3.142949, E_S \approx -0.001356$

7. (a) 1.116993 (b) 1.108667 (c) 1.111363

9. (a) 1.777722 (b) 0.784958 (c) 0.780895

11. (a) 10.185560 (b) 10.208618 (c) 10.201790

13. (a) -2.364034 (b) -2.310690 (c) -2.346520

15. (a) 0.243747 (b) 0.243748 (c) 0.243751

17. (a) 8.814278 (b) 8.799212 (c) 8.804229

19. (a) $T_8 \approx 0.902333, M_8 \approx 0.905620$

(b) $|E_T| \leq 0.0078, |E_M| \leq 0.0039$

(c) $n = 71$ for $T_n, n = 50$ for M_n

21. (a) $T_{10} \approx 1.983524, E_T \approx 0.016476;$

$M_{10} \approx 2.008248, E_M \approx -0.008248;$

$S_{10} \approx 2.000110, E_S \approx -0.000110$

(b) $|E_T| \leq 0.025839, |E_M| \leq 0.012919, |E_S| \leq 0.000170$

(c) $n = 509$ for $T_n, n = 360$ for $M_n, n = 22$ for S_n

23. (a) 2.8 (b) 7.954926518 (c) 0.2894

(d) 7.954926521 (e) Actual error is much smaller.

(f) 10.9 (g) 7.953789422 (h) 0.0593

(i) Actual error is smaller. (j) $n \geq 50$

n	L_n	R_n	T_n	M_n
5	0.742943	1.286599	1.014771	0.992621
10	0.867782	1.139610	1.003696	0.998152
20	0.932967	1.068881	1.000924	0.999538

n	E_L	E_R	E_T	E_M
5	0.257057	-0.286599	-0.014771	0.007379
10	0.132218	-0.139610	-0.003696	0.001848
20	0.067033	-0.068881	-0.000924	0.000462

Observations are the same as those following Example 1.

n	T_n	M_n	S_n
6	6.695473	6.252572	6.403292
12	6.474023	6.363008	6.400206

n	E_T	E_M	E_S
6	-0.295473	0.147428	-0.003292
12	-0.074023	0.036992	-0.000206

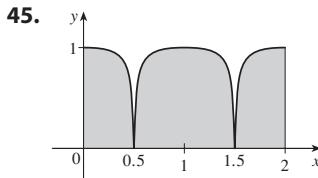
Observations are the same as those following Example 1.

29. (a) 19 (b) 18.6 (c) 18.6 31. (a) 14.4 (b) 0.5

33. 21.6 Degrees Celsius 35. 18.8 m/s

37. 10,177 megawatt-hours

39. (a) 190 (b) 828 41. 28 43. 59.4



EXERCISES 7.8 ■ PAGE 587

Abbreviations: C, convergent; D, divergent

1. (a), (c) Infinite discontinuity (b), (d) Infinite interval

3. $\frac{1}{2} - 1/(2t^2); 0.495, 0.49995, 0.4999995; 0.5$

5. 1 7. $\frac{1}{2}$ 9. D 11. 2 13. $-\frac{1}{4}$ 15. $\frac{11}{6}$

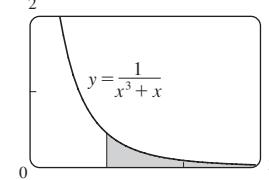
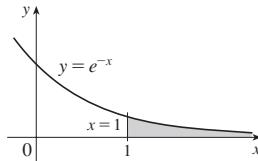
17. $\frac{1}{2}$ 19. 0 21. D 23. D 25. $\ln 2$

27. $-\frac{1}{4}$ 29. D 31. $-\pi/8$ 33. 2

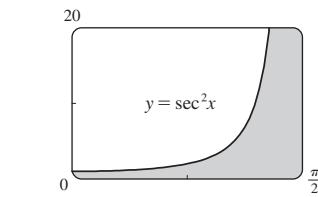
35. D 37. $\frac{32}{3}$ 39. D 41. $\frac{9}{2}$ 43. D 45. $-\frac{1}{4}$

47. $-2/e$

49. $1/e$ 51. $\frac{1}{2}\ln 2$

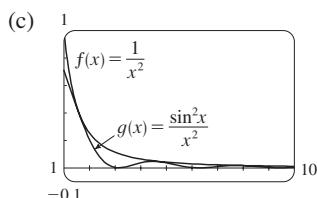


53. Infinite area



55. (a)	t	$\int_1^t \left[(\sin^2 x)/x^2 \right] dx$
	2	0.447453
	5	0.577101
	10	0.621306
	100	0.668479
	1,000	0.672957
	10,000	0.673407

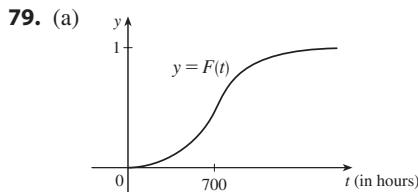
It appears that the integral is convergent.



57. C **59.** D **61.** D **63.** D **65.** D **67.** π

69. $p < 1, 1/(1-p)$ **71.** $p > -1, -1/(p+1)^2$

75. π **77.** $\sqrt{2GM/R}$



- (b) The rate at which the fraction $F(t)$ increases as t increases
(c) 1; all bulbs burn out eventually

81. $\gamma = \frac{cN}{\lambda(k+\lambda)}$ **83.** 1000

85. (a) $F(s) = 1/s, s > 0$ (b) $F(s) = 1/(s-1), s > 1$
(c) $F(s) = 1/s^2, s > 0$

91. $C = 1; \ln 2$ **93.** No

CHAPTER 7 REVIEW ■ PAGE 591

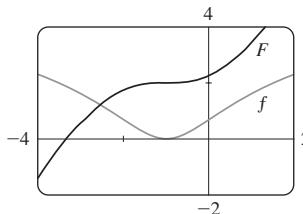
True-False Quiz

1. True 3. False 5. False 7. False
9. False 11. True 13. (a) True (b) False
15. False 17. False

Exercises

1. $\frac{7}{2} + \ln 2$ 3. $e^{\sin x} + C$ 5. $\ln|2t+1| - \ln|t+1| + C$
7. $\frac{2}{15}$ 9. $-\cos(\ln t) + C$
11. $\frac{1}{4}x^2[2(\ln x)^2 - 2\ln x + 1] + C$ 13. $\sqrt{3} - \frac{1}{3}\pi$
15. $3e^{\sqrt[3]{x}}(x^{2/3} - 2x^{1/3} + 2) + C$
17. $\frac{1}{6}[2x^3 \tan^{-1} x - x^2 + \ln(1+x^2)] + C$
19. $-\frac{1}{2} \ln|x| + \frac{3}{2} \ln|x+2| + C$
21. $x \sinh x - \cosh x + C$
23. $\ln|x-2 + \sqrt{x^2-4x}| + C$

- 25.** $\frac{1}{18} \ln(9x^2 + 6x + 5) + \frac{1}{9} \tan^{-1}\left[\frac{1}{2}(3x+1)\right] + C$
27. $\sqrt{2} + \ln(\sqrt{2}+1)$ **29.** $\ln \left| \frac{\sqrt{x^2+1}-1}{x} \right| + C$
31. $-\cos(\sqrt{1+x^2}) + C$
33. $\frac{3}{2} \ln(x^2+1) - 3 \tan^{-1} x + \sqrt{2} \tan^{-1}(x/\sqrt{2}) + C$
35. $\frac{2}{5}$ **37.** 0 **39.** $6 - \frac{3}{2}\pi$
41. $\frac{x}{\sqrt{4-x^2}} - \sin^{-1}\left(\frac{x}{2}\right) + C$
43. $4\sqrt{1+\sqrt{x}} + C$ **45.** $\frac{1}{2} \sin 2x - \frac{1}{8} \cos 4x + C$
47. $\frac{1}{8}e - \frac{1}{4}$ **49.** $\tan^{-1}\left(\frac{1}{2}\sqrt{e^x-4}\right) + C$ **51.** $\frac{1}{36}$
53. D **55.** $4 \ln 4 - 8$ **57.** $-\frac{4}{3}$ **59.** $\pi/4$
61. $(x+1) \ln(x^2+2x+2) + 2 \arctan(x+1) - 2x + C$



- 63.** 0
65. $\frac{1}{4}(2x-1)\sqrt{4x^2-4x-3}$
 $- \ln|2x-1 + \sqrt{4x^2-4x-3}| + C$
67. $\frac{1}{2} \sin x \sqrt{4 + \sin^2 x} + 2 \ln(\sin x + \sqrt{4 + \sin^2 x}) + C$
71. No
73. (a) 1.925444 (b) 1.920915 (c) 1.922470
75. (a) 0.01348, $n \geq 368$ (b) 0.00674, $n \geq 260$
77. 13.7 km
79. (a) 3.8 (b) 1.786721, 0.000646 (c) $n \geq 30$
81. (a) D (b) C
83. 2 **85.** $\frac{3}{16}\pi^2$

PROBLEMS PLUS ■ PAGE 595

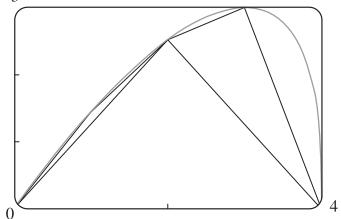
1. About 4.7 centimeters from the center **3.** 0
9. $f(\pi) = -\pi/2$ **13.** $(b^b a^{-a})^{1/(b-a)} e^{-1}$ **15.** $\frac{1}{8}\pi - \frac{1}{12}$
17. $2 - \sin^{-1}(2/\sqrt{5})$

CHAPTER 8

EXERCISES 8.1 ■ PAGE 603

1. $4\sqrt{5}$ **3.** $\int_0^2 \sqrt{1+9x^4} dx$ **5.** $\int_1^4 \sqrt{1 + \left(1 - \frac{1}{x}\right)^2} dx$
7. $\int_0^{\pi/2} \sqrt{1 + \cos^2 y} dy$ **9.** $2\sqrt{3} - \frac{2}{3}$ **11.** $\frac{5}{3}$ **13.** $\frac{59}{24}$
15. $\frac{1}{2}[\ln(1\sqrt{3}) - \ln(\sqrt{2}-1)]$ **17.** $\ln(\sqrt{2}+1)$
19. $\frac{32}{3}$ **21.** $\frac{3}{4} + \frac{1}{2} \ln 2$ **23.** $\ln 3 - \frac{1}{2}$
25. $\sqrt{2} + \ln(1 + \sqrt{2})$ **27.** 10.0556 **29.** 3.0609
31. 1.0054 **33.** 15.498085; 15.374568

35. (a), (b) 3



$$L_1 = 4, L_2 \approx 6.43, L_4 \approx 7.50$$

$$(c) \int_0^4 \sqrt{1 + [4(3-x)/(3(4-x)^{2/3})]^2} dx \quad (d) 7.7988$$

$$37. \sqrt{1+e^4} - \ln(1+\sqrt{1+e^4}) + 2 - \sqrt{2} + \ln(1+\sqrt{2})$$

$$39. 6 \quad 41. s(x) = \frac{2}{27}[(1+9x)^{3/2} - 10\sqrt{10}]$$

$$43. s(x) = 2\sqrt{2}(\sqrt{1+x} - 1) \quad 45. 209.1 \text{ m}$$

$$47. 62.55 \text{ cm} \quad 49. \approx 7.42 \text{ m above the ground} \quad 53. 12.4$$

EXERCISES 8.2 ■ PAGE 611

$$1. (a) \int_1^8 2\pi \sqrt[3]{x} \sqrt{1 + \frac{1}{9}x^{-4/3}} dx \quad (b) \int_1^2 2\pi y \sqrt{1 + 9y^4} dy$$

$$3. (a) \int_0^{\ln 3} \pi(e^x - 1) \sqrt{1 + \frac{1}{4}e^{2x}} dx$$

$$(b) \int_0^1 2\pi y \sqrt{1 + \frac{4}{(2y+1)^2}} dy$$

$$5. (a) \int_1^8 2\pi x \sqrt{1 + \frac{16}{x^4}} dx \quad (b) \int_{1/2}^4 \frac{8\pi}{y} \sqrt{1 + \frac{16}{y^4}} dy$$

$$7. (a) \int_0^{\pi/2} 2\pi x \sqrt{1 + \cos^2 x} dx$$

$$(b) \int_1^2 2\pi \sin^{-1}(y-1) \sqrt{1 + \frac{1}{2y-y^2}} dy$$

$$9. \frac{1}{27}\pi(145\sqrt{145} - 1) \quad 11. \frac{1}{6}\pi(17\sqrt{17} - 5\sqrt{5})$$

$$13. \pi\sqrt{5} + 4\pi \ln\left(\frac{1+\sqrt{5}}{2}\right) \quad 15. \frac{21}{2}\pi \quad 17. \frac{3712}{15}\pi$$

$$19. \pi a^2 \quad 21. \int_{-1}^1 2\pi e^{-x^2} \sqrt{1 + 4x^2 e^{-2x^2}} dx; 11.0753$$

$$23. \int_0^1 2\pi(y+y^3) \sqrt{1 + (1+3y^2)^2} dy; 13.5134$$

$$25. \int_1^4 2\pi y \sqrt{1 + [2y + (1/y)]^2} dy; 286.9239$$

$$27. \frac{1}{4}\pi[4 \ln(\sqrt{17} + 4) - 4 \ln(\sqrt{2} + 1) - \sqrt{17} + 4\sqrt{2}]$$

$$29. \frac{1}{6}\pi[\ln(\sqrt{10} + 3) + 3\sqrt{10}] \quad 31. 1,230,507$$

$$35. (a) \frac{1}{3}\pi a^2 \quad (b) \frac{56}{45}\pi\sqrt{3}a^2$$

$$37. (a) 2\pi \left[b^2 + \frac{a^2 b \sin^{-1}(\sqrt{a^2 - b^2}/a)}{\sqrt{a^2 - b^2}} \right]$$

$$(b) 2\pi a^2 + \frac{2\pi ab^2}{\sqrt{a^2 - b^2}} \ln \frac{a + \sqrt{a^2 - b^2}}{b}$$

$$39. (a) \int_a^b 2\pi[c - f(x)] \sqrt{1 + [f'(x)]^2} dx$$

$$(b) \int_0^4 2\pi(4 - \sqrt{x}) \sqrt{1 + 1/(4x)} dx \approx 80.6095$$

$$41. 4\pi^2 r^2 \quad 45. \text{Both equal } \pi \int_a^b (e^{x/2} + e^{-x/2})^2 dx.$$

EXERCISES 8.3 ■ PAGE 622

$$1. (a) 915.5 \text{ kg/m}^2 \quad (b) 8340 \text{ N} \quad (c) 2502 \text{ N}$$

$$3. 31136 \text{ N} \quad 5. \approx 2.36 \times 10^7 \text{ N} \quad 7. 470,400 \text{ N}$$

$$9. 1793 \text{ kg} \quad 11. \frac{2}{3}\delta ah^2 \quad 13. \approx 9450 \text{ N}$$

$$15. (a) \approx 314 \text{ N} \quad (b) \approx 353 \text{ N}$$

17. (a) $4.9 \times 10^4 \text{ N}$ (shallow end), approximately equals $4.5 \times 10^5 \text{ N}$ (deep end), and approximately equals $4.2 \times 10^5 \text{ N}$ (one of the sides) (b) $3.9 \times 10^6 \text{ N}$ (bottom of the pool)

$$19. 8372 \text{ kg} \quad 21. 330; 22$$

$$23. 23; -20; (-1, 1.15) \quad 25. \left(\frac{2}{3}, \frac{4}{3}\right) \quad 27. \left(\frac{3}{2}, \frac{3}{5}\right)$$

$$29. \left(\frac{9}{20}, \frac{9}{20}\right) \quad 31. \left(\pi - \frac{3}{2}\sqrt{3}, \frac{3}{8}\sqrt{3}\right) \quad 33. \left(\frac{8}{5}, -\frac{1}{2}\right)$$

$$35. \left(\frac{28}{3(\pi+2)}, \frac{10}{3(\pi+2)}\right) \quad 37. \left(-\frac{1}{5}, -\frac{12}{35}\right)$$

$$41. (0, \frac{1}{12}) \quad 45. \frac{1}{3}\pi r^2 h \quad 47. \left(\frac{8}{\pi}, \frac{8}{\pi}\right)$$

$$49. 4\pi^2 rR$$

EXERCISES 8.4 ■ PAGE 628

$$1. \$21,104 \quad 3. \$140,000; \$60,000 \quad 5. \$11,332.78$$

$$7. p = 25 - \frac{1}{30}x; \$1500 \quad 9. \$6.67 \quad 11. \$55,735$$

$$13. (a) 3800 \quad (b) \$324,900$$

$$15. \frac{2}{3}(16\sqrt{2} - 8) \approx \$9.75 \text{ million}$$

$$17. \$65,230.48 \quad 19. \frac{(1-k)(b^{2-k} - a^{2-k})}{(2-k)(b^{1-k} - a^{1-k})}$$

$$21. \approx 1.19 \times 10^{-4} \text{ cm}^3/\text{s} \quad 23. \approx 6.59 \text{ L/min}$$

$$25. 5.77 \text{ L/min}$$

EXERCISES 8.5 ■ PAGE 636

1. (a) The probability that a randomly chosen tire will have a lifetime between 50,000 and 65,000 kilometers

(b) The probability that a randomly chosen tire will have a lifetime of at least 40,000 kilometers

$$3. (a) f(x) \geq 0 \text{ for all } x \text{ and } \int_{-\infty}^{\infty} f(x) dx = 1 \quad (b) \frac{17}{81}$$

$$5. (a) 1/\pi \quad (b) \frac{1}{2}$$

$$7. (a) f(x) \geq 0 \text{ for all } x \text{ and } \int_{-\infty}^{\infty} f(x) dx = 1 \quad (b) 5$$

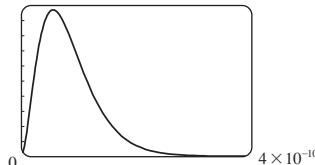
$$11. (a) \approx 0.465 \quad (b) \approx 0.153 \quad (c) \text{About 4.8 s}$$

$$13. (a) \frac{19}{32} \quad (b) 40 \text{ min} \quad 15. \approx 36\%$$

$$17. (a) 0.0668 \quad (b) \approx 5.21\% \quad 19. \approx 0.9545$$

$$21. (b) 0; a_0$$

$$(c) 1 \times 10^{10}$$



$$(d) 1 - 41e^{-8} \approx 0.986 \quad (e) \frac{3}{2}a_0$$

CHAPTER 8 REVIEW ■ PAGE 638

True-False Quiz

$$1. \text{True} \quad 3. \text{False} \quad 5. \text{True} \quad 7. \text{True}$$

Exercises

$$1. \frac{1}{54}(109\sqrt{109} - 1) \quad 3. \frac{53}{6}$$

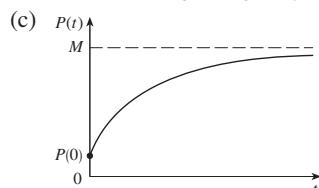
5. (a) 3.5121 (b) 22.1391 (c) 29.8522
 7. 3.8202 9. $\frac{124}{5}$ 11. 6533 N 13. $(\frac{4}{3}, \frac{4}{3})$
 15. $(\frac{8}{5}, 1)$ 17. $2\pi^2$ 19. \$7166.67
 21. (a) $f(x) \geq 0$ for all x and $\int_{-\infty}^{\infty} f(x) dx = 1$
 (b) ≈ 0.3455 (c) 5; yes
 23. (a) $1 - e^{-3/8} \approx 0.313$ (b) $e^{-5/4} \approx 0.287$
 (c) $8 \ln 2 \approx 5.55$ min

PROBLEMS PLUS ■ PAGE 640

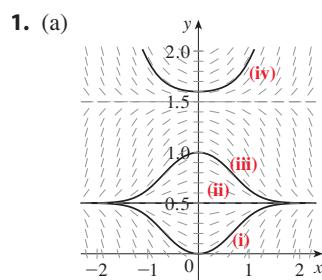
1. $\frac{2}{3}\pi - \frac{1}{2}\sqrt{3}$
 3. (a) $2\pi r(r \pm d)$ (b) $\approx 3.36 \times 10^6 \text{ mi}^2$
 (d) $\approx 7.84 \times 10^7 \text{ mi}^2$
 5. (a) $P(z) = P_0 + g \int_0^z \rho(x) dx$
 (b) $(P_0 - \rho_0 g H)(\pi r^2) + \rho_0 g H e^{L/H} \int_r^r e^{x/H} \cdot 2\sqrt{r^2 - x^2} dx$
 7. Height $\sqrt{2} b$, volume $(\frac{28}{27}\sqrt{6} - 2)\pi b^3$ 9. 0.14 m
 11. $2/\pi$; $1/\pi$ 13. $(0, -1)$

CHAPTER 9**EXERCISES 9.1 ■ PAGE 648**

1. $dr/dt = k/r$ 3. $dv/dt = k(M - v)$
 5. $dy/dt = k(N - y)$ 7. Yes 9. No 11. Yes
 15. (a) $\frac{1}{2}, -1$ 17. (d)
 19. (a) It must be either 0 or decreasing
 (c) $y = 0$ (d) $y = 1/(x + 2)$
 21. (a) $0 < P < 4200$ (b) $P > 4200$
 (c) $P = 0, P = 4200$
 25. (a) III (b) I (c) IV (d) II
 27. (a) At the beginning; stays positive, but decreases
 (c)



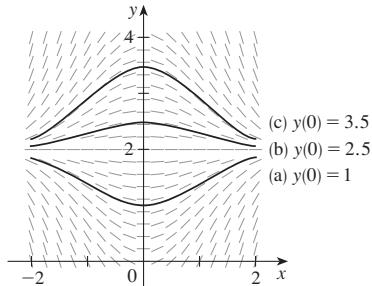
29. It approaches 0 as c approaches c_s .

EXERCISES 9.2 ■ PAGE 657

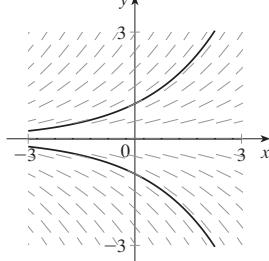
- (b) $y = 0.5, y = 1.5$

3. III 5. IV

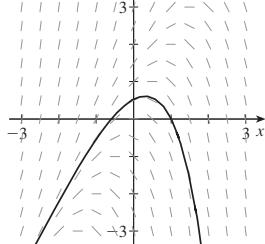
7.



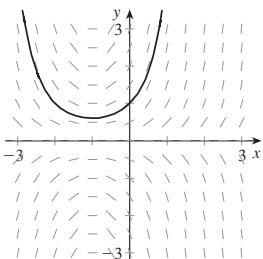
9.



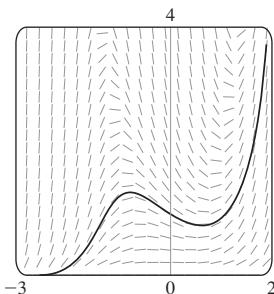
11.



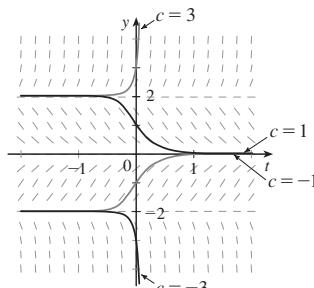
13.



15.

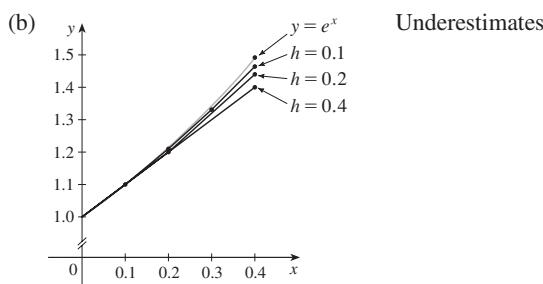


17.



$$-2 \leq c \leq 2; -2, 0, 2$$

19. (a) (i) 1.4 (ii) 1.44 (iii) 1.4641



(c) (i) 0.0918 (ii) 0.0518 (iii) 0.0277

It appears that the error is also halved (approximately).

21. $-1, -3, -6.5, -12.25$ **23.** 1.7616

25. (a) (i) 3 (ii) 2.3928 (iii) 2.3701 (iv) 2.3681

(c) (i) -0.6321 (ii) -0.0249 (iii) -0.0022 (iv) -0.0002

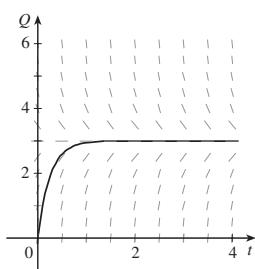
It appears that the error is also divided by 10 (approximately).

27. (a), (d)

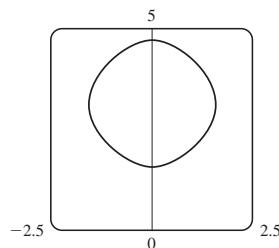
(b) 3

(c) Yes, $Q = 3$

(e) 2.77 C

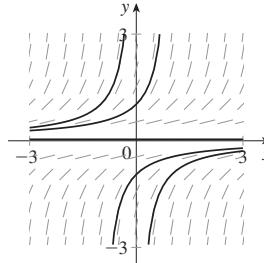


27. $\cos y = \cos x - 1$

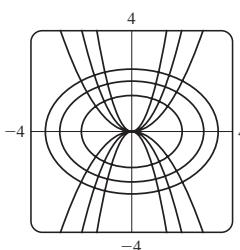


29. (a), (c)

(b) $y = \frac{1}{K-x}$



31. $y = Cx^2$



EXERCISES 9.3 ■ PAGE 664

1. $y = -1/(x^3 + C)$, $y = 0$

3. $y = (\frac{1}{4}x^2 + C)^2$, $y = 0$

5. $y = \pm\sqrt{x^2 + 2 \ln|x| + C}$

7. $e^y - y = 2x + \sin x + C$ **9.** $p = Ke^{(t^3/3)-t} - 1$

11. $\theta \sin \theta + \cos \theta = -\frac{1}{2}e^{-t^2} + C$

13. $y = -\ln(1 - \frac{1}{2}x^2)$ **15.** $A = b^3 e^{b \sin br}$

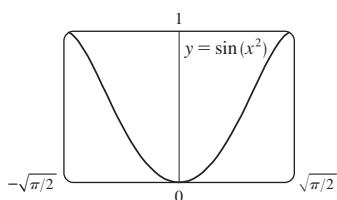
17. $u = -\sqrt{t^2 + \tan t + 25}$

19. $\frac{1}{2}y^2 + \frac{1}{3}(3 + y^2)^{3/2} = \frac{1}{2}x^2 \ln x - \frac{1}{4}x^2 + \frac{41}{12}$

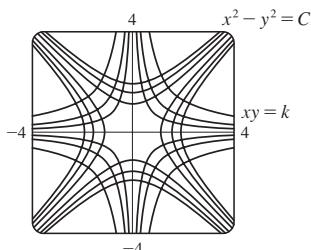
21. $y = \sqrt{x^2 + 4}$ **23.** $y = Ke^x - x - 1$

25. (a) $\sin^{-1}y = x^2 + C$

(b) $y = \sin(x^2)$, $-\sqrt{\pi/2} \leq x \leq \sqrt{\pi/2}$ (c) No



33. $x^2 - y^2 = C$



35. $y = 1 + e^{2-(x^2/2)}$ **37.** $y = (\frac{1}{2}x^2 + 2)^2$

39. $Q(t) = 3 - 3e^{-4t}$; 3 **41.** $P(t) = M - Me^{-kt}$; M

43. (a) $x = a - \frac{4}{(kt + 2/\sqrt{a})^2}$

(b) $t = \frac{2}{k\sqrt{a-b}} \left(\tan^{-1} \sqrt{\frac{b}{a-b}} - \tan^{-1} \sqrt{\frac{b-x}{a-b}} \right)$

45. (a) $C(t) = (C_0 - r/k)e^{-kt} + r/k$ (b) r/k ; the concentration approaches r/k regardless of the value of C_0 .

47. (a) $15e^{-t/100}$ kg (b) $15e^{-0.2} \approx 12.3$ kg

49. About 4.9% **51.** g/k

53. (a) $L_1 = KL_2^k$ (b) $B = KV^{0.0794}$

55. (a) $dA/dt = k\sqrt{A}(M - A)$

(b) $A(t) = M \left(\frac{Ce^{\sqrt{M}kt} - 1}{Ce^{\sqrt{M}kt} + 1} \right)^2$, where $C = \frac{\sqrt{M} + \sqrt{A_0}}{\sqrt{M} - \sqrt{A_0}}$ and $A_0 = A(0)$

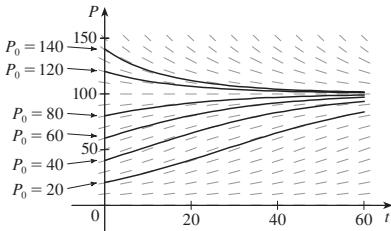
57. (b) $v_e = \sqrt{2gR}$ (c) $v_e \approx 11,173 \text{ m/s} \approx 11.2 \text{ km/s}$

EXERCISES 9.4 ■ PAGE 676

1. (a) 1200; 0.04 (b) $P(t) = \frac{1200}{1 + 19e^{-0.04t}}$ (c) ≈ 87

3. (a) 100; 0.05 (b) Where P is close to 0 or 100; on the line $P = 50$; $0 < P_0 < 100$; $P_0 > 100$

(c)



Solutions approach 100; some increase and some decrease, some have an inflection point but others don't; solutions with $P_0 = 20$ and $P_0 = 40$ have inflection points at $P = 50$.

(d) $P = 0$, $P = 100$; other solutions move away from $P = 0$ and toward $P = 100$.

5. (a) $\approx 3.23 \times 10^7 \text{ kg}$ (b) $\approx 1.55 \text{ years}$ 7. 9000

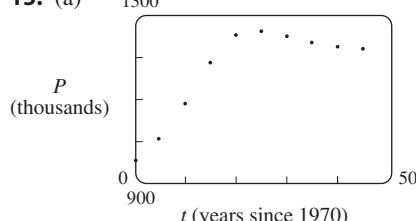
9. (a) $\frac{dP}{dt} = \frac{1}{305} P \left(1 - \frac{P}{20}\right)$ (b) 6.24 billion

(c) 7.57 billion; 13.87 billion

11. (a) $\frac{dy}{dt} = ky(1 - y)$ (b) $y = \frac{y_0}{y_0 + (1 - y_0)e^{-kt}}$

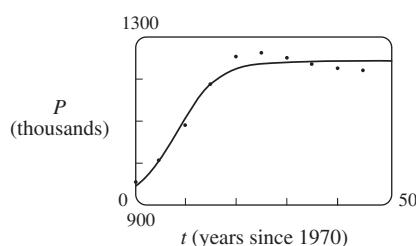
(c) 3:36 PM

15. (a)



(b) $f(t) = \frac{345.5899}{1 + 7.9977e^{-0.2482t}}$

(c) $P(t) = 900 + \frac{345.5899}{1 + 7.9977e^{-0.2482t}}$



(d) Population approaches 1.246 million

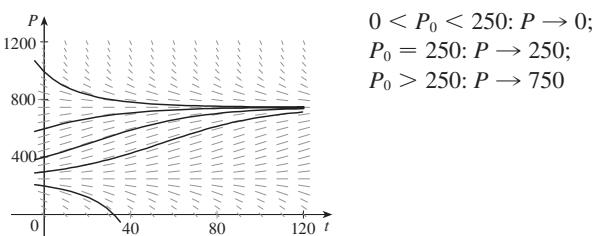
17. (a) $P(t) = \frac{m}{k} + \left(P_0 - \frac{m}{k}\right)e^{kt}$ (b) $m < kP_0$

(c) $m = kP_0$, $m > kP_0$ (d) Declining

19. (a) Fish are caught at a rate of 15 per week.

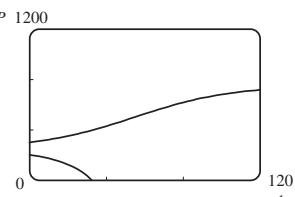
(b) See part (d). (c) $P = 250$, $P = 750$

(d)

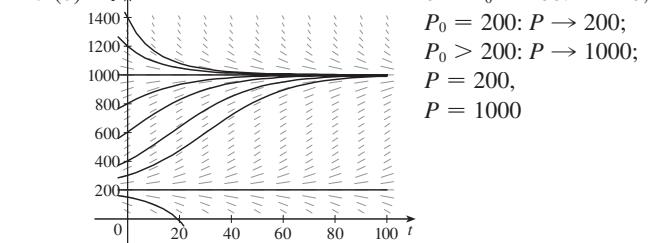


(e) $P(t) = \frac{250 - 750ke^{t/25}}{1 - ke^{t/25}}$

where $k = \frac{1}{11}, -\frac{1}{9}$



21. (b)



(c) $P(t) = \frac{m(M - P_0) + M(P_0 - m)e^{(M-m)(k/M)t}}{M - P_0 + (P_0 - m)e^{(M-m)(k/M)t}}$

23. (a) $P(t) = P_0 e^{(k/r)[\sin(rt - \phi) + \sin \phi]}$ (b) Does not exist

EXERCISES 9.5 ■ PAGE 684

1. No 3. Yes; $\frac{du}{dt} - \frac{e^t}{\sqrt{t}} u = -\sqrt{t}$

5. $y = 1 + Ce^{-x}$ 7. $y = x - 1 + Ce^{-x}$

9. $y = \frac{2}{3}\sqrt{x} + C/x$ 11. $y = x^2(\ln x + C)$

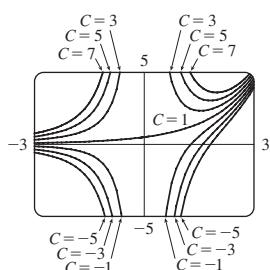
13. $y = \frac{1}{3}t^{-3}(1 + t^2)^{3/2} + Ct^{-3}$

15. $y = e^{-\sin x} \int x e^{\sin x} dx + Ce^{-\sin x}$ 17. $y = x^2 + 3/x$

19. $y = \frac{1}{x} \ln x - \frac{1}{x} + \frac{3}{x^2}$ 21. $u = -t^2 + t^3$

23. $y = -x \cos x - x$

25. $y = \frac{(x-1)e^x + C}{x^2}$

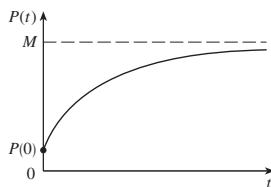


29. $y = \pm \left(Cx^4 + \frac{2}{5x} \right)^{-1/2}$

31. (a) $I(t) = 4 - 4e^{-5t}$ (b) $4 - 4e^{-1/2} \approx 1.57 \text{ A}$

33. $Q(t) = 3(1 - e^{-4t}), I(t) = 12e^{-4t}$

35. $P(t) = M + Ce^{-kt}$



37. $y = \frac{2}{5}(100 + 2t) - 40,000(100 + 2t)^{-3/2}; 0.2275 \text{ kg/L}$

39. (b) mg/c (c) $(mg/c)[t + (m/c)e^{-ct/m}] - m^2g/c^2$

41. (b) $P(t) = \frac{M}{1 + Mce^{-kt}}$

EXERCISES 9.6 ■ PAGE 691

1. (a) x = predators, y = prey; growth is restricted only by predators, which feed only on prey.

(b) x = prey, y = predators; growth is restricted by carrying capacity and by predators, which feed only on prey.

3. (a) Competition

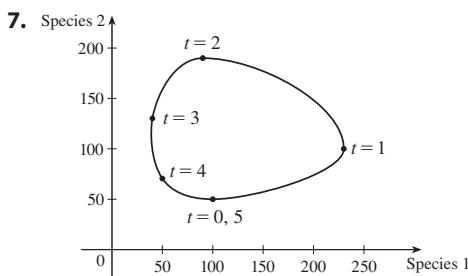
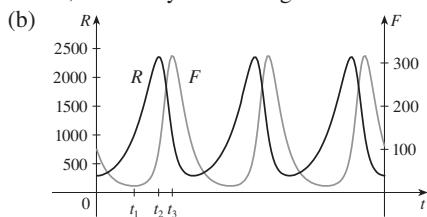
(b) (i) $x = 0, y = 0$: zero populations

(ii) $x = 0, y = 400$: In the absence of an x -population, the y -population stabilizes at 400.

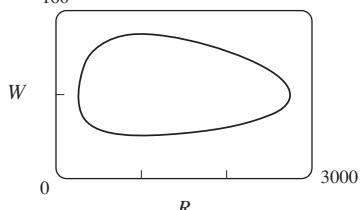
(iii) $x = 125, y = 0$: In the absence of a y -population, the x -population stabilizes at 125.

(iv) $x = 50, y = 300$: Both populations are stable.

5. (a) The rabbit population starts at about 300, increases to 2400, then decreases back to 300. The fox population starts at 100, decreases to about 20, increases to about 315, decreases to 100, and the cycle starts again.



9. (b)



11. (a) Population stabilizes at 5000.

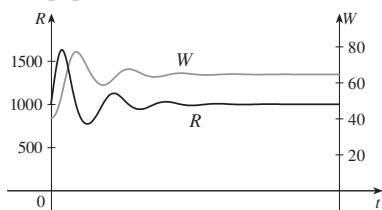
 (b) (i) $W = 0, R = 0$: Zero populations

 (ii) $W = 0, R = 5000$: In the absence of wolves, the rabbit population is always 5000.

 (iii) $W = 64, R = 1000$: Both populations are stable.

(c) The populations stabilize at 1000 rabbits and 64 wolves.

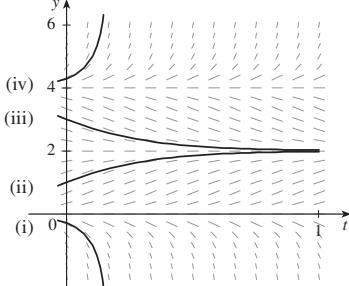
(d)

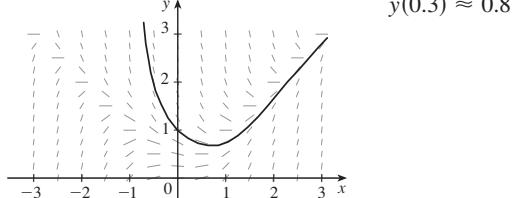

CHAPTER 9 REVIEW ■ PAGE 694
True-False Quiz

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

Exercises

1. (a)


 (b) $0 \leq c \leq 4; y = 0, y = 2, y = 4$

3. (a)

(b) 0.75676

(c) $y = x$ and $y = -x$; there is a loc max or loc min.

5. $y = \left(\frac{1}{2}x^2 + C\right)e^{-\sin x}$

7. $y = \pm\sqrt{\ln(x^2 + 2x^{3/2} + C)}$

9. $r(t) = 5e^{t-1^2}$ 11. $y = \frac{1}{2}x(\ln x)^2 + 2x$

13. $x = C - \frac{1}{2}y^2$

15. (a) $P(t) = \frac{2000}{1 + 19e^{-0.1t}}$; ≈ 560

(b) $t = -10 \ln \frac{2}{57} \approx 33.5$

17. (a) $L(t) = L_\infty - [L_\infty - L(0)]e^{-kt}$

(b) $L(t) = 53 - 43e^{-0.2t}$

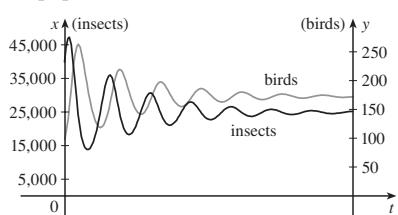
19. 15 days 21. $k \ln h + h = (-R/V)t + C$

23. (a) Stabilizes at 200,000

(b) (i) $x = 0, y = 0$: Zero populations(ii) $x = 200,000, y = 0$: In the absence of birds, the insect population is always 200,000.(iii) $x = 25,000, y = 175$: Both populations are stable.

(c) The populations stabilize at 25,000 insects and 175 birds.

(d)

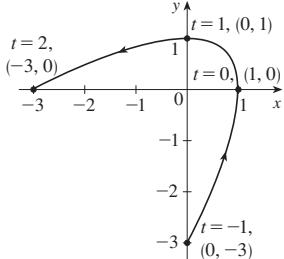
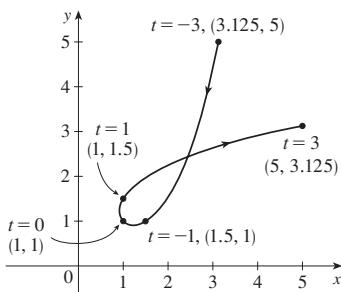
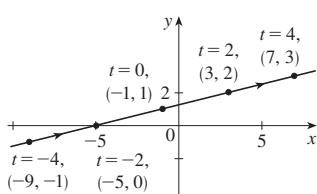
**PROBLEMS PLUS ■ PAGE 697**

1. $f(x) = \pm 10e^x$ 5. $y = x^{1/n}$ 7. 20°C

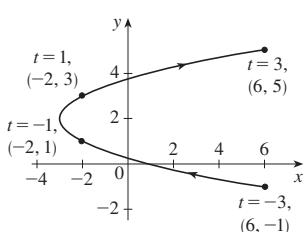
9. (b) $f(x) = \frac{x^2 - L^2}{4L} - \frac{L}{2} \ln\left(\frac{x}{L}\right)$ (c) No

11. (a) 9.5 h (b) $2,700\pi \approx 8482 \text{ m}^2$; $471 \text{ m}^2/\text{h}$ (c) 5.5 h

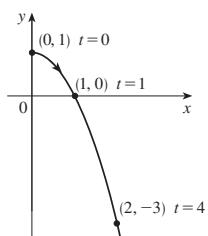
13. $x^2 + (y - 6)^2 = 25$ 15. $y = K/x, K \neq 0$

3.**5.****7. (a)**

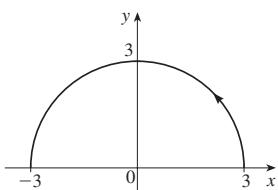
(b) $y = \frac{1}{4}x + \frac{5}{4}$

9. (a)

(b) $x = y^2 - 4y + 1$, $-1 \leq y \leq 5$

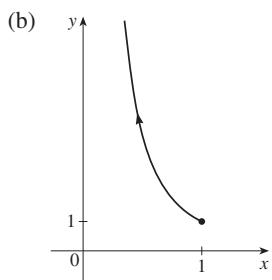
11. (a)

(b) $y = 1 - x^2, x \geq 0$

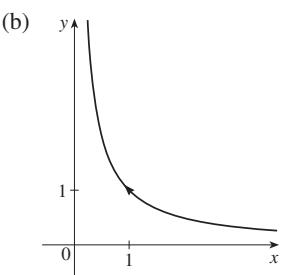
13. (a) $x^2 + y^2 = 9, y \geq 0$ **(b)****CHAPTER 10****EXERCISES 10.1 ■ PAGE 706**

1. $(2, \frac{1}{3}), (0, 1), (0, 3), (2, 9), (6, 27)$

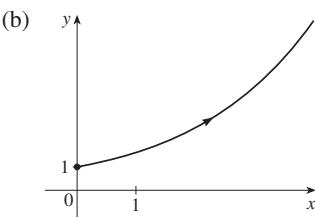
15. (a) $y = 1/x^2, 0 < x \leq 1$



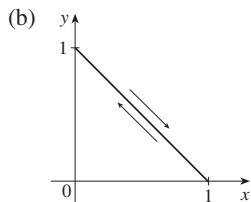
17. (a) $y = 1/x, x > 0$



19. (a) $y = e^{x/2}, x \geq 0$



21. (a) $x + y = 1, 0 \leq x \leq 1$



23. 2π seconds; clockwise

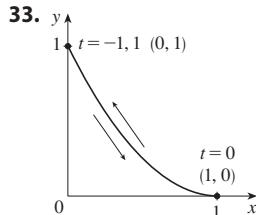
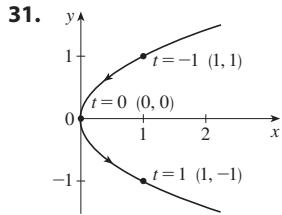
25. Moves counterclockwise along the circle

$$(x - 5)^2 + (y - 3)^2 = 4 \text{ from } (3, 3) \text{ to } (7, 3)$$

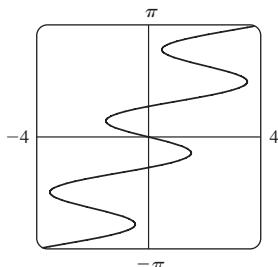
27. Moves 3 times clockwise around the ellipse

$$(x^2/25) + (y^2/4) = 1, \text{ starting and ending at } (0, -2)$$

29. It is contained in the rectangle described by $1 \leq x \leq 4$ and $2 \leq y \leq 3$.



35.



37. (b) $x = -2 + 5t, y = 7 - 8t, 0 \leq t \leq 1$

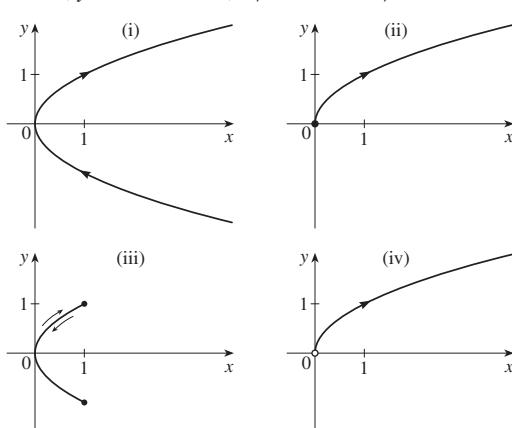
39. One option: $x = 5 \sin(t/2), y = 5 \cos(t/2)$ where t is time in seconds

41. (a) $x = 2 \cos t, y = 1 - 2 \sin t, 0 \leq t \leq 2\pi$

(b) $x = 2 \cos t, y = 1 + 2 \sin t, 0 \leq t \leq 6\pi$

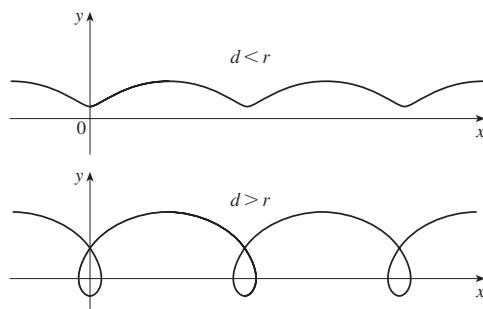
(c) $x = 2 \cos t, y = 1 + 2 \sin t, \pi/2 \leq t \leq 3\pi/2$

45. (b)



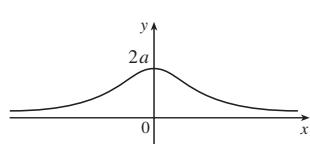
47. The curve $y = x^{2/3}$ is generated in (a). In (b), only the portion with $x \geq 0$ is generated, and in (c) we get only the portion with $x > 0$.

49.



51. $x = a \cos \theta, y = b \sin \theta; (x^2/a^2) + (y^2/b^2) = 1$, ellipse

53.

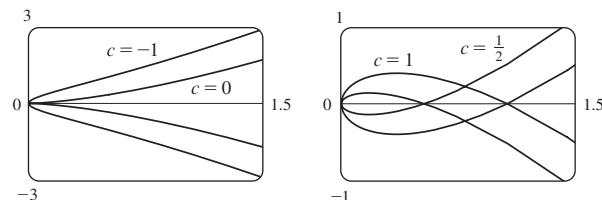


55. (a) No (b) Yes; (6, 11) when $t = 1$

57. (a) $(0, 0); t = 1, t = -1$

(b) $(-1, -1); t = \frac{1 + \sqrt{5}}{2}, t = \frac{1 - \sqrt{5}}{2}$

59. For $c = 0$, there is a cusp; for $c > 0$, there is a loop whose size increases as c increases.



61. The curves roughly follow the line $y = x$ and start having loops when a is between 1.4 and 1.6 (more precisely, when $a > \sqrt{2}$); the loops increase in size as a increases.

63. As n increases, the number of oscillations increases; a and b determine the width and height.

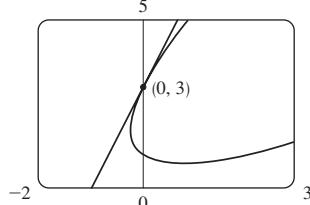
EXERCISES 10.2 ■ PAGE 717

1. $6t^2 + 3, 4 - 10t, \frac{4 - 10t}{6t^2 + 3}$

3. $e'(t+1), 1 + \cos t, \frac{1 + \cos t}{e'(t+1)}$ **5.** $\ln 2 - \frac{1}{4}$

7. $y = -x$ **9.** $y = \frac{1}{2}x + \frac{3}{2}$ **11.** $y = -x + \frac{5}{4}$

13. $y = 3x + 3$



15. $\frac{2t+1}{2t}, -\frac{1}{4t^3}, t < 0$

17. $e^{-2t}(1-t), e^{-3t}(2t-3), t > \frac{3}{2}$

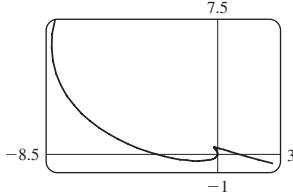
19. $\frac{t+1}{t-1}, \frac{-2t}{(t-1)^3}, 0 < t < 1$

21. Horizontal at $(0, -3)$, vertical at $(\pm 2, -2)$

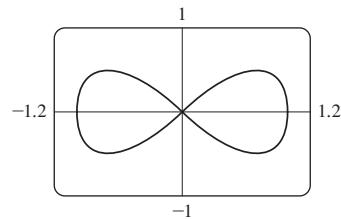
23. Horizontal at $(\frac{1}{2}, -1)$ and $(-\frac{1}{2}, 1)$, no vertical

25. $(0.6, 2); (5 \cdot 6^{-6/5}, e^{6^{-1/5}})$

27.



29. $y = x, y = -x$



31. (a) $d \sin \theta / (r - d \cos \theta)$ **33.** $(4, 0)$ **35.** $\frac{24}{5}$

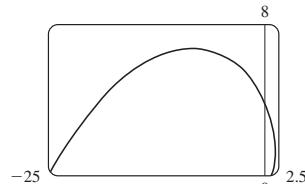
37. $\frac{4}{3}$ **39.** πab **41.** $2\pi r^2 + \pi d^2$

43. $\int_{-1}^3 \sqrt{(6t - 3t^2)^2 + (2t - 2)^2} dt \approx 15.2092$

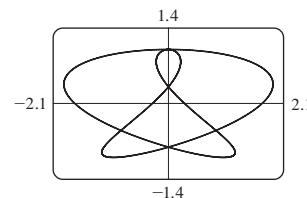
45. $\int_0^{4\pi} \sqrt{5 - 4 \cos t} dt \approx 26.7298$ **47.** $\frac{2}{3}(10\sqrt{10} - 1)$

49. $\frac{1}{2}\sqrt{2} + \frac{1}{2}\ln(1 + \sqrt{2})$

51. $\sqrt{2}(e^\pi - 1)$



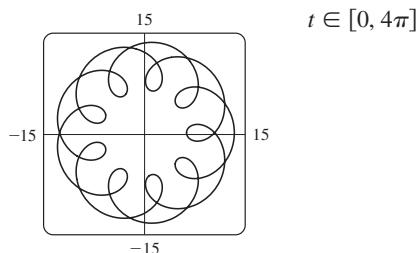
53. 16.7102



55. $6\sqrt{2}, \sqrt{2}$ **57.** $\sqrt{293} \approx 17.12$ m/s

59. $\sqrt{5}e \approx 6.08$ m/s **61.** (a) v_0 m/s (b) $v_0 \cos \alpha$ m/s

63. (a)



(b) 294

65. $\frac{3}{8}\pi a^2$

67. $\int_0^{\pi/2} 2\pi t \cos t \sqrt{t^2 + 1} dt \approx 4.7394$

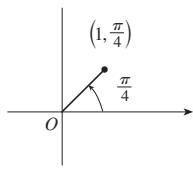
69. $\int_0^1 2\pi e^{-t} \sqrt{1 + 2e^t + e^{2t} + e^{-2t}} dt \approx 10.6705$

71. $\frac{2}{1215}\pi(247\sqrt{13} + 64)$ **73.** $\frac{6}{5}\pi a^2$

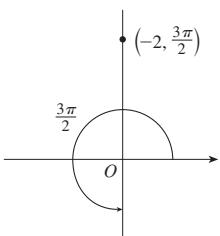
75. $\frac{24}{5}\pi(949\sqrt{26} + 1)$ **81.** $\frac{1}{4}$

EXERCISES 10.3 ■ PAGE 730

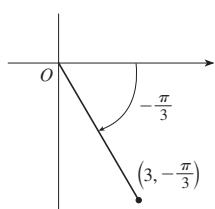
1. (a)


 $(1, 9\pi/4), (-1, 5\pi/4)$

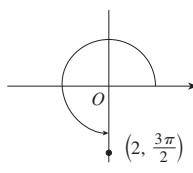
(b)


 $(2, \pi/2), (-2, 7\pi/2)$

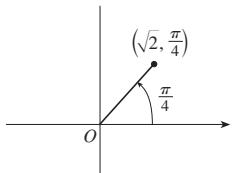
(c)


 $(3, 5\pi/3), (-3, 2\pi/3)$

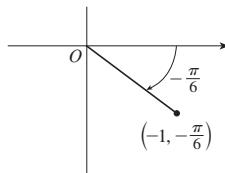
3. (a)


 $(0, -2)$

(b)


 $(1, 1)$

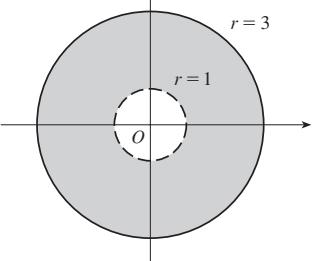
(c)


 $(-\sqrt{3}/2, 1/2)$

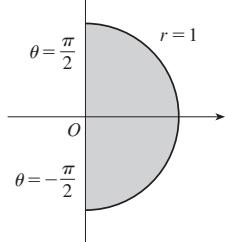
 5. (a) (i) $(4\sqrt{2}, 3\pi/4)$ (ii) $(-4\sqrt{2}, 7\pi/4)$

 (b) (i) $(6, \pi/3)$ (ii) $(-6, 4\pi/3)$

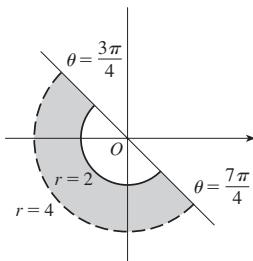
7.



9.



11.


 13. $2\sqrt{7}$ 15. $x^2 + y^2 = 5$; circle, center O , radius $\sqrt{5}$

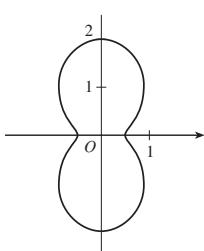
 17. $x^2 + y^2 = 5x$; circle, center $(5/2, 0)$, radius $5/2$

 19. $x^2 - y^2 = 1$; hyperbola, center O , foci on x -axis

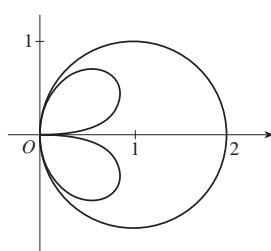
 21. $r = \sqrt{7}$ 23. $\theta = \pi/3$ 25. $r = 4 \sin \theta$

 27. (a) $\theta = \pi/6$ (b) $x = 3$

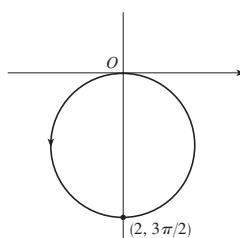
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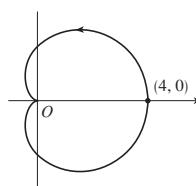
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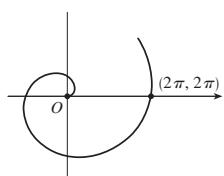
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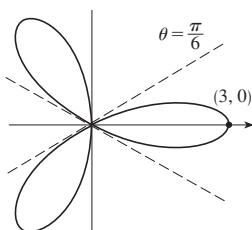
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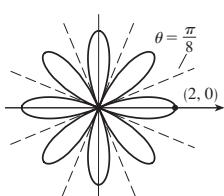
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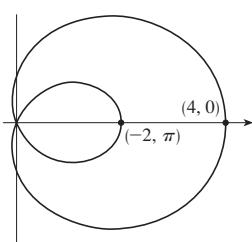
39.



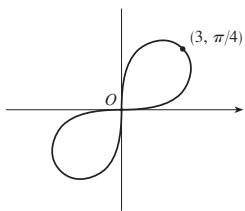
41.



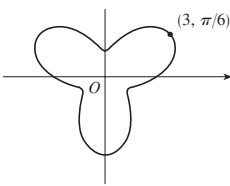
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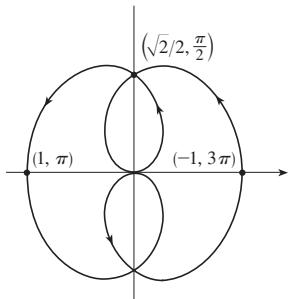
45.



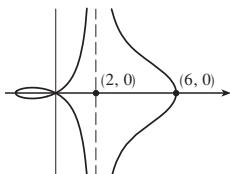
47.



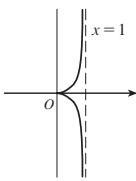
49.



51.



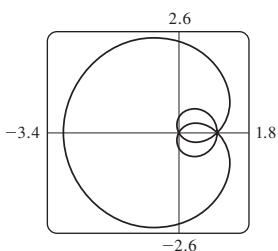
53.



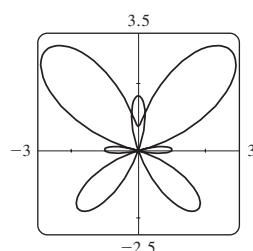
55. (a) For $c < -1$, the inner loop begins at $\theta = \sin^{-1}(-1/c)$ and ends at $\theta = \pi - \sin^{-1}(-1/c)$; for $c > 1$, it begins at $\theta = \pi + \sin^{-1}(1/c)$ and ends at $\theta = 2\pi - \sin^{-1}(1/c)$.

57. Center $(b/2, a/2)$, radius $\sqrt{a^2 + b^2}/2$

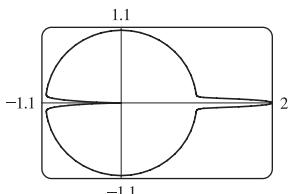
59.



61.



63.



65. By counterclockwise rotation through angle $\pi/6, \pi/3$, or α about the origin

67. For $c = 0$, the curve is a circle. As c increases, the left side gets flatter, then has a dimple for $0.5 < c < 1$, a cusp for $c = 1$, and a loop for $c > 1$.

EXERCISES 10.4 ■ PAGE 737

1.

$$\pi^2/8$$

9.

$$4\pi$$

3.

$$\pi/2$$

5.

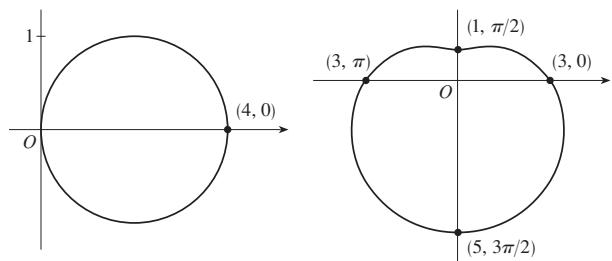
$$\frac{1}{2}$$

7.

$$\frac{41}{4}\pi$$

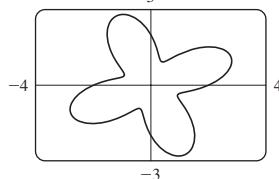
11.

$$11\pi$$



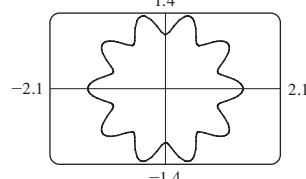
13.

$$\frac{9}{2}\pi$$



15.

$$\frac{3}{2}\pi$$



17.

$$\frac{4}{3}\pi$$

19.

$$\frac{1}{16}\pi$$

21.

$$\pi - \frac{3}{2}\sqrt{3}$$

23.

$$\frac{4}{3}\pi + 2\sqrt{3}$$

25.

$$4\sqrt{3} - \frac{4}{3}\pi$$

27.

$$\pi$$

29.

$$\frac{9}{8}\pi - \frac{9}{4}$$

31.

$$\frac{1}{2}\pi - 1$$

33.

$$-\sqrt{3} + 2 + \frac{1}{3}\pi$$

35.

$$\frac{1}{4}(\pi + 3\sqrt{3})$$

37.

$$(\frac{1}{2}, \pi/6), (\frac{1}{2}, 5\pi/6), \text{ and the pole}$$

39.

$$(1, \theta) \text{ where } \theta = \pi/12, 5\pi/12, 13\pi/12, 17\pi/12$$

and $(-1, \theta) \text{ where } \theta = 7\pi/12, 11\pi/12, 19\pi/12, 23\pi/12$

41.

$$(1, \pi/6), (1, 5\pi/6), (1, 7\pi/6), (1, 11\pi/6)$$

43.

$$21\pi/2$$

45.

$$\pi/8$$

47.

Intersection at $\theta \approx 0.89, 2.25$; area ≈ 3.46

49.

$$2\pi$$

51.

$$\frac{8}{3}[(\pi^2 + 1)^{3/2} - 1]$$

53.

$$6\sqrt{2} + 12$$

55.

$$\frac{16}{3}$$

57.

$$\int_{\pi}^{4\pi} \sqrt{\cos^2(\theta/5) + \frac{1}{25} \sin^2(\theta/5)} d\theta$$

59.

$$2.4221$$

61.

$$8.0091$$

63.

$$1/\sqrt{3}$$

65.

$$-\pi$$

67.

$$1$$

69.

Horizontal at $(0, 0)$ [the pole], $(1, \pi/2)$;

vertical at $(1/\sqrt{2}, \pi/4), (1/\sqrt{2}, 3\pi/4)$

71.

Horizontal at $(\frac{3}{2}, \pi/3), (0, \pi)$ [the pole], and $(\frac{3}{2}, 5\pi/3)$;

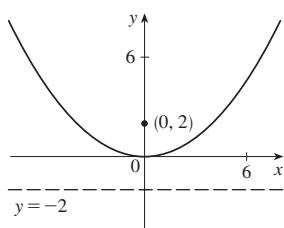
vertical at $(2, 0), (\frac{1}{2}, 2\pi/3), (\frac{1}{2}, 4\pi/3)$

75.

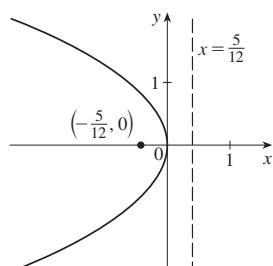
(b) $2\pi(2 - \sqrt{2})$

EXERCISES 10.5 ■ PAGE 746

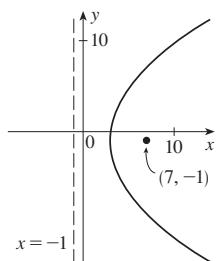
1. $(0, 0), (0, 2), y = -2$



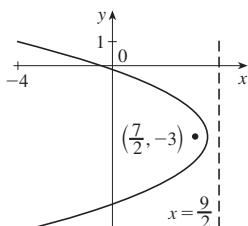
3. $(0, 0), \left(-\frac{5}{12}, 0\right), x = \frac{5}{12}$



5. $(3, -1), (7, -1), x = -1$

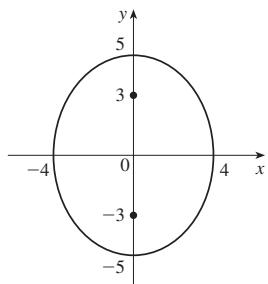


7. $(4, -3), \left(\frac{7}{2}, -3\right), x = \frac{9}{2}$

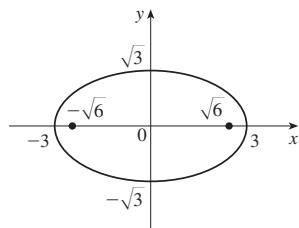


9. $x = -y^2$, focus $(-\frac{1}{4}, 0)$, directrix $x = \frac{1}{4}$

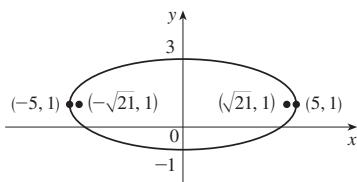
11. $(0, \pm 5), (0, \pm 3)$



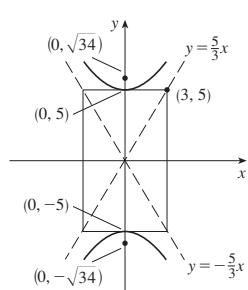
13. $(\pm 3, 0), (\pm \sqrt{6}, 0)$



15. $(\pm 5, 1), (\pm \sqrt{21}, 1)$

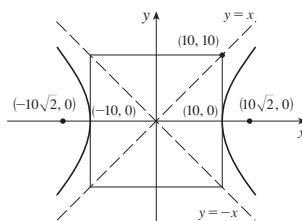


17. $\frac{x^2}{4} + \frac{y^2}{9} = 1$, foci $(0, \pm \sqrt{5})$

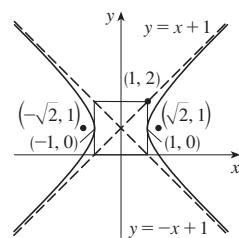


19. $(0, \pm 5), (0, \pm \sqrt{34}), y = \pm \frac{5}{3}x$

21. $(\pm 10, 0), (\pm 10\sqrt{2}, 0), y = \pm x$



23. $(\pm 1, 1), (\pm \sqrt{2}, 1), y - 1 = \pm x$



25. $\frac{x^2}{9} - \frac{y^2}{9} = 1; (\pm 3\sqrt{2}, 0), y = \pm x$

 27. Hyperbola, $(\pm 1, 0), (\pm \sqrt{5}, 0)$

 29. Ellipse, $(\pm \sqrt{2}, 1), (\pm 1, 1)$

 31. Parabola, $(1, -2), (1, -\frac{11}{6})$

33. $y^2 = 4x$ 35. $y^2 = -12(x + 1)$

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

39. $\frac{x^2}{25} + \frac{y^2}{21} = 1$ 41. $\frac{x^2}{12} + \frac{(y - 4)^2}{16} = 1$

43. $\frac{(x + 1)^2}{12} + \frac{(y - 4)^2}{16} = 1$ 45. $\frac{x^2}{9} - \frac{y^2}{16} = 1$

47. $\frac{(y - 1)^2}{25} - \frac{(x + 3)^2}{39} = 1$ 49. $\frac{x^2}{9} - \frac{y^2}{36} = 1$

51. $\frac{x^2}{3,763,600} + \frac{y^2}{3,753,196} = 1$

53. (a) $\frac{1.30x^2}{10,000} + \frac{5.83y^2}{100,000} = 1$ (b) ≈ 399 km

57. (a) Ellipse (b) Hyperbola (c) No curve

61. 15.9

63. $\frac{b^2 c}{a} + ab \ln\left(\frac{a}{b + c}\right)$ where $c^2 = a^2 + b^2$

65. $(0, 4/\pi)$ 69. $\frac{x^2}{16} + \frac{y^2}{15} = 1$

EXERCISES 10.6 ■ PAGE 755

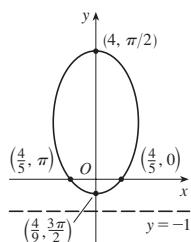
1. $r = \frac{2}{1 + \cos \theta}$ 3. $r = \frac{8}{1 - 2 \sin \theta}$

5. $r = \frac{10}{3 - 2 \cos \theta}$ 7. $r = \frac{6}{1 + \sin \theta}$

9. VI 11. II 13. IV

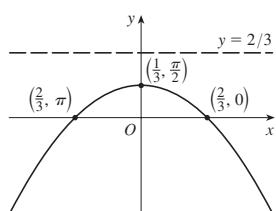
15. (a) $\frac{4}{5}$ (b) Ellipse (c) $y = -1$

(d)



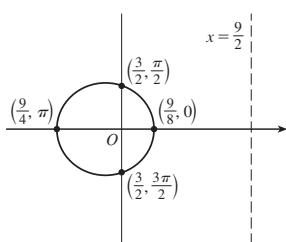
17. (a) 1 (b) Parabola (c) $y = \frac{2}{3}$

(d)



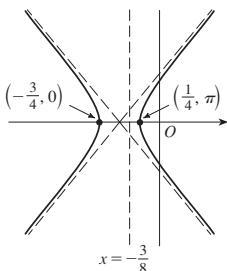
19. (a) $\frac{1}{3}$ (b) Ellipse (c) $x = \frac{9}{2}$

(d)

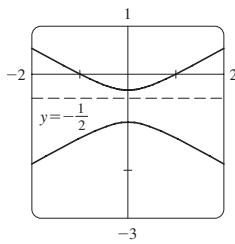


21. (a) 2 (b) Hyperbola (c) $x = -\frac{3}{8}$

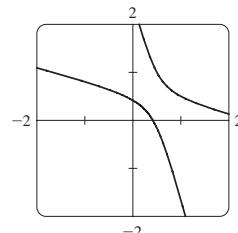
(d)



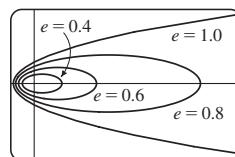
23. (a) 2, $y = -\frac{1}{2}$



$$(b) r = \frac{1}{1 - 2 \sin(\theta - 3\pi/4)}$$



25. The ellipse is nearly circular when e is close to 0 and becomes more elongated as $e \rightarrow 1^-$. At $e = 1$, the curve becomes a parabola.



$$31. r = \frac{2.26 \times 10^8}{1 + 0.093 \cos \theta}$$

$$33. r = \frac{1.07}{1 + 0.97 \cos \theta}; 35.64 \text{ AU}$$

$$35. 7.0 \times 10^7 \text{ km} \quad 37. 3.6 \times 10^8 \text{ km}$$

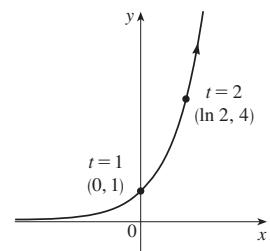
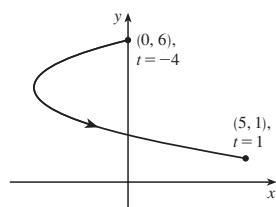
CHAPTER 10 REVIEW ■ PAGE 757

True-False Quiz

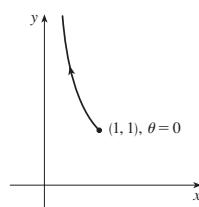
1. False 3. False 5. False 7. True 9. True
11. True

Exercises

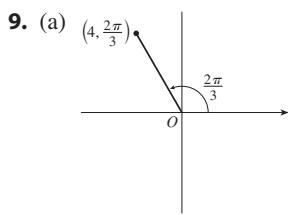
$$1. x = y^2 - 8y + 12, 1 \leq y \leq 6 \quad 3. y = e^{2x}$$



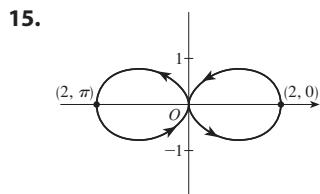
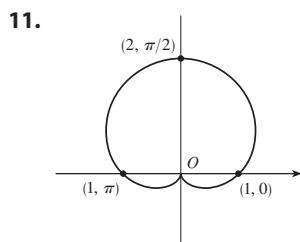
$$5. y = 1/x, 0 < x \leq 1$$



$$7. x = t, y = \sqrt{t}; x = t^4, y = t^2; \\ x = \tan^2 t, y = \tan t, 0 \leq t < \pi/2$$

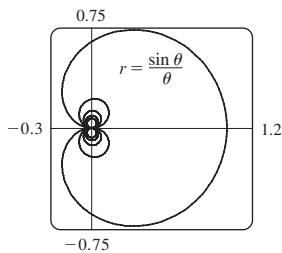


9. (a) $(4, \frac{2\pi}{3})$
(b) $(3\sqrt{2}, 3\pi/4), (-3\sqrt{2}, 7\pi/4)$



19. $r = \frac{2}{\cos \theta + \sin \theta}$

21.

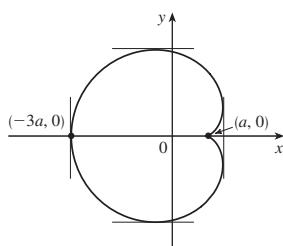


23. 2 25. -1

27. $\frac{1 + \sin t}{1 + \cos t}, \frac{1 + \cos t + \sin t}{(1 + \cos t)^3}$

29. $(\frac{11}{8}, \frac{3}{4})$

31. Vertical tangent at $(\frac{3}{2}a, \pm\frac{1}{2}\sqrt{3}a)$, $(-3a, 0)$; horizontal tangent at $(a, 0)$, $(-\frac{1}{2}a, \pm\frac{3}{2}\sqrt{3}a)$



33. 18 35. $(2, \pm\pi/3)$ 37. $\frac{1}{2}(\pi - 1)$
39. $2(5\sqrt{5} - 1)$

(-2, $2\sqrt{3}$)

41. $\frac{2\sqrt{\pi^2 + 1} - \sqrt{4\pi^2 + 1}}{2\pi} + \ln\left(\frac{2\pi + \sqrt{4\pi^2 + 1}}{\pi + \sqrt{\pi^2 + 1}}\right)$

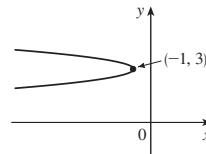
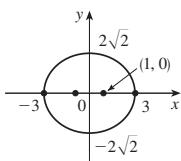
43. (a) $\sqrt{90} \approx 9.49$ m/s (b) $\frac{1}{24}(65\sqrt{65} - 1) \approx 21.79$ m/s

45. $471,295\pi/1024$

47. All curves have the vertical asymptote $x = 1$. For $c < -1$, the curve bulges to the right; at $c = -1$, the curve is the line $x = 1$; and for $-1 < c < 0$, it bulges to the left. At $c = 0$ there is a cusp at $(0, 0)$ and for $c > 0$, there is a loop.

49. $(\pm 1, 0), (\pm 3, 0)$

51. $(-\frac{25}{24}, 3), (-1, 3)$



53. $\frac{x^2}{25} + \frac{y^2}{9} = 1$ 55. $\frac{y^2}{72/5} - \frac{x^2}{8/5} = 1$

57. $\frac{x^2}{25} + \frac{(8y - 399)^2}{160,801} = 1$ 59. $r = \frac{4}{3 + \cos \theta}$

PROBLEMS PLUS ■ PAGE 760

1. $\frac{2}{3}\pi + 2 - 2\sqrt{3}$ 3. $[-\frac{3}{4}\sqrt{3}, \frac{3}{4}\sqrt{3}] \times [-1, 2]$

CHAPTER 11

EXERCISES 11.1 ■ PAGE 773

Abbreviations: C, convergent; D, divergent

1. (a) A sequence is an ordered list of numbers. It can also be defined as a function whose domain is the set of positive integers.
(b) The terms a_n approach 8 as n becomes large.
(c) The terms a_n become large as n becomes large.

3. 0, 7, 26, 63, 124 5. 6, 11, 20, 37, 70 7. 1, $-\frac{1}{4}, \frac{1}{9}, -\frac{1}{16}, \frac{1}{25}$.

9. $-1, 1, -1, 1, -1$ 11. $-1, \frac{2}{3}, -\frac{1}{3}, \frac{2}{15}, -\frac{2}{45}$

13. 1, 3, 7, 15, 31 15. $2, \frac{2}{3}, \frac{2}{5}, \frac{2}{7}, \frac{2}{9}$ 17. $a_n = 1/(2n)$

19. $a_n = -3(-\frac{2}{3})^{n-1}$ 21. $a_n = (-1)^{n+1} \frac{n^2}{n+1}$

23. 0.4286, 0.4615, 0.4737, 0.4800, 0.4839, 0.4865, 0.4884, 0.4898, 0.4909, 0.4918; yes; $\frac{1}{2}$

25. 0.5000, 1.2500, 0.8750, 1.0625, 0.9688, 1.0156, 0.9922, 1.0039, 0.9980, 1.0010; yes; 1 27. 0 29. 2

31. D 33. 0 35. 1 37. 2 39. D

41. 0 43. 0 45. D 47. 0 49. 0

51. 1 53. e^2 55. $\ln 2$ 57. $\pi/2$ 59. D

61. D 63. D 65. $\pi/4$ 67. D 69. 0

71. (a) 1060, 1123.60, 1191.02, 1262.48, 1338.23 (b) D

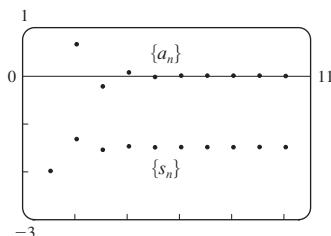
73. (b) 5734 75. $-1 < r < 1$

77. Convergent by the Monotonic Sequence Theorem; $5 \leq L \leq 8$

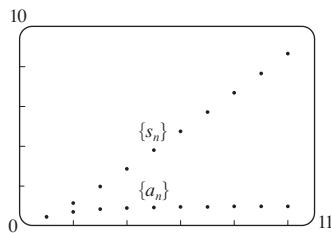
- 79.** Decreasing; yes **81.** Not monotonic; no
83. Increasing; yes
85. 2 **87.** $\frac{1}{2}(3 + \sqrt{5})$ **89.** (b) $\frac{1}{2}(1 + \sqrt{5})$
91. (a) 0 (b) 9, 11

EXERCISES 11.2 ■ PAGE 785

- 1.** (a) A sequence is an ordered list of numbers whereas a series is the *sum* of a list of numbers.
(b) A series is convergent if the sequence of partial sums is a convergent sequence. A series is divergent if it is not convergent.
3. 2
5. 1, 1.125, 1.1620, 1.1777, 1.1857, 1.1903, 1.1932, 1.1952; C
7. 0.8415, 1.7508, 1.8919, 1.1351, 0.1762, -0.1033, 0.5537, 1.5431; D
9. 0.5, 0.55, 0.5611, 0.5648, 0.5663, 0.5671, 0.5675, 0.5677; C
11. -2, -1.33333, -1.55556, -1.48148, -1.50617, -1.49794, -1.50069, -1.49977, -1.50008, -1.49997; convergent, sum = -1.5



- 13.** 0.44721, 1.15432, 1.98637, 2.88080, 3.80927, 4.75796, 5.71948, 6.68962, 7.66581, 8.64639; divergent



- 15.** (a) Yes (b) No **17.** $-\frac{3}{2}$ **19.** $\frac{11}{6}$
21. $e - 1$ **23.** D **25.** $\frac{25}{3}$ **27.** $\frac{400}{9}$ **29.** $\frac{1}{7}$
31. D **33.** D **35.** $\frac{2}{3}$ **37.** D **39.** 9
41. D **43.** $\frac{\sin 100}{1 - \sin 100} \approx -0.336$ **45.** D
47. D **49.** $e/(e - 1)$

- 51.** (b) 1 (c) 2 (d) All rational numbers with a terminating decimal representation, except 0

- 53.** $\frac{8}{9}$ **55.** $\frac{838}{333}$ **57.** 45,679/37,000
59. $-\frac{1}{5} < x < \frac{1}{5}; \frac{-5x}{1 + 5x}$
61. $-1 < x < 5; \frac{3}{5 - x}$

- 63.** $x > 2$ or $x < -2; \frac{x}{x - 2}$ **65.** $x < 0; \frac{1}{1 - e^x}$
67. 1 **69.** $a_1 = 0, a_n = \frac{2}{n(n+1)}$ for $n > 1$, sum = 1
71. (a) 125 mg; 131.25 mg
(b) $Q_{n+1} = 100 + 0.25Q_n$ (c) 133.3 mg
73. (a) 157.875 mg; $\frac{3000}{19}(1 - 0.05^n)$ (b) $\frac{3000}{19} \approx 157.895$ mg
75. (a) $S_n = \frac{D(1 - c^n)}{1 - c}$ (b) 5 **77.** $\frac{1}{2}(\sqrt{3} - 1)$
83. $\frac{1}{n(n+1)}$ **85.** The series is divergent.
91. $\{s_n\}$ is bounded and increasing.
93. (a) $0, \frac{1}{9}, \frac{2}{9}, \frac{1}{3}, \frac{2}{3}, \frac{7}{9}, \frac{8}{9}, 1$
95. (a) $\frac{1}{2}, \frac{5}{6}, \frac{23}{24}, \frac{119}{120}; \frac{(n+1)! - 1}{(n+1)!}$ (c) 1

EXERCISES 11.3 ■ PAGE 796

- 1.** C

3. C **5.** D **7.** D **9.** C **11.** C **13.** C
15. D **17.** C **19.** C **21.** D **23.** D **25.** C
27. C **29.** f is neither positive nor decreasing.
31. $p > 1$ **33.** $p < -1$ **35.** $(1, \infty)$
37. (a) $\frac{9}{10}\pi^4$ (b) $\frac{1}{90}\pi^4 - \frac{17}{16}$
39. (a) 1.54977, error ≤ 0.1 (b) 1.64522, error ≤ 0.005
(c) 1.64522 compared to 1.64493 (d) $n > 1000$
41. 0.00145 **47.** $b < 1/e$

EXERCISES 11.4 ■ PAGE 802

- 1.** (a) Nothing (b) C **5.** (c) **7.** C **9.** D
11. C **13.** D **15.** C **17.** C **19.** D
21. D **23.** C **25.** D **27.** C **29.** D
31. C **33.** C **35.** C **37.** D **39.** C
41. 0.1993, error $< 2.5 \times 10^{-5}$
43. 0.0739, error $< 6.4 \times 10^{-8}$
53. Yes **55.** (a) False (b) False (c) True

EXERCISES 11.5 ■ PAGE 810

Abbreviations: AC, absolutely convergent;
CC, conditionally convergent

- 1.** (a) A series whose terms are alternately positive and negative (b) $0 < b_{n+1} \leq b_n$ and $\lim_{n \rightarrow \infty} b_n = 0$, where $b_n = |a_n|$ (c) $|R_n| \leq b_{n+1}$
3. D **5.** C **7.** D **9.** C **11.** C **13.** D

15. C 17. C 19. C

21. (a) The series $\sum a_n$ is absolutely convergent if $\sum |a_n|$ converges. (b) The series $\sum a_n$ is conditionally convergent if $\sum a_n$ converges but $\sum |a_n|$ diverges. (c) It converges absolutely.

23. CC 25. CC 27. AC 29. AC 31. CC

33. CC 35. -0.5507 37. 5 39. 5

41. -0.4597 43. -0.1050

45. An underestimate 47. p is not a negative integer.

49. $\{b_n\}$ is not decreasing. 53. (b) $\sum_{n=2}^{\infty} \frac{(-1)^n}{n \ln n}$; $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n}$

EXERCISES 11.6 ■ PAGE 816

1. (a) D (b) C (c) May converge or diverge

3. AC 5. D 7. AC 9. AC 11. D

13. AC 15. AC 17. AC 19. D 21. AC

23. AC 25. D 27. CC 29. AC 31. D

33. AC 35. D 37. AC 39. (a) and (d)

43. (a) $\frac{661}{960} \approx 0.68854$, error < 0.00521(b) $n \geq 11$, 0.693109**EXERCISES 11.7 ■ PAGE 819**

1. (a) C (b) C 3. (a) C (b) D

5. (a) D (b) C 7. (a) C (b) D

9. D 11. CC 13. D 15. D 17. C 19. C

21. C 23. C 25. C 27. C 29. D 31. D

33. D 35. C 37. C 39. C 41. D

43. C 45. D 47. C

EXERCISES 11.8 ■ PAGE 8241. A series of the form $\sum_{n=0}^{\infty} c_n(x - a)^n$, where x is a variable and a and the c_n 's are constants3. 1, $[-1, 1]$ 5. 1, $(-1, 1)$ 7. 5, $(-5, 5)$ 9. 3, $[-3, 3]$ 11. 1, $[-1, 1)$ 13. $\infty, (-\infty, \infty)$ 15. 4, $[-4, 4]$ 17. $\frac{1}{4}, (-\frac{1}{4}, \frac{1}{4})$ 19. 2, $[-2, 2)$ 21. 1, $[1, 3]$ 23. 2, $[-4, 0)$ 25. $\infty, (-\infty, \infty)$ 27. 1, $[-1, 1)$ 29. $b, (a - b, a + b)$ 31. 0, $\{\frac{1}{2}\}$ 33. $\frac{1}{5}, [\frac{3}{5}, 1]$ 35. $\infty, (-\infty, \infty)$ 37. (a) Yes (b) No39. k^k 41. No 45. 2**EXERCISES 11.9 ■ PAGE 831**1. 10 3. $\sum_{n=0}^{\infty} (-1)^n x^n, (-1, 1)$ 5. $\sum_{n=0}^{\infty} x^{2n}, (-1, 1)$ 7. 2 $\sum_{n=0}^{\infty} \frac{1}{3^{n+1}} x^n, (-3, 3)$ 9. $\sum_{n=0}^{\infty} \frac{(-1)^n x^{4n+2}}{2^{4n+4}}, (-2, 2)$ 11. $-\frac{1}{2} - \sum_{n=1}^{\infty} \frac{(-1)^n 3x^n}{2^{n+1}}, (-2, 2)$ 13. $\sum_{n=0}^{\infty} \left(-1 - \frac{1}{3^{n+1}} \right) x^n, (-1, 1)$ 15. (a) $\sum_{n=0}^{\infty} (-1)^n (n+1)x^n, R = 1$

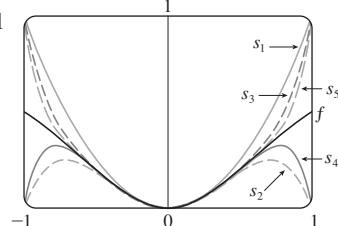
(b) $\frac{1}{2} \sum_{n=0}^{\infty} (-1)^n (n+2)(n+1)x^n, R = 1$

(c) $\frac{1}{2} \sum_{n=2}^{\infty} (-1)^n n(n-1)x^n, R = 1$

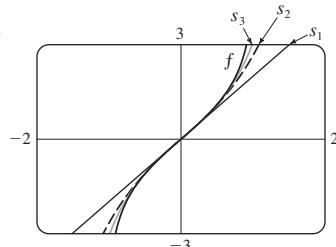
17. $\sum_{n=0}^{\infty} (-1)^n 4^n (n+1)x^{n+1}, R = \frac{1}{4}$

19. $\sum_{n=0}^{\infty} (2n+1)x^n, R = 1$ 21. $\ln 5 - \sum_{n=1}^{\infty} \frac{x^n}{n5^n}, R = 5$

23. $\sum_{n=0}^{\infty} (-1)^n x^{2n+2}, R = 1$



25. $\sum_{n=0}^{\infty} \frac{2x^{2n+1}}{2n+1}, R = 1$



27. $C + \sum_{n=0}^{\infty} \frac{t^{8n+2}}{8n+2}, R = 1$

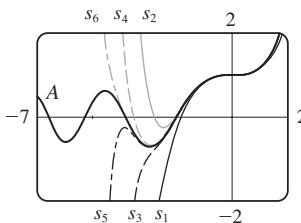
29. $C + \sum_{n=1}^{\infty} (-1)^{n-1} \frac{x^{n+3}}{n(n+3)}, R = 1$

31. 0.044522 33. 0.000395 35. 0.19740

39. (b) 0.920

41. (a) $(-\infty, \infty)$

(b), (c)



43. $(-1, 1), f(x) = (1+2x)/(1-x^2)$

45. $[-1, 1], [-1, 1), (-1, 1)$ 47. $\sum_{n=1}^{\infty} n^2 x^n, R = 1$

EXERCISES 11.10 ■ PAGE 846

1. $b_8 = f^{(8)}(5)/8!$ 3. $\sum_{n=0}^{\infty} (n+1)x^n, R = 1$

5. $x + x^2 + \frac{1}{2}x^3 + \frac{1}{6}x^4$

7. $2 + \frac{1}{12}(x - 8) - \frac{1}{288}(x - 8)^2 + \frac{5}{20736}(x - 8)^3$

9. $\frac{1}{2} + \frac{\sqrt{3}}{2}\left(x - \frac{\pi}{6}\right) - \frac{1}{4}\left(x - \frac{\pi}{6}\right)^2 - \frac{\sqrt{3}}{12}\left(x - \frac{\pi}{6}\right)^3$

11. $\sum_{n=0}^{\infty} (n+1)x^n, R = 1$

13. $\sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!}, R = \infty$

15. $3 - 3x^2 + 2x^4, R = \infty$

19. $\sum_{n=0}^{\infty} \frac{x^{2n+1}}{(2n+1)!}, R = \infty$

21. $50 + 105(x-2) + 92(x-2)^2 + 42(x-2)^3 + 10(x-2)^4 + (x-2)^5, R = \infty$

23. $\ln 2 + \sum_{n=1}^{\infty} (-1)^{n+1} \frac{1}{n2^n} (x-2)^n, R = 2$

25. $\sum_{n=0}^{\infty} \frac{2^n e^6}{n!} (x-3)^n, R = \infty$

27. $\sum_{n=0}^{\infty} \frac{(-1)^{n+1}}{(2n+1)!} (x-\pi)^{2n+1}, R = \infty$

29. $\sum_{n=0}^{\infty} (-1)^n \frac{2^{2n+1}}{(2n+1)!} (x-\pi)^{2n+1}, R = \infty$

35. $1 - \frac{1}{4}x - \sum_{n=2}^{\infty} \frac{3 \cdot 7 \cdot \dots \cdot (4n-5)}{4^n \cdot n!} x^n, R = 1$

37. $\sum_{n=0}^{\infty} (-1)^n \frac{(n+1)(n+2)}{2^{n+4}} x^n, R = 2$

39. $\sum_{n=0}^{\infty} (-1)^n \frac{1}{2n+1} x^{4n+2}, R = 1$

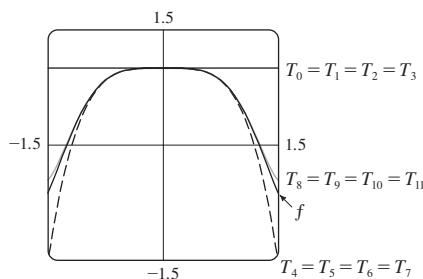
41. $\sum_{n=0}^{\infty} (-1)^n \frac{2^{2n}}{(2n)!} x^{2n+1}, R = \infty$

43. $\sum_{n=0}^{\infty} (-1)^n \frac{1}{2^{2n}(2n)!} x^{4n+1}, R = \infty$

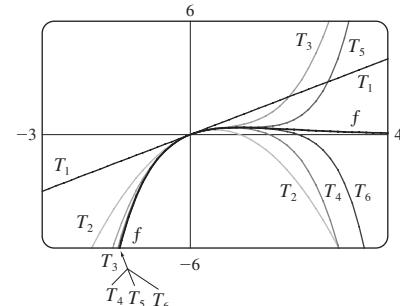
45. $\frac{1}{2}x + \sum_{n=1}^{\infty} (-1)^n \frac{1 \cdot 3 \cdot 5 \cdot \dots \cdot (2n-1)}{n!2^{3n+1}} x^{2n+1}, R = 2$

47. $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{2^{2n-1}}{(2n)!} x^{2n}, R = \infty$

51. $\sum_{n=0}^{\infty} (-1)^n \frac{1}{(2n)!} x^{4n}, R = \infty$



53. $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{(n-1)!} x^n, R = \infty$



55. 0.99619

57. (a) $1 + \sum_{n=1}^{\infty} \frac{1 \cdot 3 \cdot 5 \cdot \dots \cdot (2n-1)}{2^n n!} x^{2n}$

(b) $x + \sum_{n=1}^{\infty} \frac{1 \cdot 3 \cdot 5 \cdot \dots \cdot (2n-1)}{(2n+1)2^n n!} x^{2n+1}$

59. $C + \sum_{n=0}^{\infty} \binom{\frac{1}{2}}{n} \frac{x^{3n+1}}{3n+1}, R = 1$

61. $C + \sum_{n=1}^{\infty} (-1)^n \frac{1}{2n(2n)!} x^{2n}, R = \infty$

63. 0.0059 65. 0.40102 67. $\frac{1}{2}$ 69. $\frac{1}{120}$ 71. $\frac{3}{5}$

73. $1 - \frac{3}{2}x^2 + \frac{25}{24}x^4$

75. $1 + \frac{1}{6}x^2 + \frac{7}{360}x^4$

77. $x - \frac{2}{3}x^4 + \frac{23}{45}x^6$

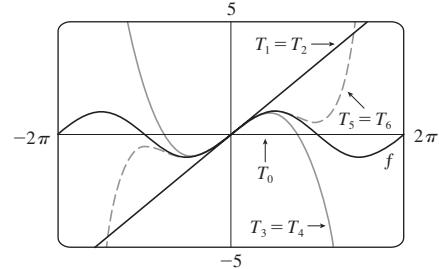
79. e^{-x^4} 81. $\tan^{-1}(x/2)$

83. $1/e$ 85. $\ln \frac{8}{5}$ 87. $1/\sqrt{2}$ 89. $e^3 - 1$

93. $\frac{203!}{101!}$

EXERCISES 11.11 ■ PAGE 856

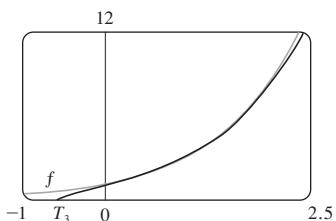
1. (a) $T_0(x) = 0, T_1(x) = T_2(x) = x, T_3(x) = T_4(x) = x - \frac{1}{6}x^3, T_5(x) = x - \frac{1}{6}x^3 + \frac{1}{120}x^5$



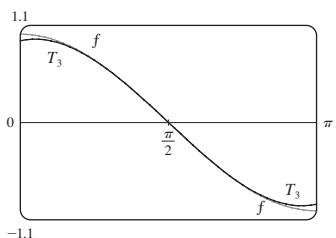
(b)	x	f	T_0	$T_1 = T_2$	$T_3 = T_4$	T_5
$\pi/4$	0.7071	0	0.7854	0.7047	0.7071	
$\pi/2$	1	0	1.5708	0.9248	1.0045	
π	0	0	3.1416	-2.0261	0.5240	

(c) As n increases, $T_n(x)$ is a good approximation to $f(x)$ on a larger and larger interval.

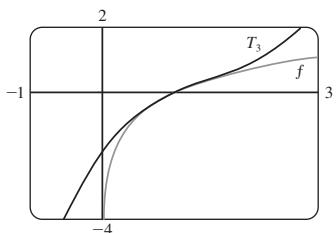
3. $e + e(x - 1) + \frac{1}{2}e(x - 1)^2 + \frac{1}{6}e(x - 1)^3$



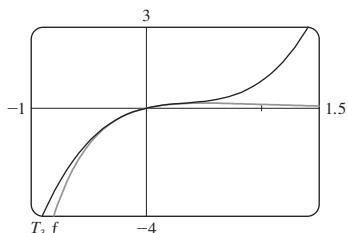
5. $-\left(x - \frac{\pi}{2}\right) + \frac{1}{6}\left(x - \frac{\pi}{2}\right)^3$



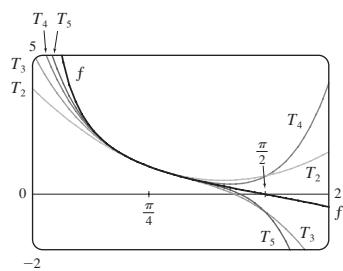
7. $(x - 1) - \frac{1}{2}(x - 1)^2 + \frac{1}{3}(x - 1)^3$



9. $x - 2x^2 + 2x^3$



11. $T_5(x) = 1 - 2\left(x - \frac{\pi}{4}\right) + 2\left(x - \frac{\pi}{4}\right)^2 - \frac{8}{3}\left(x - \frac{\pi}{4}\right)^3 + \frac{10}{3}\left(x - \frac{\pi}{4}\right)^4 - \frac{64}{15}\left(x - \frac{\pi}{4}\right)^5$



13. (a) $1 - (x - 1) + (x - 1)^2$ (b) 0.112 453

15. (a) $1 + \frac{2}{3}(x - 1) - \frac{1}{9}(x - 1)^2 + \frac{4}{81}(x - 1)^3$

(b) 0.000 097

17. (a) $1 + \frac{1}{2}x^2$ (b) 0.001 447

19. (a) $1 + x^2$ (b) 0.000 053

21. (a) $x^2 - \frac{1}{6}x^4$ (b) 0.041 667

23. 0.17365 25. Four 27. $-1.037 < x < 1.037$

29. $-0.86 < x < 0.86$ 31. 21 m, no

37. (c) Corrections differ by about 8×10^{-9} km.

CHAPTER 11 REVIEW ■ PAGE 860

True-False Quiz

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

11. True 13. True 15. False 17. True

19. True 21. True

Exercises

1. $\frac{1}{2}$ 3. D 5. 0 7. e^{12} 9. 2 11. C
13. C 15. D 17. C 19. C 21. C 23. CC

25. AC 27. $\frac{1}{11}$ 29. $\pi/4$ 31. e^{-e} 35. 0.9721

37. 0.189 762 24, error $< 6.4 \times 10^{-7}$

41. 4, $[-6, 2)$ 43. 0.5, $[2.5, 3.5)$

45. $\frac{1}{2} \sum_{n=0}^{\infty} (-1)^n \left[\frac{1}{(2n)!} \left(x - \frac{\pi}{6}\right)^{2n} + \frac{\sqrt{3}}{(2n+1)!} \left(x - \frac{\pi}{6}\right)^{2n+1} \right]$

47. $\sum_{n=0}^{\infty} (-1)^n x^{n+2}, R = 1$ 49. $\ln 4 - \sum_{n=1}^{\infty} \frac{x^n}{n 4^n}, R = 4$

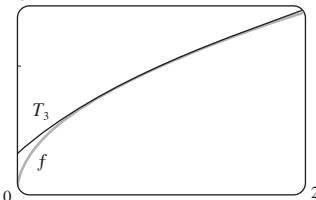
51. $\sum_{n=0}^{\infty} (-1)^n \frac{x^{8n+4}}{(2n+1)!}, R = \infty$

53. $\frac{1}{2} + \sum_{n=1}^{\infty} \frac{1 \cdot 5 \cdot 9 \cdots (4n-3)}{n! 2^{6n+1}} x^n, R = 16$

55. $C + \ln|x| + \sum_{n=1}^{\infty} \frac{x^n}{n \cdot n!}$

57. (a) $1 + \frac{1}{2}(x - 1) - \frac{1}{8}(x - 1)^2 + \frac{1}{16}(x - 1)^3$

(b) 1.5 (c) 0.000 006



59. $-\frac{1}{6}$

PROBLEMS PLUS ■ PAGE 863

1. (b) 0 if $x = 0$, $(1/x) - \cot x$ if $x \neq k\pi$, k an integer

3. (a) $s_n = 3 \cdot 4^n, l_n = 1/3^n, p_n = 4^n/3^{n-1}$ (c) $\frac{2}{5}\sqrt{3}$

7. $\frac{3\pi}{4}$

9. $(-1, 1), \frac{x^3 + 4x^2 + x}{(1-x)^4}$

11. $\ln \frac{1}{2}$

15. (a) $\frac{250}{101}\pi(e^{-(n-1)\pi/5} - e^{-n\pi/5})$ (b) $\frac{250}{101}\pi$

17. $\frac{\pi}{2\sqrt{3}} - 1$

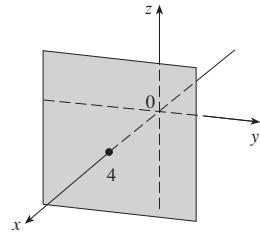
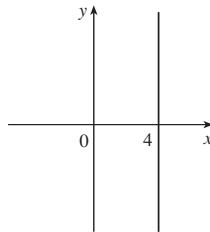
19. $-\left(\frac{\pi}{2} - \pi k\right)^2$, where k is a positive integer

CHAPTER 12

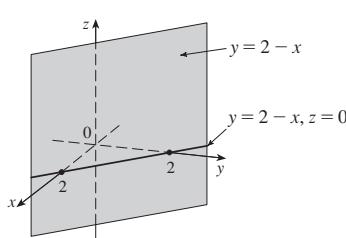
EXERCISES 12.1 ■ PAGE 873

1. $(4, 0, -3)$ 3. $C; A$

5. A line parallel to the y -axis and 4 units to the right of it; a vertical plane parallel to the yz -plane and 4 units in front of it.



7. A vertical plane that intersects the xy -plane in the line $y = 2 - x, z = 0$



9. 6

11. $|PQ| = 6, |QR| = 2\sqrt{10}, |RP| = 6$; isosceles triangle

13. (a) No (b) Yes

15. $(x+3)^2 + (y-2)^2 + (z-5)^2 = 16$; $(y-2)^2 + (z-5)^2 = 7, x=0$ (a circle)

17. $(x-3)^2 + (y-8)^2 + (z-1)^2 = 30$

19. $(-4, 0, 1), 5$ 21. $(\frac{1}{2}, -1, 0), \sqrt{3}/2$

25. (a) $(x+1)^2 + (y-4)^2 + (z-5)^2 = 25$

(b) $(x+1)^2 + (y-4)^2 + (z-5)^2 = 1$

(c) $(x+1)^2 + (y-4)^2 + (z-5)^2 = 16$

27. A horizontal plane 2 units below the xy -plane

29. A half-space consisting of all points on or to the right of the plane $y = 1$

31. All points on or between the vertical planes $x = -1$ and $x = 2$

33. All points on a circle with radius 2 and center on the z -axis that is contained in the plane $z = -1$

35. All points on or inside a circular cylinder of radius 5 with axis the x -axis

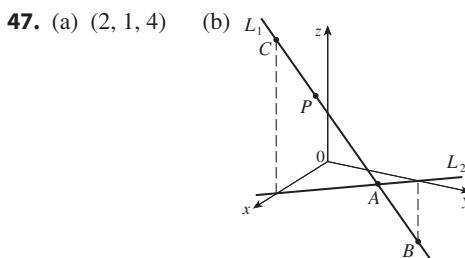
37. All points on a sphere with radius 2 and center $(0, 0, 0)$

39. All points on or between spheres with radii 1 and $\sqrt{5}$ and centers $(0, 0, 0)$

41. All points on or inside a cube with edges along the coordinate axes and opposite vertices at the origin and $(3, 3, 3)$

43. $0 < x < 5$ 45. $r^2 < x^2 + y^2 + z^2 < R^2$

47. (a) $(2, 1, 4)$



49. $14x - 6y - 10z = 9$; a plane perpendicular to AB

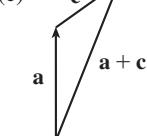
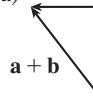
51. $2\sqrt{3} - 3$

EXERCISES 12.2 ■ PAGE 881

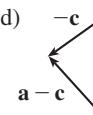
1. (a) Scalar (b) Vector (c) Vector (d) Scalar

3. $\overrightarrow{AB} = \overrightarrow{DC}, \overrightarrow{DA} = \overrightarrow{CB}, \overrightarrow{DE} = \overrightarrow{EB}, \overrightarrow{EA} = \overrightarrow{CE}$

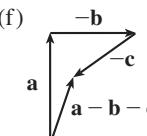
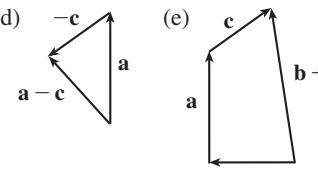
5. (a)



(d)

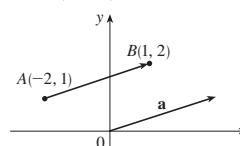


(e)

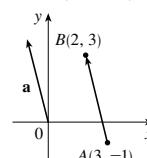


7. $\mathbf{c} = \frac{1}{2}\mathbf{a} + \frac{1}{2}\mathbf{b}, \mathbf{d} = \frac{1}{2}\mathbf{b} - \frac{1}{2}\mathbf{a}$

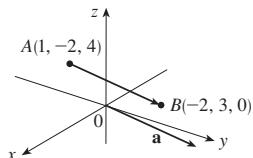
9. $\mathbf{a} = \langle 3, 1 \rangle$

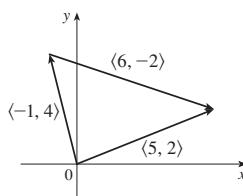
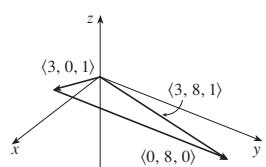


11. $\mathbf{a} = \langle -1, 4 \rangle$



13. $\mathbf{a} = \langle -3, 5, -4 \rangle$



15. $\langle 5, 2 \rangle$

 17. $\langle 3, 8, 1 \rangle$

 19. $\langle 6, 3 \rangle, \langle 6, 14 \rangle, 5, 13$

 21. $6\mathbf{i} - 3\mathbf{j} - 2\mathbf{k}, 20\mathbf{i} - 12\mathbf{j}, \sqrt{29}, 7$

23. $\left\langle \frac{3}{\sqrt{10}}, -\frac{1}{\sqrt{10}} \right\rangle$

25. $\frac{8}{9}\mathbf{i} - \frac{1}{9}\mathbf{j} + \frac{4}{9}\mathbf{k}$

 27. 60°

29. $\langle -2\sqrt{3}, 2 \rangle$

 31. $\approx 15.32 \text{ m/s}, \approx 12.86 \text{ m/s}$

33. $100\sqrt{7} \approx 264.6 \text{ N}, \approx 139.1^\circ$

35. $\approx -177.39\mathbf{i} + 211.41\mathbf{j}, \approx 177.39\mathbf{i} + 138.59\mathbf{j};$

 $\approx 275.97 \text{ N}, \approx 225.11 \text{ N}$

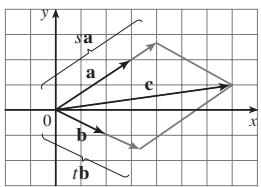
37. $\approx 26.1 \text{ N}$

39. $\approx N 41.6^\circ W, \approx 237.3 \text{ km/h}$

41. $\pm(\mathbf{i} + 4\mathbf{j})/\sqrt{17}$

 43. $\mathbf{0}$

45. (a), (b) (d) $s = \frac{9}{7}, t = \frac{11}{7}$


 47. A sphere with radius 1, centered at (x_0, y_0, z_0)
EXERCISES 12.3 ■ PAGE 890

 1. (b), (c), (d) are meaningful 3. -3.6 5. 19 7. 1

9. $14\sqrt{3}$

11. $\mathbf{u} \cdot \mathbf{v} = \frac{1}{2}, \mathbf{u} \cdot \mathbf{w} = -\frac{1}{2}$

15. $\cos^{-1}\left(\frac{17}{13\sqrt{2}}\right) \approx 22^\circ$

17. $\cos^{-1}\left(-\frac{5}{6}\right) \approx 146^\circ$

19. $\cos^{-1}\left(\frac{-2}{3\sqrt{70}}\right) \approx 95^\circ$

21. $48^\circ, 75^\circ, 57^\circ$

23. (a) Orthogonal

(b) Neither

(c) Parallel

(d) Orthogonal

25. Yes

27. $(\mathbf{i} - \mathbf{j} - \mathbf{k})/\sqrt{3}$ [or $(-\mathbf{i} + \mathbf{j} + \mathbf{k})/\sqrt{3}$]

29. $\approx 36.9^\circ$

31. 0° at $(0, 0)$, $\approx 8.1^\circ$ at $(1, 1)$

33. $\frac{4}{9}, \frac{1}{9}, \frac{8}{9}; 63.6^\circ, 83.6^\circ, 27.3^\circ$

35. $3/\sqrt{14}, -1/\sqrt{14}, -2/\sqrt{14}; 36.7^\circ, 105.5^\circ, 122.3^\circ$

37. $1/\sqrt{3}, 1/\sqrt{3}, 1/\sqrt{3}; 54.7^\circ, 54.7^\circ, 54.7^\circ$

39. $4, \left\langle -\frac{20}{13}, \frac{48}{13} \right\rangle$

41. $\frac{1}{9}, \left\langle \frac{4}{81}, \frac{7}{81}, -\frac{4}{81} \right\rangle$

43. $-7/\sqrt{19}, -\frac{21}{19}\mathbf{i} + \frac{21}{19}\mathbf{j} - \frac{7}{19}\mathbf{k}$

 47. $\langle 0, 0, -2\sqrt{10} \rangle$ or any vector of the form

$\langle s, t, 3s - 2\sqrt{10} \rangle, s, t \in \mathbb{R}$

49. 144 J

51. $2400 \cos(40^\circ) \approx 1839 \text{ J}$

53. $\frac{13}{5}$

55. $\approx 54.7^\circ$

EXERCISES 12.4 ■ PAGE 899

1. $15\mathbf{i} - 10\mathbf{j} - 3\mathbf{k}$

3. $14\mathbf{i} + 4\mathbf{j} + 2\mathbf{k}$

5. $-\frac{3}{2}\mathbf{i} + \frac{7}{4}\mathbf{j} + \frac{2}{3}\mathbf{k}$

7. $(3t^3 - 2t^2)\mathbf{i} + (t^2 - 3t^4)\mathbf{j} + (2t^4 - t^3)\mathbf{k}$

9. $\mathbf{0}$

11. $\mathbf{i} + \mathbf{j} + \mathbf{k}$

13. (a) Scalar

(b) Meaningless

(c) Vector

(d) Meaningless

(e) Meaningless

(f) Scalar

15. 6; into the page

17. $\langle -7, 10, 8 \rangle, \langle 7, -10, -8 \rangle$

19. $\left\langle -\frac{1}{3\sqrt{3}}, -\frac{1}{3\sqrt{3}}, \frac{5}{3\sqrt{3}} \right\rangle, \left\langle \frac{1}{3\sqrt{3}}, \frac{1}{3\sqrt{3}}, -\frac{5}{3\sqrt{3}} \right\rangle$

27. 20

29. (a) $\langle -10, 11, 3 \rangle$

(b) $\frac{1}{2}\sqrt{230}$

31. (a) $\langle 12, -1, 17 \rangle$

(b) $\frac{1}{2}\sqrt{434}$

33. 9

35. 16

39. $10.8 \sin 80^\circ \approx 10.6 \text{ N} \cdot \text{m}$

41. $\approx 417 \text{ N}$

43. 60°

45. (b) $\sqrt{97}/3$

53. (a) No

(b) No

(c) Yes

EXERCISES 12.5 ■ PAGE 910

1. (a) True

(b) False

(c) True

(d) False

(e) False

(f) True

(g) False

(h) True

(i) True

(j) False

(k) True

3. $\mathbf{r} = (-\mathbf{i} + 8\mathbf{j} + 7\mathbf{k}) + t(\frac{1}{2}\mathbf{i} + \frac{1}{3}\mathbf{j} + \frac{1}{4}\mathbf{k})$

$x = -1 + \frac{1}{2}t, y = 8 + \frac{1}{3}t, z = 7 + \frac{1}{4}t$

5. $\mathbf{r} = (5\mathbf{i} + 7\mathbf{j} + \mathbf{k}) + t(3\mathbf{i} - 2\mathbf{j} + 2\mathbf{k})$

$x = 5 + 3t, y = 7 - 2t, z = 1 + 2t$

7. $x = 8t, y = -t, z = 3t; x/8 = -y = z/3$

9. $x = 12 - 19t, y = 9, z = -13 + 24t$

$(x - 12)/(-19) = (z + 13)/24, y = 9$

11. $x = -6 + 2t, y = 2 + 3t, z = 3 + t$

$(x + 6)/2 = (y - 2)/3 = z - 3$

13. Yes

15. (a) $(x - 1)/(-1) = (y + 5)/2 = (z - 6)/(-3)$

(b) $(-1, -1, 0), (-\frac{3}{2}, 0, -\frac{3}{2}), (0, -3, 3)$

17. $\mathbf{r}(t) = (6\mathbf{i} - \mathbf{j} + 9\mathbf{k}) + t(\mathbf{i} + 7\mathbf{j} - 9\mathbf{k}), 0 \leq t \leq 1$

19. Skew

21. $(4, -1, -5)$

23. $5x + 4y + 6z = 29$

25. $-x + 2y + 3z = 3$

27. $4x - y + 5z = -4$

29. $2x - y + 3z = -0.2$ or $10x - 5y + 15z = -1$

31. $x + y + z = 2$

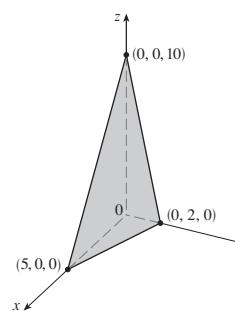
33. $5x - 3y - 8z = -9$

35. $8x + y - 2z = 31$

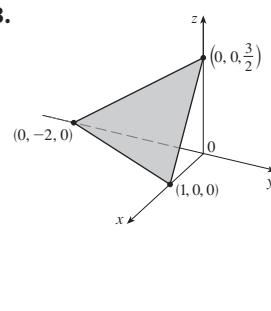
37. $x - 2y - z = -3$

39. $3x - 8y - z = -38$

41.



43.



45. $(-2, 6, 3)$ 47. $\left(\frac{2}{5}, 4, 0\right)$ 49. $1, 0, -1$

51. Perpendicular

53. Neither, $\cos^{-1}\left(-\frac{1}{\sqrt{6}}\right) \approx 114.1^\circ$

55. Parallel

57. (a) $x = 1, y = -t, z = t$ (b) $\cos^{-1}\left(\frac{5}{3\sqrt{3}}\right) \approx 15.8^\circ$

59. $x = 1, y - 2 = -z$

61. $x + 2y + z = 5$

63. $(x/a) + (y/b) + (z/c) = 1$

65. $x = 3t, y = 1 - t, z = 2 - 2t$

67. P_2 and P_3 are parallel, P_1 and P_4 are identical

69. $\sqrt{61/14}$ 71. $\frac{18}{7}$ 73. $5/(2\sqrt{14})$

77. $1/\sqrt{6}$ 79. $13/\sqrt{69}$

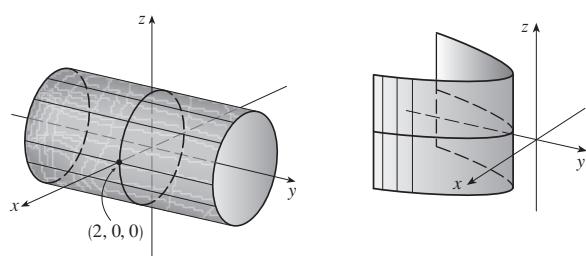
81. (a) $x = 325 + 440t, y = 810 - 135t, z = 561 + 38t, 0 \leq t \leq 1$ (b) No

EXERCISES 12.6 ■ PAGE 919

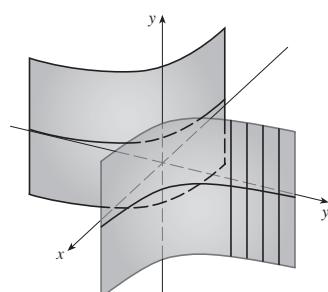
1. (a) Parabola

(b) Parabolic cylinder with rulings parallel to the z -axis(c) Parabolic cylinder with rulings parallel to the x -axis

3. Circular cylinder of radius 2 5. Parabolic cylinder



7. Hyperbolic cylinder

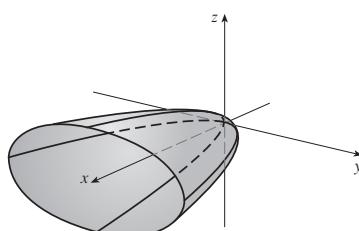
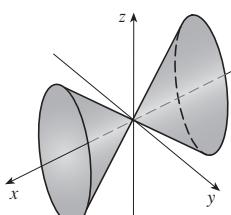
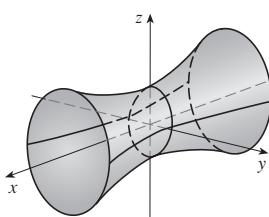


9. $z = \cos x$

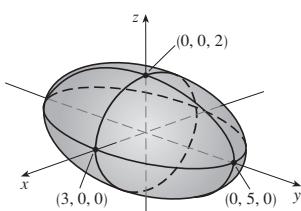
11. (a) $x = k, y^2 - z^2 = 1 - k^2$, hyperbola ($k \neq \pm 1$);

$y = k, x^2 - z^2 = 1 - k^2$, hyperbola ($k \neq \pm 1$);

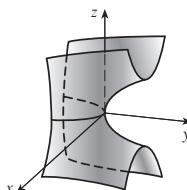
$z = k, x^2 + y^2 = 1 + k^2$, circle

(b) The hyperboloid is rotated so that its axis is the y -axis.(c) The hyperboloid is shifted one unit in the negative y -direction.13. Elliptic paraboloid with axis the x -axis15. Elliptic cone with axis the x -axis17. Hyperboloid of one sheet with axis the x -axis

19. Ellipsoid

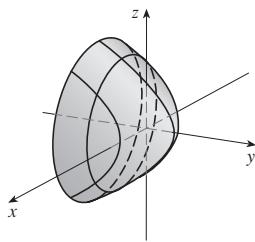


21. Hyperbolic paraboloid



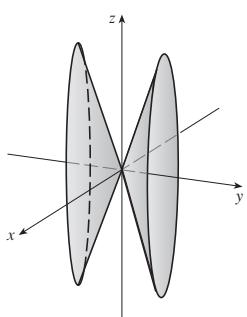
23. VII 25. II 27. VI 29. VIII

31. Circular paraboloid



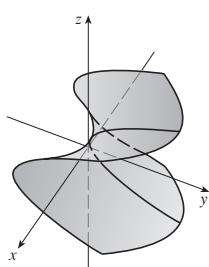
33. $y^2 = x^2 + \frac{z^2}{9}$

Elliptic cone with axis the y-axis

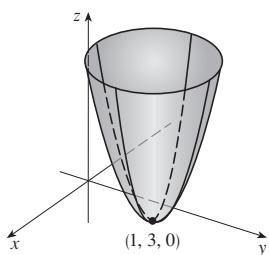


35. $y = z^2 - \frac{x^2}{2}$

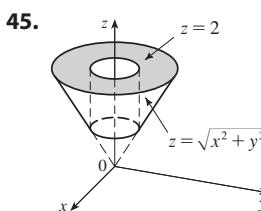
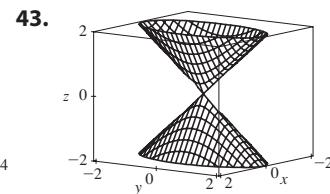
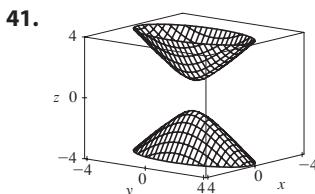
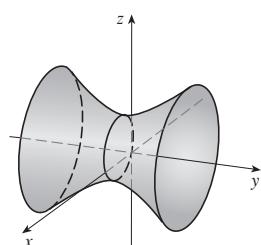
Hyperbolic paraboloid



37. $z = (x - 1)^2 + (y - 3)^2$

Circular paraboloid with vertex $(1, 3, 0)$ and axis the vertical line $x = 1, y = 3$ 

39. $\frac{(x - 2)^2}{5} - \frac{y^2}{5} + \frac{(z - 1)^2}{5} = 1$

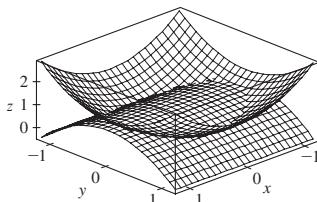
Hyperboloid of one sheet with center $(2, 0, 1)$ and axis the horizontal line $x = 2, z = 1$ 

47. $x = y^2 + z^2$ 49. $-4x = y^2 + z^2$, paraboloid

51. (a) $\frac{x^2}{(6378.137)^2} + \frac{y^2}{(6378.137)^2} + \frac{z^2}{(6356.523)^2} = 1$

(b) Circle (c) Ellipse

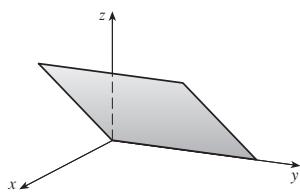
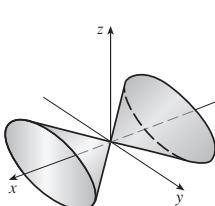
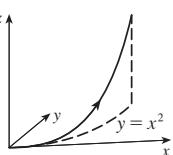
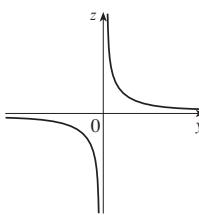
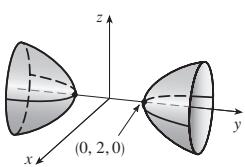
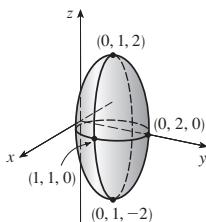
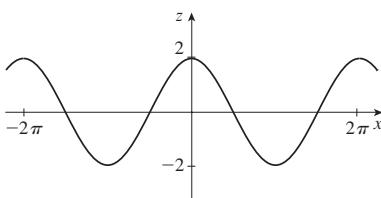
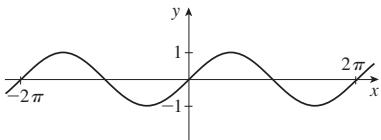
55.

**CHAPTER 12 REVIEW ■ PAGE 922****True-False Quiz**

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

Exercises

1. (a) $(x + 1)^2 + (y - 2)^2 + (z - 1)^2 = 69$
 (b) $(y - 2)^2 + (z - 1)^2 = 68, x = 0$
 (c) Center $(4, -1, -3)$, radius 5
 3. $\mathbf{u} \cdot \mathbf{v} = 3\sqrt{2}; |\mathbf{u} \times \mathbf{v}| = 3\sqrt{2}$; out of the page
 5. $-2, -4$ 7. (a) 2 (b) -2 (c) -2 (d) 0
 9. $\cos^{-1}\left(\frac{1}{3}\right) \approx 71^\circ$ 11. (a) $\langle 4, -3, 4 \rangle$ (b) $\sqrt{41}/2$
 13. $\approx 166 \text{ N}, \approx 114 \text{ N}$
 15. $x = 4 - 3t, y = -1 + 2t, z = 2 + 3t$
 17. $x = -2 + 2t, y = 2 - t, z = 4 + 5t$
 19. $-4x + 3y + z = -14$ 21. (1, 4, 4) 23. Skew
 25. $x + y + z = 4$ 27. $22/\sqrt{26}$

29. Plane**31.** Cone**15.****17.****33.** Hyperboloid of two sheets**35.** Ellipsoid**19.**

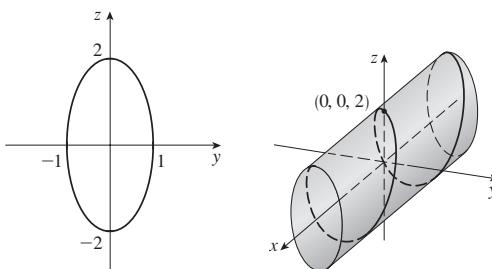
37. $4x^2 + y^2 + z^2 = 16$

PROBLEMS PLUS ■ PAGE 925

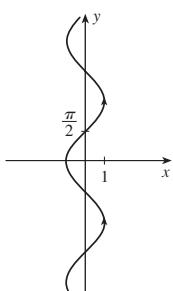
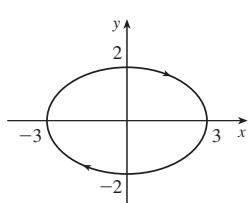
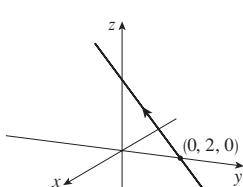
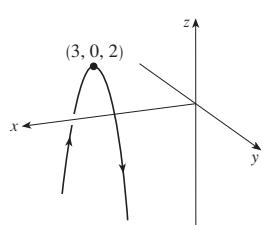
1. $(\sqrt{3} - \frac{3}{2})$ m

3. (a) $(x+1)/(-2c) = (y-c)/(c^2-1) = (z-c)/(c^2+1)$
(b) $x^2 + y^2 = t^2 + 1, z = t$ (c) $4\pi/3$

5. 20

**CHAPTER 13****EXERCISES 13.1 ■ PAGE 933**

1. $(-1, 3)$ **3.** $\mathbf{i} + \mathbf{j} + \mathbf{k}$ **5.** $\langle -1, \pi/2, 0 \rangle$

7.**9.****11.****13.**

21. $\langle -2 + 7t, 1 + t, -3t \rangle, 0 \leq t \leq 1;$

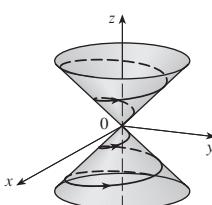
$x = -2 + 7t, y = 1 + t, z = -3t, 0 \leq t \leq 1$

23. $\langle 3.5 - 1.7t, -1.4 + 1.7t, 2.1 \rangle, 0 \leq t \leq 1;$

$x = 3.5 - 1.7t, y = -1.4 + 1.7t, z = 2.1, 0 \leq t \leq 1$

25. II **27.** V

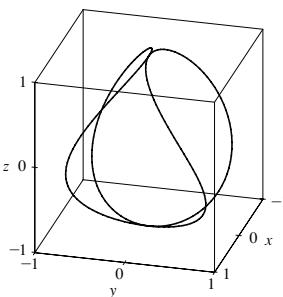
29. IV **31.** $y = 4$ **33.** $z = -y$

35.

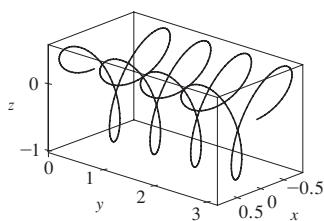
37. $y = e^{x/2}, z = e^x, z = y^2$

39. $(0, 0, 0), (1, 0, 1)$

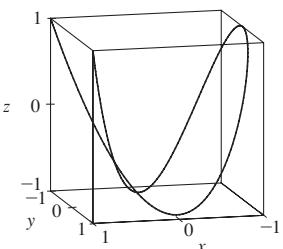
41.



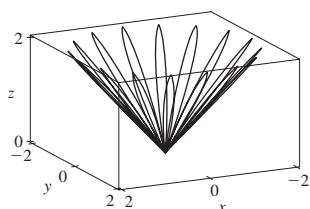
43.



45.



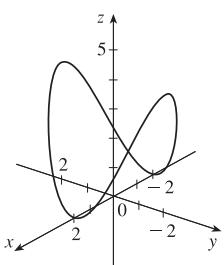
47.



51. $\mathbf{r}(t) = t \mathbf{i} + \frac{1}{2}(t^2 - 1) \mathbf{j} + \frac{1}{2}(t^2 + 1) \mathbf{k}$

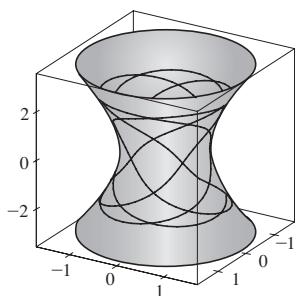
53. $\mathbf{r}(t) = \cos t \mathbf{i} + \sin t \mathbf{j} + \cos 2t \mathbf{k}, 0 \leq t \leq 2\pi$

55. $x = 2 \cos t, y = 2 \sin t, z = 4 \cos^2 t, 0 \leq t \leq 2\pi$



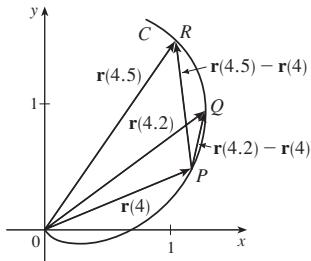
57. Yes

59. (a)

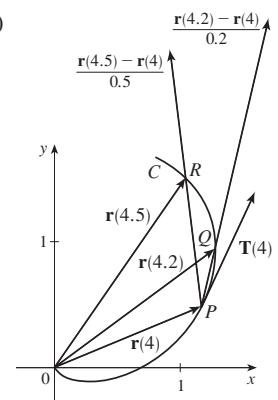


EXERCISES 13.2 ■ PAGE 940

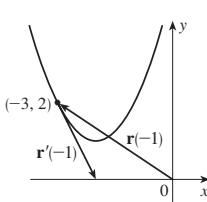
1. (a)



(b), (d)

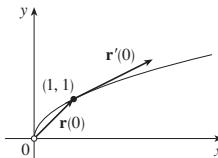


3. (a), (c)



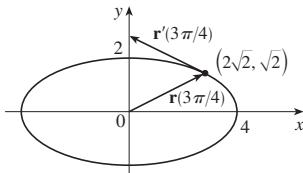
(b) $\mathbf{r}'(t) = \langle 1, 2t \rangle$

5. (a), (c)



(b) $\mathbf{r}'(t) = 2e^{2t} \mathbf{i} + e^t \mathbf{j}$

7. (a), (c)



(b) $\mathbf{r}'(t) = 4 \cos t \mathbf{i} + 2 \sin t \mathbf{j}$

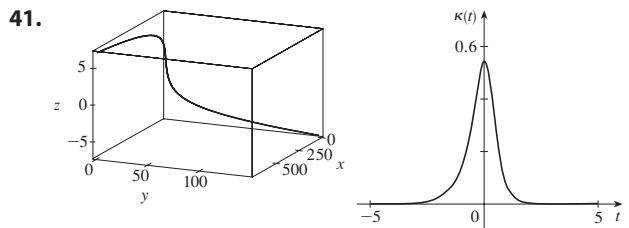
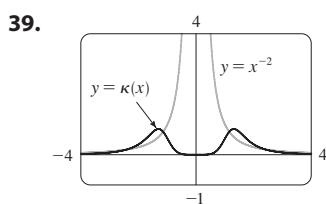
9. $\mathbf{r}'(t) = \left\langle \frac{1}{2\sqrt{t-2}}, 0, -\frac{2}{t^3} \right\rangle$

11. $\mathbf{r}'(t) = 2t\mathbf{i} - 2t \sin(t^2)\mathbf{j} + 2 \sin t \cos t \mathbf{k}$
 13. $\mathbf{r}'(t) = (t \cos t + \sin t)\mathbf{i} + e^t(\cos t - \sin t)\mathbf{j} + (\cos^2 t - \sin^2 t)\mathbf{k}$
 15. $\mathbf{r}'(t) = \mathbf{b} + 2t\mathbf{c}$ 17. $\left\langle \frac{2}{7}, \frac{3}{7}, \frac{6}{7} \right\rangle$ 19. $\frac{3}{5}\mathbf{j} + \frac{4}{5}\mathbf{k}$
 21. $\langle 3/\sqrt{34}, 3/\sqrt{34}, -4/\sqrt{34} \rangle$
 23. $\langle 4t^3, 1, 2t \rangle, \langle 4/\sqrt{21}, 1/\sqrt{21}, 2/\sqrt{21} \rangle, \langle 12t^2, 0, 2 \rangle, \langle 2, 16t^3, -12t^2 \rangle$,
 $x = 2 + 2t, y = 4 + 2t, z = 1 + t$
 27. $x = 1 - t, y = t, z = 1 - t$
 29. $\mathbf{r}(t) = (3 - 4t)\mathbf{i} + (4 + 3t)\mathbf{j} + (2 - 6t)\mathbf{k}$
 31. $x = t, y = 1 - t, z = 2t$
 33. $x = -\pi - t, y = \pi + t, z = -\pi t$
 35. 66° 37. $2\mathbf{i} - 4\mathbf{j} + 32\mathbf{k}$
 39. $(\ln 2)\mathbf{i} + (\pi/4)\mathbf{j} + \frac{1}{2}\ln 2\mathbf{k}$
 41. $\tan^{-1} t\mathbf{i} + \frac{1}{2}e^{t^2}\mathbf{j} + \frac{2}{3}t^{3/2}\mathbf{k} + \mathbf{C}$
 43. $t^2\mathbf{i} + t^3\mathbf{j} + \left(\frac{2}{3}t^{3/2} - \frac{2}{3}\right)\mathbf{k}$
 49. $2t \cos t + 2 \sin t - 2 \cos t \sin t$ 51. 35

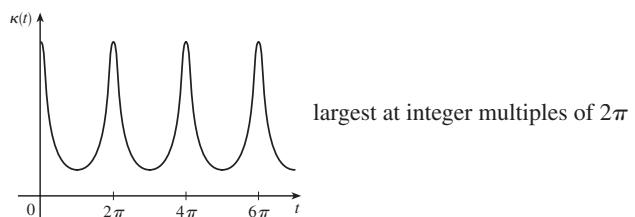
EXERCISES 13.3 ■ PAGE 951

1. (a) $2\sqrt{21}$ 3. $10\sqrt{10}$ 5. $e - e^{-1}$ 7. $\frac{1}{27}(13^{3/2} - 8)$
 9. 18.6833 11. 10.3311 13. 42
 15. (a) $s(t) = \sqrt{26}(t - 1)$;
 $\mathbf{r}(t(s)) = \left(4 - \frac{s}{\sqrt{26}}\right)\mathbf{i} + \left(\frac{4s}{\sqrt{26}} + 1\right)\mathbf{j} + \left(\frac{3s}{\sqrt{26}} + 3\right)\mathbf{k}$
 (b) $\left(4 - \frac{4}{\sqrt{26}}, \frac{16}{\sqrt{26}} + 1, \frac{12}{\sqrt{26}} + 3\right)$
 17. $(3 \sin 1, 4, 3 \cos 1)$
 19. (a) $\frac{1}{\sqrt{5}}\langle 2, \sin t, \cos t \rangle, \langle 0, \cos t, -\sin t \rangle$ (b) $1/(5t)$
 21. (a) $\frac{1}{\sqrt{1+4t^2}}\langle 1, 2t, 0 \rangle, \frac{1}{\sqrt{1+4t^2}}\langle -2t, 1, 0 \rangle$
 (b) $2/(1+4t^2)^{3/2}$

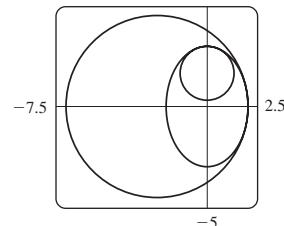
23. (a) $\frac{1}{\sqrt{1+5t^2}}\langle 1, t, 2t \rangle, \frac{1}{\sqrt{5+25t^2}}\langle -5t, 1, 2 \rangle$
 (b) $\sqrt{5}/(1+5t^2)^{3/2}$
 25. $6t^2/(9t^4+4t^2)^{3/2}$ 27. $\frac{\sqrt{6}}{2(3t^2+1)^2}$
 29. $\frac{1}{7}\sqrt{19/14}$ 31. $12x^2/(1+16x^6)^{3/2}$
 33. $e^x|x+2|/[1+(xe^x+e^x)^2]^{3/2}$
 35. $(-\frac{1}{2}\ln 2, 1/\sqrt{2})$; approaches 0 37. (a) P (b) 1.3, 0.7



43. a is $y = f(x)$, b is $y = \kappa(x)$
 45. $\kappa(t) = \frac{6\sqrt{4 \cos^2 t - 12 \cos t + 13}}{(17 - 12 \cos t)^{3/2}}$



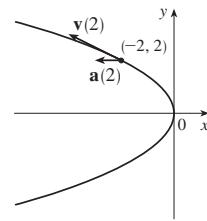
47. $6t^2/(4t^2+9t^4)^{3/2}$
 49. $1/(\sqrt{2}e^t)$ 51. $\left\langle \frac{2}{3}, \frac{2}{3}, \frac{1}{3} \right\rangle, \left\langle -\frac{1}{3}, \frac{2}{3}, -\frac{2}{3} \right\rangle, \left\langle -\frac{2}{3}, \frac{1}{3}, \frac{2}{3} \right\rangle$
 53. $x - 2z = -4\pi, 2x + z = 2\pi$
 55. $(x + \frac{5}{2})^2 + y^2 = \frac{81}{4}, x^2 + (y - \frac{5}{3})^2 = \frac{16}{9}$



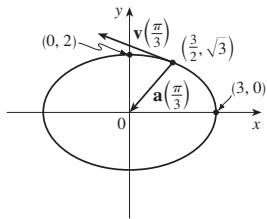
57. $(-1, -3, 1)$
 59. $2x + y + 4z = 7, 6x - 8y - z = -3$ 67. 0
 69. $-2/(e^{2t} + e^{-2t} + 4), -\frac{1}{3}$
 75. (b) $\mathbf{r}_e(t) = -\cos t\mathbf{i} - \sin t\mathbf{j} + t\mathbf{k}$
 (c) $\mathbf{r}_e(t) = -4t^3\mathbf{i} + (3t^2 + \frac{1}{2})\mathbf{j}$ or $y_e = \frac{1}{2} + 3(x/4)^{2/3}$
 77. $2.07 \times 10^{10} \text{ \AA} \approx 2 \text{ m}$

EXERCISES 13.4 ■ PAGE 961

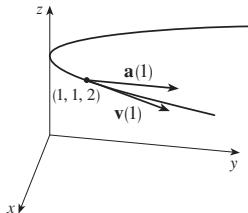
1. (a) $1.8\mathbf{i} - 3.8\mathbf{j} - 0.7\mathbf{k}, 2.0\mathbf{i} - 2.4\mathbf{j} - 0.6\mathbf{k}, 2.8\mathbf{i} + 1.8\mathbf{j} - 0.3\mathbf{k}, 2.8\mathbf{i} + 0.8\mathbf{j} - 0.4\mathbf{k}$
 (b) $2.4\mathbf{i} - 0.8\mathbf{j} - 0.5\mathbf{k}, 2.58$
 3. $\mathbf{v}(t) = \langle -t, 1 \rangle$
 $\mathbf{a}(t) = \langle -1, 0 \rangle$
 $|\mathbf{v}(t)| = \sqrt{t^2 + 1}$



5. $\mathbf{v}(t) = -3 \sin t \mathbf{i} + 2 \cos t \mathbf{j}$
 $\mathbf{a}(t) = -3 \cos t \mathbf{i} - 2 \sin t \mathbf{j}$
 $|\mathbf{v}(t)| = \sqrt{5 \sin^2 t + 4}$



7. $\mathbf{v}(t) = \mathbf{i} + 2t\mathbf{j}$
 $\mathbf{a}(t) = 2\mathbf{j}$
 $|\mathbf{v}(t)| = \sqrt{1 + 4t^2}$



9. $\langle 2t+1, 2t-1, 3t^2 \rangle, \langle 2, 2, 6t \rangle, \sqrt{9t^4 + 8t^2 + 2}$

11. $\sqrt{2}\mathbf{i} + e^t\mathbf{j} - e^{-t}\mathbf{k}, e^t\mathbf{j} + e^{-t}\mathbf{k}, e^t + e^{-t}$

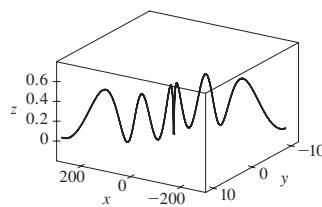
13. $e^t[(\cos t - \sin t)\mathbf{i} + (\sin t + \cos t)\mathbf{j} + (t+1)\mathbf{k}], e^t[-2\sin t\mathbf{i} + 2\cos t\mathbf{j} + (t+2)\mathbf{k}], e^t\sqrt{t^2 + 2t + 3}$

15. $\mathbf{v}(t) = (2t+3)\mathbf{i} - \mathbf{j} + t^2\mathbf{k},$

$\mathbf{r}(t) = (t^2 + 3t)\mathbf{i} + (1-t)\mathbf{j} + (\frac{1}{3}t^3 + 1)\mathbf{k}$

17. (a) $\mathbf{r}(t) = (\frac{1}{3}t^3 + t)\mathbf{i} + (t - \sin t + 1)\mathbf{j} + (\frac{1}{4} - \frac{1}{4}\cos 2t)\mathbf{k}$

(b)



19. $t = 4$

21. $\mathbf{r}(t) = t\mathbf{i} - t\mathbf{j} + \frac{5}{2}t^2\mathbf{k}, |\mathbf{v}(t)| = \sqrt{25t^2 + 2}$

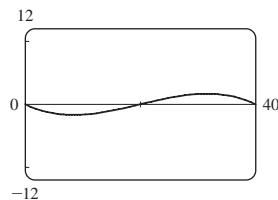
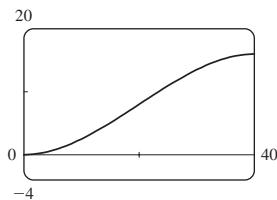
23. (a) ≈ 3535 m (b) ≈ 1531 m (c) 200 m/s

25. ≈ 30 m/s 27. ≈ 198 m/s

29. $13.0^\circ < \theta < 36.0^\circ, 55.4^\circ < \theta < 85.5^\circ$

31. $(250, -50, 0); 10\sqrt{93} \approx 96.4$ m/s

33. (a) 16 m (b) $\approx 23.6^\circ$ upstream



35. The path is contained in a circle that lies in a plane perpendicular to \mathbf{c} with center on a line through the origin in the direction of \mathbf{c} .

37. $\frac{4 + 18t^2}{\sqrt{4 + 9t^2}}, \frac{6t}{\sqrt{4 + 9t^2}}$ 39. 0, 1

41. $\frac{7}{\sqrt{30}}, \sqrt{\frac{131}{30}}$

43. $4.5 \text{ cm/s}^2, 9.0 \text{ cm/s}^2$ 45. $t = 1$

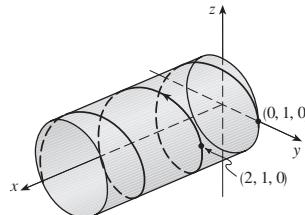
CHAPTER 13 REVIEW ■ PAGE 965

True-False Quiz

1. True 3. False 5. False 7. False
 9. True 11. False 13. True 15. True

Exercises

1. (a)



(b) $\mathbf{r}'(t) = \mathbf{i} - \pi \sin \pi t \mathbf{j} + \pi \cos \pi t \mathbf{k}, \mathbf{r}''(t) = -\pi^2 \cos \pi t \mathbf{j} - \pi^2 \sin \pi t \mathbf{k}$

3. $\mathbf{r}(t) = 4 \cos t \mathbf{i} + 4 \sin t \mathbf{j} + (5 - 4 \cos t) \mathbf{k}, 0 \leq t \leq 2\pi$

5. $\frac{1}{3}\mathbf{i} - (2/\pi^2)\mathbf{j} + (2/\pi)\mathbf{k}$ 7. 86.631 9. 90°

11. (a) $\frac{1}{\sqrt{13}} \langle 3 \sin t, -3 \cos t, 2 \rangle$ (b) $\langle \cos t, \sin t, 0 \rangle$

(c) $\frac{1}{\sqrt{13}} \langle -2 \sin t, 2 \cos t, 3 \rangle$

(d) $\frac{3}{13 \sin t \cos t}$ or $\frac{3}{13} \sec t \csc t$

(e) $\frac{2}{13 \sin t \cos t}$ or $\frac{2}{13} \sec t \csc t$

13. $12/17^{3/2}$ 15. $x - 2y + 2\pi = 0$

17. $\mathbf{v}(t) = (1 + \ln t)\mathbf{i} + \mathbf{j} - e^{-t}\mathbf{k}, |\mathbf{v}(t)| = \sqrt{2 + 2 \ln t + (\ln t)^2 + e^{-2t}}, \mathbf{a}(t) = (1/t)\mathbf{i} + e^{-t}\mathbf{k}$

19. $\mathbf{r}(t) = (t^3 + t)\mathbf{i} + (t^4 - t)\mathbf{j} + (3t - t^3)\mathbf{k}$

21. $\approx 37.3^\circ, \approx 157.4$ m

23. (c) $-2e^{-t}\mathbf{v}_d + e^{-t}\mathbf{R}$

PROBLEMS PLUS ■ PAGE 968

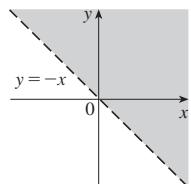
1. (a) $\mathbf{v} = \omega R(-\sin \omega t \mathbf{i} + \cos \omega t \mathbf{j})$ (c) $\mathbf{a} = -\omega^2 \mathbf{r}$
 3. (a) $90^\circ, v_0^2/(2g)$
 5. (a) ≈ 0.25 m to the right of the table's edge, ≈ 4.9 m/s
 (b) $\approx 5.9^\circ$ (c) ≈ 0.56 m to the right of the table's edge
 7. 56°

9. $(a_2b_3 - a_3b_2)(x - c_1) + (a_3b_1 - a_1b_3)(y - c_2) + (a_1b_2 - a_2b_1)(z - c_3) = 0$

CHAPTER 14**EXERCISES 14.1 ■ PAGE 984**

1. (a) $-\frac{3}{7}$ (b) $\frac{4}{5}$ (c) $\frac{(x+h)^2y}{2(x+h)-y^2}$ (d) $\frac{x^2}{2-x}$

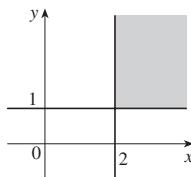
3. (a) $9 \ln 4$ (b) $\{(x, y) | y > -x\}$



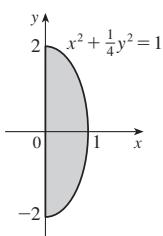
(c) \mathbb{R}

5. (a) 1 (b) $\{(x, y, z) | z \leq x/2, y \leq 0\}$, the points on or below the plane $z = x/2$ that are to the right of the xz -plane

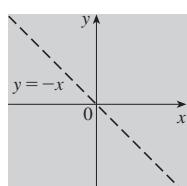
7. $\{(x, y) | x \geq 2, y \geq 1\}$



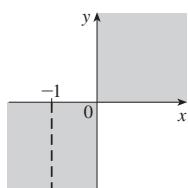
9. $\{(x, y) | x^2 + \frac{1}{4}y^2 \leq 1, x \geq 0\}$



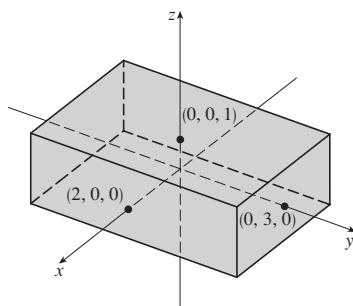
11. $\{(x, y) | y \neq -x\}$



13. $\{(x, y) | xy \geq 0, x \neq -1\}$



15. $\{(x, y, z) | -2 \leq x \leq 2, -3 \leq y \leq 3, -1 \leq z \leq 1\}$



17. (a) $\approx 1.90 \text{ m}^2$; the surface area of a person 178 cm tall who weighs 73 kg is approximately 1.90 square meters.

19. (a) -27; a temperature of -15°C with wind blowing at 40 km/h feels equivalent to about -27°C without wind.

(b) When the temperature is -20°C , what wind speed gives a wind chill of -30°C ? 20 km/h

(c) With a wind speed of 20 km/h, what temperature gives a wind chill of -49°C ? -35°C

(d) A function of wind speed that gives wind-chill values when the temperature is -5°C

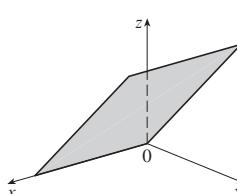
(e) A function of temperature that gives wind-chill values when the wind speed is 50 km/h

21. (a) (a) 2.4; a 40 km/h wind blowing in the open sea for 15 h will create waves about 2.4 m high.

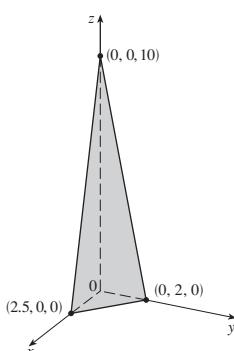
(b) $f(30, t)$ is a function of t giving the wave heights produced by 30 km/h winds blowing for t hours.

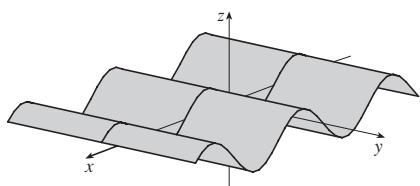
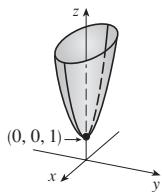
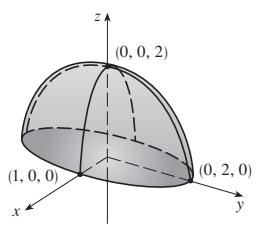
(c) $f(v, 30)$ is a function of v giving the wave heights produced by winds of speed v blowing for 30 hours.

23. $z = y$, plane through the x -axis



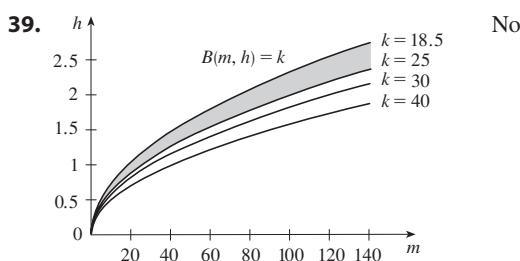
25. $4x + 5y + z = 10$, plane



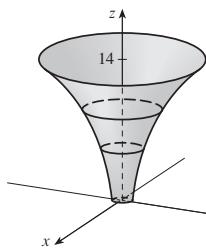
27. $z = \sin x$, cylinder

 29. $z = x^2 + 4y^2 + 1$, elliptic paraboloid

 31. $z = \sqrt{4 - 4x^2 - y^2}$, top half of ellipsoid

 33. $\approx 56, \approx 35$

 35. $11^\circ\text{C}, 19.5^\circ\text{C}$

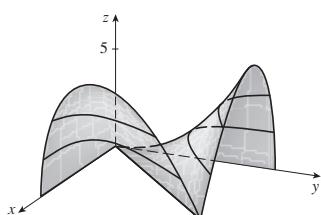
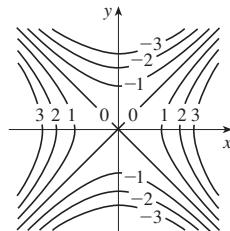
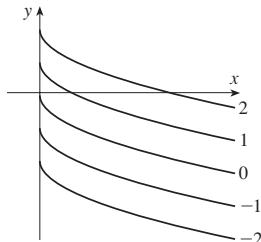
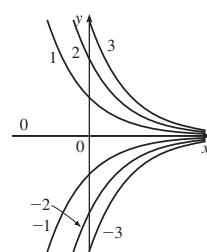
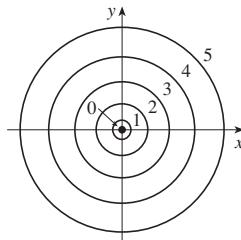
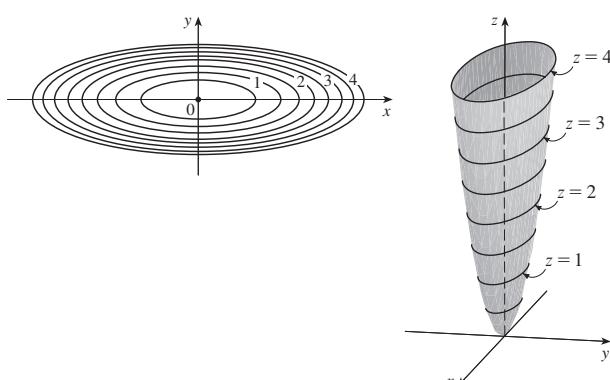
37. Steep; nearly flat



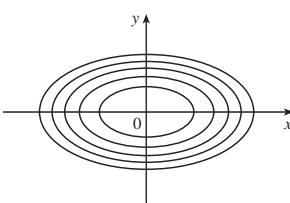
41.



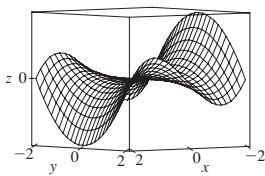
43.


 45. $x^2 - y^2 = k$

 47. $y = -\sqrt{x} + k$

 49. $y = ke^{-x}$

 51. $x^2 + y^2 = k^3 (k \geq 0)$

 53. $x^2 + 9y^2 = k$


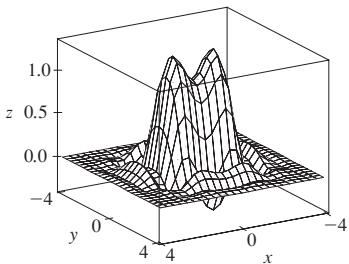
55.



57.



59.



61.

(a) C (b) II

63. (a) F (b) I

65.

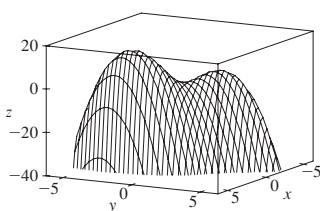
(a) B

(b) VI

67. Family of parallel planes

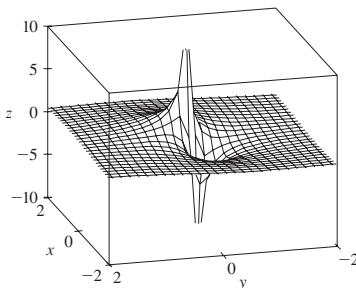
69. $k = 0$: cone with axis the z -axis; $k > 0$: family of hyperboloids of one sheet with axis the z -axis; $k < 0$: family of hyperboloids of two sheets with axis the z -axis71. (a) Shift the graph of f upward 2 units(b) Stretch the graph of f vertically by a factor of 2(c) Reflect the graph of f about the xy -plane(d) Reflect the graph of f about the xy -plane and then shift it upward 2 units

73.



f appears to have a maximum value of about 15. There are two local maximum points but no local minimum point.

75.



The function values approach 0 as x, y become large; as (x, y) approaches the origin, f approaches $\pm\infty$ or 0, depending on the direction of approach.

77. If $c = 0$, the graph is a cylindrical surface. For $c > 0$, the level curves are ellipses. The graph curves upward as we leave the origin, and the steepness increases as c increases. For $c < 0$,

the level curves are hyperbolas. The graph curves upward in the y -direction and downward, approaching the xy -plane, in the x -direction giving a saddle-shaped appearance near $(0, 0, 1)$.

79. $c = -2, 0, 2$ 81. (b) $y = 0.75x + 0.01$

EXERCISES 14.2 ■ PAGE 998

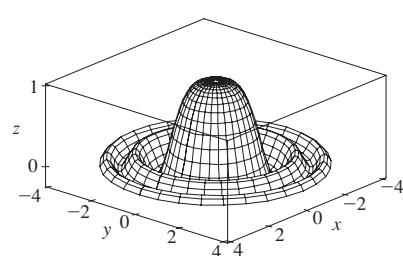
1. Nothing; if f is continuous, then $f(3, 1) = 6$ 3. $-\frac{5}{2}$ 5. 56 7. -6 9. $\pi/2$ 11. $-\frac{1}{2}$ 19. 12521. 0 23. Does not exist 25. 2 27. -2

29. Does not exist 31. 0 33. 0

35. The graph shows that the function approaches different numbers along different lines.

37. $h(x, y) = (2x + 3y - 6)^2 + \sqrt{2x + 3y - 6};$ $\{(x, y) \mid 2x + 3y \geq 6\}$ 39. Along the line $y = x$ 41. \mathbb{R}^2 43. $\{(x, y) \mid x^2 + y^2 \neq 1\}$ 45. $\{(x, y) \mid x^2 + y^2 \leq 1, x \geq 0\}$ 47. $\{(x, y, z) \mid x^2 + y^2 + z^2 \leq 1\}$ 49. $\{(x, y) \mid (x, y) \neq (0, 0)\}$ 51. 0 53. -1

55.



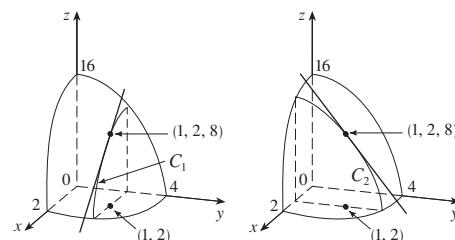
EXERCISES 14.3 ■ PAGE 1007

1. $f_T(34, 75) \approx 2^\circ\text{C}$; for a temperature of 34°C and relative humidity of 60%, the apparent temperature rises by 2°C for each degree the actual temperature increases. $f_H(34, 75) \approx 0.3^\circ\text{C}$; for a temperature of 34°C and relative humidity of 60%, the apparent temperature rises by 0.3°C for each percent that the relative humidity increases.

3. (a) The rate of change of temperature as longitude varies, with latitude and time fixed; the rate of change as only latitude varies; the rate of change as only time varies

(b) Positive, negative, positive

5. (a) Negative (b) Negative

7. $f_x(1, 2) = -8 =$ slope of C_1 , $f_y(1, 2) = -4 =$ slope of C_2 9. $f_x(x, y) = 4x^3 + 5y^3$, $f_y(x, y) = 15xy^2$

11. $g_x(x, y) = 3x^2 \sin y, g_y(x, y) = x^3 \cos y$

13. $\frac{\partial z}{\partial x} = \frac{1}{x+t^2}, \frac{\partial z}{\partial t} = \frac{2t}{x+t^2}$

15. $f_x(x, y) = y^2 e^{xy}, f_y(x, y) = e^{xy} + xye^{xy}$

17. $g_x(x, y) = 5y(1+2xy)(x+x^2y)^4,$

$g_y(x, y) = 5x^2y(x+x^2y)^4 + (x+x^2y)^5$

19. $f_x(x, y) = \frac{(ad-bc)y}{(cx+dy)^2}, f_y(x, y) = \frac{(bc-ad)x}{(cx+dy)^2}$

21. $g_u(u, v) = 10uv(u^2v-v^3)^4,$
 $g_v(u, v) = 5(u^2-3v^2)(u^2v-v^3)^4$

23. $R_p(p, q) = \frac{q^2}{1+p^2q^4}, R_q(p, q) = \frac{2pq}{1+p^2q^4}$

25. $F_x(x, y) = \cos(e^x), F_y(x, y) = -\cos(e^y)$

27. $f_x = 3x^2yz^2, f_y = x^3z^2 + 2z, f_z = 2x^3yz + 2y$

29. $\partial w/\partial x = 1/(x+2y+3z), \partial w/\partial y = 2/(x+2y+3z),$
 $\partial w/\partial z = 3/(x+2y+3z)$

31. $\partial p/\partial t = 2t^3/\sqrt{t^4+u^2\cos v},$

$\partial p/\partial u = u \cos v/\sqrt{t^4+u^2\cos v},$

$\partial p/\partial v = -u^2 \sin v/(2\sqrt{t^4+u^2\cos v})$

33. $h_x = 2xy \cos(z/t), h_y = x^2 \cos(z/t),$
 $h_z = (-x^2y/t) \sin(z/t), h_t = (x^2yz/t^2) \sin(z/t)$

35. $\partial u/\partial x_i = x_i/\sqrt{x_1^2+x_2^2+\dots+x_n^2}$

37. 1 39. $\frac{1}{6}$ 41. $\frac{\partial z}{\partial x} = -\frac{x}{3z}, \frac{\partial z}{\partial y} = -\frac{2y}{3z}$

43. $\frac{\partial z}{\partial x} = \frac{yz}{e^z-xy}, \frac{\partial z}{\partial y} = \frac{xz}{e^z-xy}$

45. (a) $f'(x), g'(y)$ (b) $f'(x+y), f'(x+y)$

47. $f_{xx} = 12x^2y - 12xy^2, f_{xy} = 4x^3 - 12x^2y = f_{yx}, f_{yy} = -4x^3$

49. $z_{xx} = \frac{8y}{(2x+3y)^3}, z_{xy} = \frac{6y-4x}{(2x+3y)^3} = z_{yx},$
 $z_{yy} = -\frac{12x}{(2x+3y)^3}$

51. $v_{ss} = 2 \cos(s^2-t^2) - 4s^2 \sin(s^2-t^2),$

$v_{st} = 4st \sin(s^2-t^2) = v_{ts},$

$v_{tt} = -2 \cos(s^2-t^2) - 4t^2 \sin(s^2-t^2)$

57. $24xy^2 - 6y, 24x^2y - 6x$

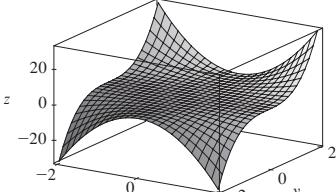
59. $(2x^2y^2z^5 + 6xyz^3 + 2z)e^{xyz^2}$

61. $\frac{3}{4}v(u+v^2)^{-5/2}$ 63. $4/(y+2z)^3, 0$

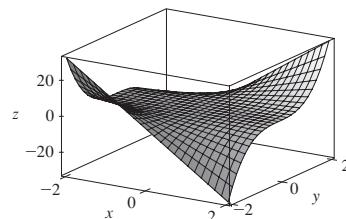
65. $f_x(x, y) = y^2 - 3x^2y, f_y(x, y) = 2xy - x^3$

67. $6yz^2$ 69. $c = f, b = f_x, a = f_y$

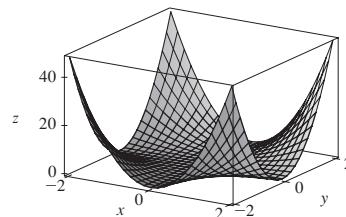
71.



$f(x, y) = x^2y^3$



$f_x(x, y) = 2xy^3$



$f_y(x, y) = 3x^2y^2$

73. $\approx 12.2, \approx 16.8, \approx 23.25$

83. R^2/R_1^2

85. $\frac{\partial T}{\partial P} = \frac{V-nb}{nR}, \frac{\partial P}{\partial V} = \frac{2n^2a}{V^3} - \frac{nRT}{(V-nb)^2}$

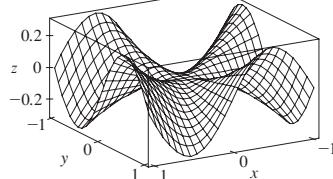
87. (a) ≈ 0.0035 ; for a person 178 cm tall who weighs 73 kg, an increase in weight causes the surface area to increase at a rate of about $0.0035 \text{ m}^2/\text{kg}$. (b) ≈ 0.0145 ; for a person 178 cm tall who weighs 73 kg, an increase in height (with no change in weight) causes the surface area to increase at a rate of about $0.0145 \text{ m}^2/\text{kg}$ of height.

89. $\partial P/\partial v = 3Av^2 - \frac{B(mg/x)^2}{v^2}$ is the rate of change of the power needed during flapping mode with respect to the bird's velocity when the mass and fraction of flapping time remain constant; $\partial P/\partial x = -\frac{2Bm^2g^2}{x^3v}$ is the rate at which the power changes when only the fraction of time spent in flapping mode varies; $\partial P/\partial m = \frac{2Bmg^2}{x^2v}$ is the rate of change of the power when only the mass varies.

93. $x = 1+t, y = 2, z = 2-2t$

95. No 99. -2

101. (a)



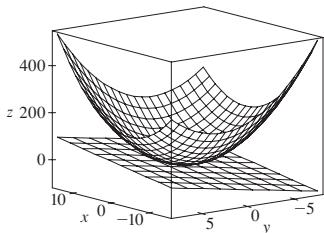
(b) $f_x(x, y) = \frac{x^4y + 4x^2y^3 - y^5}{(x^2+y^2)^2}, f_y(x, y) = \frac{x^5 - 4x^3y^2 - xy^4}{(x^2+y^2)^2}$

 (c) 0, 0 (e) No, because f_{xy} and f_{yx} are not continuous.

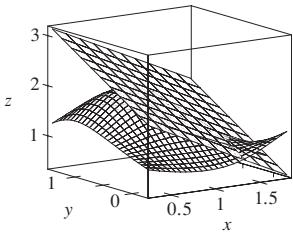
EXERCISES 14.4 ■ PAGE 1019

1. $z = -4x - 4y + 24$ 3. $z = 4x - y - 6$
 5. $z = x - y + 1$ 7. $z = -2x - y - 3$
 9. $x + y + z = 0$

11.



13.



15. $12x - 16y + 32$ 17. $6x + 4y - 23$
 19. $2x + y - 1$ 21. $2x + 2y + \pi - 4$ 25. 6.3
 27. $\frac{3}{7}x + \frac{2}{7}y + \frac{6}{7}z; 6.9914$ 29. $2T + 0.3H - 40.5; 44.4^\circ\text{C}$
 31. $dm = 5p^4q^3 dp + 3p^5q^2 dq$
 33. $dz = -2e^{-2x} \cos 2\pi t dx - 2\pi e^{-2x} \sin 2\pi t dt$
 35. $dH = 2xy^4 dx + (4x^2y^3 + 3y^2z^5) dy + 5y^3z^4 dz$
 37. $dR = \beta^2 \cos \gamma d\alpha + 2\alpha\beta \cos \gamma d\beta - \alpha\beta^2 \sin \gamma dy$
 39. $\Delta z = 0.9225, dz = 0.9$ 41. 5.4 cm^2 43. 16 cm^3
 45. (a) $5.89\pi\varepsilon \text{ m}^3$ (b) $\approx 0.0015 \text{ m} \approx 0.15 \text{ cm}$
 47. $\approx -0.0165mg$; decrease 49. $\frac{1}{17} \approx 0.059 \Omega$
 51. (a) $0.8264m - 34.56h + 38.02$ (b) 18.801

EXERCISES 14.5 ■ PAGE 1029

1. $36t^3 + 15t^4$ 3. $2t(y^3 - 2xy + 3xy^2 - x^2)$
 5. $\frac{1}{2\sqrt{t}} \cos x \cos y + \frac{1}{t^2} \sin x \sin y$
 7. $e^{y/z} [2t - (x/z) - (2xy/z^2)]$
 9. $\partial z/\partial s = 10s + 14t, \partial z/\partial t = 14s + 20t$
 11. $\partial z/\partial s = 5(x - y)^4(2st - t^2), \partial z/\partial t = 5(x - y)^4(s^2 - 2st)$
 13. $\frac{\partial z}{\partial s} = \frac{3 \sin t - 2t \sin s}{3x + 2y}, \frac{\partial z}{\partial t} = \frac{3s \cos t + 2 \cos s}{3x + 2y}$
 15. $\frac{\partial z}{\partial s} = -\frac{t \sin \theta}{r^2} + \frac{2s \cos \theta}{r}, \frac{\partial z}{\partial t} = -\frac{s \sin \theta}{r^2} + \frac{2t \cos \theta}{r}$
 17. 42 19. 7, 2
 21. $\frac{\partial u}{\partial r} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial r} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial r}, \frac{\partial u}{\partial s} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial s} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial s},$
 $\frac{\partial u}{\partial t} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial t} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial t}$

23. $\frac{\partial T}{\partial x} = \frac{\partial T}{\partial p} \frac{\partial p}{\partial x} + \frac{\partial T}{\partial q} \frac{\partial q}{\partial x} + \frac{\partial T}{\partial r} \frac{\partial r}{\partial x},$

$\frac{\partial T}{\partial y} = \frac{\partial T}{\partial p} \frac{\partial p}{\partial y} + \frac{\partial T}{\partial q} \frac{\partial q}{\partial y} + \frac{\partial T}{\partial r} \frac{\partial r}{\partial y},$

$\frac{\partial T}{\partial z} = \frac{\partial T}{\partial p} \frac{\partial p}{\partial z} + \frac{\partial T}{\partial q} \frac{\partial q}{\partial z} + \frac{\partial T}{\partial r} \frac{\partial r}{\partial z}$

25. 1582, 3164, -700 27. $2\pi, -2\pi$

29. $\frac{5}{144}, -\frac{5}{96}, \frac{5}{144}$ 31. $\frac{2x + y \sin x}{\cos x - 2y}$

33. $\frac{1 + x^4y^2 + y^2 + x^4y^4 - 2xy}{x^2 - 2xy - 2x^5y^3}$

35. $-\frac{x}{3z}, -\frac{2y}{3z}$ 37. $\frac{yz}{e^z - xy}, \frac{xz}{e^z - xy}$

39. $2^\circ\text{C}/\text{s}$ 41. $\approx -0.33 \text{ m/s}$ per minute

43. (a) $6 \text{ m}^3/\text{s}$ (b) $10 \text{ m}^2/\text{s}$ (c) 0 m/s

45. $\approx -0.27 \text{ L/s}$ 47. $-1/(12\sqrt{3}) \text{ rad/s}$

49. (a) $\partial z/\partial r = (\partial z/\partial x) \cos \theta + (\partial z/\partial y) \sin \theta,$
 $\partial z/\partial \theta = -(\partial z/\partial x) r \sin \theta + (\partial z/\partial y) r \cos \theta$

53. $4rs \frac{\partial^2 z}{\partial x^2} + (4r^2 + 4s^2) \frac{\partial^2 z}{\partial x \partial y} + 4rs \frac{\partial^2 z}{\partial y^2} + 2 \frac{\partial z}{\partial y}$

EXERCISES 14.6 ■ PAGE 1043

1. $\approx -0.08 \text{ mb/km}$ 3. ≈ 0.778 5. $\sqrt{2}/2$

7. $5\sqrt{2}/74$ 9. (a) $\nabla f(x, y) = (1/y)\mathbf{i} - (x/y^2)\mathbf{j}$

(b) $\mathbf{i} - 2\mathbf{j}$ (c) -1

11. (a) $\langle 2xyz - yz^3, x^2z - xz^3, x^2y - 3xyz^2 \rangle$

(b) $\langle -3, 2, 2 \rangle$ (c) $\frac{2}{5}$

13. $\frac{4 - 3\sqrt{3}}{10}$ 15. $7/(2\sqrt{5})$ 17. 1 19. $\frac{23}{42}$

21. $-\frac{56}{5}$ 23. $\frac{2}{5}$ 25. $-\frac{18}{7}$ 27. $20\sqrt{10}, \langle 20, -60 \rangle$

29. 1, $\langle 0, 1 \rangle$ 31. $\frac{3}{4}, \langle 1, -2, -2 \rangle$

33. (b) $\langle -12, 92 \rangle, -4\sqrt{538}$

35. All points on the line $y = x + 1$ 37. (a) $-40/(3\sqrt{3})$

39. (a) $32/\sqrt{3}$ (b) $\langle 38, 6, 12 \rangle$ (c) $2\sqrt{406}$

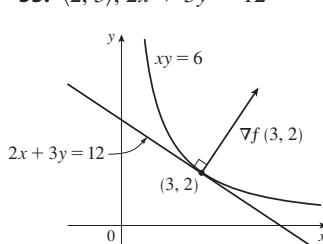
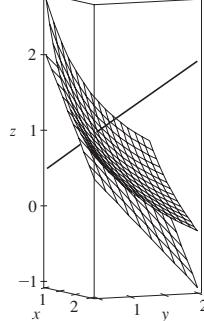
41. $\frac{327}{13}$ 45. $\frac{774}{25}$

47. (a) $x + y + z = 11$ (b) $x - 3 = y - 3 = z - 5$

49. (a) $x + 2y + 6z = 12$ (b) $x - 2 = \frac{y - 2}{2} = \frac{z - 1}{6}$

51. (a) $x + y + z = 1$ (b) $x = y = z - 1$

53. $\langle 2, 3 \rangle, 2x + 3y = 12$

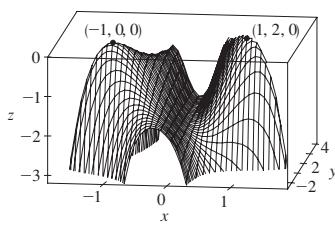


61. No 65. $(-\frac{5}{4}, -\frac{5}{4}, \frac{25}{8})$ 69. $x = -1 - 10t, y = 1 - 16t, z = 2 - 12t$ 71. $(-1, 0, 1); \approx 7.8^\circ$ 75. If $\mathbf{u} = \langle a, b \rangle$ and $\mathbf{v} = \langle c, d \rangle$, then $af_x + bf_y$ and $cf_x + df_y$ are known, so we solve linear equations for f_x and f_y .**EXERCISES 14.7 ■ PAGE 1054**1. (a) f has a local minimum at $(1, 1)$.(b) f has a saddle point at $(1, 1)$.3. Local minimum at $(1, 1)$, saddle point at $(0, 0)$ 5. Minimum $f(\frac{1}{3}, -\frac{2}{3}) = -\frac{1}{3}$ 7. Minima $f(-2, -1) = -3, f(8, 4) = -128$, saddle point at $(0, 0)$ 9. Saddle points at $(1, 1), (-1, -1)$ 11. Maximum $f(1, 4) = 14$ 13. Maximum $f(-1, 0) = 2$, minimum $f(1, 0) = -2$, saddle points at $(0, \pm 1)$ 15. Maximum $f(0, -1) = 2$, minima $f(\pm 1, 1) = -3$, saddle points at $(0, 1), (\pm 1, -1)$ 17. Maximum $f(\frac{1}{3}, \frac{1}{3}) = \frac{1}{27}$, saddle points at $(0, 0), (1, 0), (0, 1)$

19. None

21. Minima $f(0, 1) = f(\pi, -1) = f(2\pi, 1) = -1$, saddle points at $(\pi/2, 0), (3\pi/2, 0)$ 25. Minima $f(1, \pm 1) = f(-1, \pm 1) = 3$ 27. Maximum $f(\pi/3, \pi/3) = 3\sqrt{3}/2$, minimum $f(5\pi/3, 5\pi/3) = -3\sqrt{3}/2$, saddle point at (π, π) 29. Minima $f(0, -0.794) \approx -1.191$, $f(\pm 1.592, 1.267) \approx -1.310$, saddle points $(\pm 0.720, 0.259)$, lowest points $(\pm 1.592, 1.267, -1.310)$ 31. Maximum $f(0.170, -1.215) \approx 3.197$, minima $f(-1.301, 0.549) \approx -3.145, f(1.131, 0.549) \approx -0.701$, saddle points $(-1.301, -1.215), (0.170, 0.549), (1.131, -1.215)$, no highest or lowest point33. Maximum $f(0, \pm 2) = 4$, minimum $f(1, 0) = -1$ 35. Maximum $f(\pm 1, 1) = 7$, minimum $f(0, 0) = 4$ 37. Maximum $f(0, 3) = f(2, 3) = 7$, minimum $f(1, 1) = -2$ 39. Maximum $f(1, 0) = 2$, minimum $f(-1, 0) = -2$

41.

43. $2/\sqrt{3}$ 45. $(2, 1, \sqrt{5}), (2, 1, -\sqrt{5})$ 47. $\frac{100}{3}, \frac{100}{3}, \frac{100}{3}$ 49. $8r^3/(3\sqrt{3})$ 51. $\frac{4}{3}$ 53. Cube, edge length $c/12$ 55. Square base of side 40 cm, height 20 cm 57. $L^3/(3\sqrt{3})$

59. (a) $H = -p_1 \ln p_1 - p_2 \ln p_2 - (1 - p_1 - p_2) \ln(1 - p_1 - p_2)$
 (b) $\{(p_1, p_2) \mid 0 < p_1 < 1, p_2 < 1 - p_1\}$
 (c) $\ln 3; p_1 = p_2 = p_3 = \frac{1}{3}$

EXERCISES 14.8 ■ PAGE 1064

1. $\approx 59, 30$
 3. Maximum $f(\pm 1, 0) = 1$, minimum $f(0, \pm 1) = -1$
 5. Maximum $f(1, 2) = f(-1, -2) = 2$, minimum $f(1, -2) = f(-1, 2) = -2$
 7. Maximum $f(1/\sqrt{2}, \pm 1/\sqrt{2}) = f(-1/\sqrt{2}, \pm 1/\sqrt{2}) = 4$, minimum $f(\pm 1, 0) = 2$
 9. Maximum $f(2, 2, 1) = 9$, minimum $f(-2, -2, -1) = -9$
 11. Maximum $f(1, \pm \sqrt{2}, 1) = f(-1, \pm \sqrt{2}, -1) = 2$, minimum $f(1, \pm \sqrt{2}, -1) = f(-1, \pm \sqrt{2}, 1) = -2$
 13. Maximum $\sqrt{3}$, minimum 1
 15. Maximum $f(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}) = 2$, minimum $f(-\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}) = -2$
 17. 10, 10
 19. 25 m by 25 m
 21. $(-\frac{6}{5}, \frac{3}{5})$
 23. Minimum $f(1, 1) = f(-1, -1) = 2$
 25. Maximum $f(2, 2) = e^4$
 27. Maximum $f(3/\sqrt{2}, -3/\sqrt{2}) = 9 + 12\sqrt{2}$, minimum $f(-2, 2) = -8$
 29. Maximum $f(\pm 1/\sqrt{2}, \mp 1/(2\sqrt{2})) = e^{1/4}$, minimum $f(\pm 1/\sqrt{2}, \pm 1/(2\sqrt{2})) = e^{-1/4}$
 31. Maximum $f(0, 1, \sqrt{2}) = 1 + \sqrt{2}$, minimum $f(0, 1, -\sqrt{2}) = 1 - \sqrt{2}$
 33. Maximum $\frac{3}{2}$, minimum $\frac{1}{2}$
 41–53. See Exercises 43–57 in Section 14.7.
 57. Nearest $(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$, farthest $(-1, -1, 2)$
 59. Maximum ≈ 9.7938 , minimum ≈ -5.3506
 61. Maximum $f(\pm \sqrt{3}, 3) = 18$, minimum $f(0, 0) = 0$
 63. (a) c/n (b) When $x_1 = x_2 = \dots = x_n$

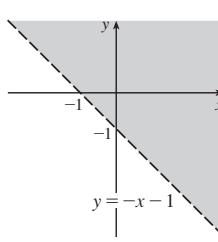
CHAPTER 14 REVIEW ■ PAGE 1069**True-False Quiz**

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

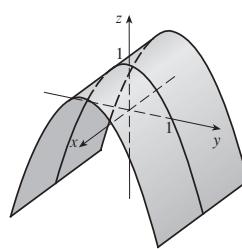
11. True

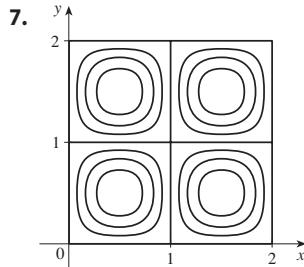
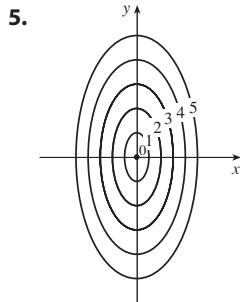
Exercises

- 1.
- $\{(x, y) \mid y > -x - 1\}$



- 3.





9. $\frac{2}{3}$

11. (a) $\approx 3.5^\circ\text{C}/\text{m}$, $-3.0^\circ\text{C}/\text{m}$ (b) $\approx 0.35^\circ\text{C}/\text{m}$ by Equation 14.6.9 (Definition 14.6.2 gives $\approx 1.1^\circ\text{C}/\text{m}$)(c) -0.25

13. $f_x = 32xy(5y^3 + 2x^2y)^7$, $f_y = (16x^2 + 120y^2)(5y^3 + 2x^2y)^7$

15. $F_\alpha = \frac{2\alpha^3}{\alpha^2 + \beta^2} + 2\alpha \ln(\alpha^2 + \beta^2)$, $F_\beta = \frac{2\alpha^2\beta}{\alpha^2 + \beta^2}$

17. $S_u = \arctan(v\sqrt{w})$, $S_v = \frac{u\sqrt{w}}{1 + v^2w}$, $S_w = \frac{uv}{2\sqrt{w}(1 + v^2w)}$

19. $f_{xx} = 24x$, $f_{xy} = -2y$, $f_{yx} = f_{yy} = -2x$

21. $f_{xx} = k(k-1)x^{k-2}y^l z^m$, $f_{xy} = klx^{k-1}y^{l-1}z^m = f_{yx}$,

$f_{xz} = kmx^{k-1}y^l z^{m-1} = f_{zx}$, $f_{yy} = l(l-1)x^k y^{l-2} z^m$,

$f_{yz} = lmx^k y^{l-1} z^{m-1} = f_{zy}$, $f_{zz} = m(m-1)x^k y^l z^{m-2}$

25. (a) $z = 8x + 4y + 1$

(b) $x = 1 + 8t$, $y = -2 + 4t$, $z = 1 - t$

27. (a) $2x - 2y - 3z = 3$

(b) $x = 2 + 4t$, $y = -1 - 4t$, $z = 1 - 6t$

29. (a) $x + 2y + 5z = 0$

(b) $x = 2 + t$, $y = -1 + 2t$, $z = 5t$

31. $(2, \frac{1}{2}, -1), (-2, -\frac{1}{2}, 1)$

33. $60x + \frac{24}{5}y + \frac{32}{5}z = 120$; 38.656

35. $2xy^3(1 + 6p) + 3x^2y^2(pe^p + e^p) + 4z^3(p \cos p + \sin p)$

37. $-47, 108$

43. $\langle 2xe^{yz^2}, x^2z^2e^{yz^2}, 2x^2yze^{yz^2} \rangle$

45. $-\frac{4}{5}$

47. $\sqrt{145}/2$, $\langle 4, \frac{9}{2} \rangle$

49.

51. Minimum $f(-4, 1) = -11$

53. Maximum $f(1, 1) = 1$; saddle points at $(0, 0)$, $(0, 3)$, $(3, 0)$

55. Maximum $f(1, 2) = 4$, minimum $f(2, 4) = -64$

57. Maximum $f(-1, 0) = 2$, minima $f(1, \pm 1) = -3$, saddle points at $(-1, \pm 1)$, $(1, 0)$

59. Maximum $f(\pm\sqrt{2/3}, 1/\sqrt{3}) = 2/(3\sqrt{3})$,

minimum $f(\pm\sqrt{2/3}, -1/\sqrt{3}) = -2/(3\sqrt{3})$

61. Maximum 1, minimum -1

63. $(\pm 3^{-1/4}, 3^{-1/4}\sqrt{2}, \pm 3^{1/4}), (\pm 3^{-1/4}, -3^{-1/4}\sqrt{2}, \pm 3^{1/4})$

65. $P(2 - \sqrt{3}), P(3 - \sqrt{3})/6, P(2\sqrt{3} - 3)/3$

PROBLEMS PLUS ■ PAGE 1073

1. $L^2W^2, \frac{1}{4}L^2W^2$ 3. (a) $x = w/3$, base = $w/3$ (b) Yes

7. $\sqrt{3/2}, 3/\sqrt{2}$

CHAPTER 15

EXERCISES 15.1 ■ PAGE 1087

1. (a) 288 (b) 144 3. (a) 0.990 (b) 1.151

5. $U < V < L$ 7. (a) ≈ 248 (b) ≈ 15.5

9. $24\sqrt{2}$ 11. 3 13. $2 + 8y^2, 3x + 27x^2$

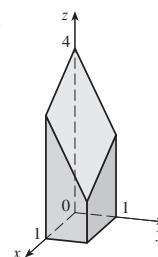
15. 222 17. $\frac{5}{2} - e^{-1}$ 19. 18

21. $\frac{15}{2} \ln 2 + \frac{3}{2} \ln 4$ or $\frac{21}{2} \ln 2$ 23. 6

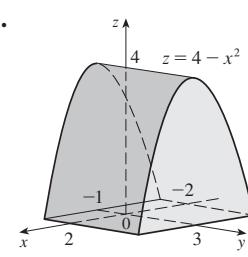
25. $\frac{31}{30}$ 27. 2 29. $9 \ln 2$

31. $\frac{1}{2}(\sqrt{3} - 1) - \frac{1}{12}\pi$ 33. $\frac{1}{2}e^{-6} + \frac{5}{2}$

35.



37.

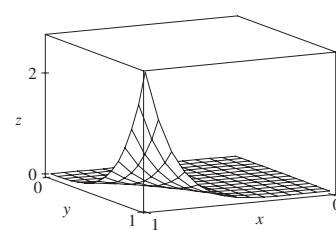


39. (a) $\int_0^2 \int_0^2 xy \, dx \, dy$ (b) 4

41. (a) $\int_1^2 \int_0^1 (1 + ye^{xy}) \, dx \, dy$ (b) $e^2 - e$

43. 51 45. $\frac{166}{27}$ 47. $\frac{8}{3}$ 49. $\frac{64}{3}$

51. $21e - 57$



53. $\frac{5}{6}$ 55. 0

57. Fubini's Theorem does not apply. The integrand has an infinite discontinuity at the origin.

EXERCISES 15.2 ■ PAGE 1097

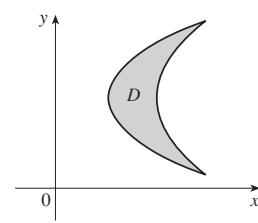
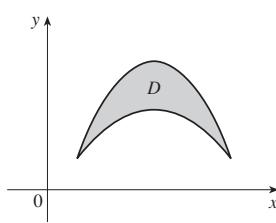
1. $\frac{868}{3}$ 3. $\frac{1}{6}(e - 1)$ 5. $\frac{1}{3} \sin 1$

7. (a) $\int_0^2 \int_x^{3x-x^2} 2y \, dy \, dx$ (b) $\frac{56}{15}$

9. (a) $\int_0^2 \int_y^{y+2} xy \, dx \, dy$ (b) 6

11. $\frac{1}{4} \ln 17$ 13. $\frac{1}{2}(1 - e^{-9})$

15. (a) (b)



17. Type I: $D = \{(x, y) \mid 0 \leq x \leq 1, 0 \leq y \leq x\}$,
 type II: $D = \{(x, y) \mid 0 \leq y \leq 1, y \leq x \leq 1\}; \frac{1}{3}$

19. $\int_0^1 \int_{-\sqrt{x}}^{\sqrt{x}} y \, dy \, dx + \int_1^4 \int_{x-2}^x y \, dy \, dx = \int_{-1}^2 \int_{y^2}^{y+2} y \, dx \, dy = \frac{9}{4}$

21. $\int_0^1 \int_0^{\cos^{-1}y} \sin^2 x \, dx \, dy = \int_0^{\pi/2} \int_0^{\cos x} \sin^2 x \, dy \, dx = \frac{1}{3}$

23. $\frac{1}{2}(1 - \cos 1)$ **25.** $\frac{11}{3}$ **27.** 0

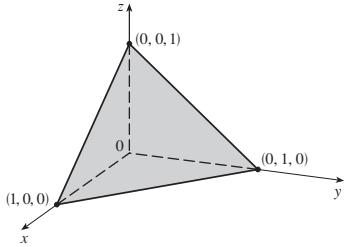
29. (a) $\int_0^1 \int_0^y (1 + xy) \, dx \, dy$ (b) $\frac{5}{8}$ **31.** $\frac{3}{4}$

33. $\frac{31}{8}$ **35.** $\frac{16}{3}$ **37.** $\frac{128}{15}$ **39.** $\frac{1}{3}$

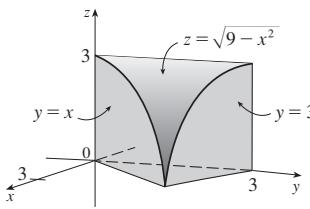
41. 0, 1.213; 0.713 **43.** $\frac{64}{3}$

45. $\frac{10}{3\sqrt{2}}$ or $\frac{5\sqrt{2}}{3}$

47.

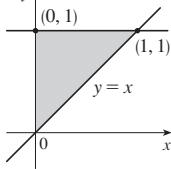


49.

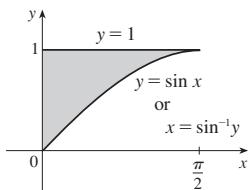


51. 13,984,735,616/14,549,535 **53.** $\pi/2$

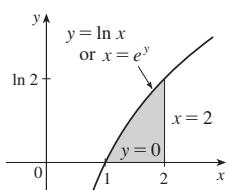
55. $\int_0^1 \int_x^1 f(x, y) \, dy \, dx$



57. $\int_0^1 \int_0^{\sin^{-1}y} f(x, y) \, dx \, dy$



59. $\int_0^{\ln 2} \int_{e^y}^2 f(x, y) \, dx \, dy$



61. $\frac{1}{6}(e^9 - 1)$ **63.** $\frac{2}{9}(2\sqrt{2} - 1)$ **65.** $\frac{1}{3}(2\sqrt{2} - 1)$

67. 1 **69.** $\frac{\sqrt{3}}{2}\pi \leq \iint_S \sqrt{4 - x^2 y^2} \, dA \leq \pi$

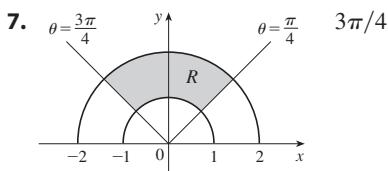
71. $\frac{3}{4}$ **75.** 9π **77.** $a^2 b + \frac{3}{2} a b^2$ **79.** $\pi a^2 b$

EXERCISES 15.3 ■ PAGE 1105

1. $\int_0^{3\pi/2} \int_0^4 f(r \cos \theta, r \sin \theta) r \, dr \, d\theta$

3. $\int_0^\pi \int_1^3 f(r \cos \theta, r \sin \theta) r \, dr \, d\theta$

5. $\int_0^1 \int_{2y-2}^{2-y} f(x, y) \, dx \, dy$



9. $\frac{1250}{3}$ **11.** $(\pi/4)(\cos 1 - \cos 9)$

13. $(\pi/2)(1 - e^{-4})$ **15.** $\frac{3}{64}\pi^2$

17. $\frac{3\pi}{2} - 4$ **19.** $\frac{3\pi}{8} + \frac{1}{4}$ **21.** $\pi/12$

23. (a) $\int_0^{\pi/2} \int_0^2 (r + r^3 \cos \theta \sin \theta) \, dr \, d\theta$ (b) $\pi + 2$

25. (a) $\int_0^{3\pi/2} \int_0^3 r^2 \sin \theta \, dr \, d\theta$ (b) 9

27. (a) $\int_0^{\pi/2} \int_0^{\sin \theta} r^2 \cos \theta \, dr \, d\theta$ (b) $\frac{1}{12}$

29. $\frac{625}{2}\pi$ **31.** 4π **33.** $\frac{4}{3}\pi a^3$

35. $(\pi/3)(2 - \sqrt{2})$ **37.** $(8\pi/3)(64 - 24\sqrt{3})$

39. $(\pi/4)(1 - e^{-4})$ **41.** $\frac{1}{120}$ **43.** 4.5951

45. $38\pi \text{ m}^3$ **47.** $2/(a+b)$ **49.** $\frac{15}{16}$

51. (a) $\sqrt{\pi}/4$ (b) $\sqrt{\pi}/2$

EXERCISES 15.4 ■ PAGE 1116

1. 285 C **3.** $(\frac{3}{4}, \frac{1}{2})$ **5.** $42k, (2, \frac{85}{28})$ **7.** $6, (\frac{3}{4}, \frac{3}{2})$

9. $\frac{8}{15}k, (0, \frac{4}{7})$ **11.** $\frac{1}{8}(1 - 3e^{-2}), \left(\frac{e^2 - 5}{e^2 - 3}, \frac{8(e^3 - 4)}{27(e^3 - 3e)}\right)$

13. $(\frac{3}{8}, 3\pi/16)$ **15.** $(0, 45/(14\pi))$

17. $(2a/5, 2a/5)$ if vertex is $(0, 0)$ and sides are along positive axes

19. 409.2k, 182k, 591.2k

21. $7ka^6/180, 7ka^6/180, 7ka^6/90$ if vertex is $(0, 0)$ and sides are along positive axes

23. $\rho bh^3/3, \rho b^3h/3; b/\sqrt{3}, h/\sqrt{3}$

25. $\rho a^4\pi/16, \rho a^4\pi/16; a/2, a/2$

27. $m = 3\pi/64, (\bar{x}, \bar{y}) = \left(\frac{16384\sqrt{2}}{10395\pi}, 0\right)$,

$I_x = \frac{5\pi}{384} - \frac{4}{105}, I_y = \frac{5\pi}{384} + \frac{4}{105}, I_0 = \frac{5\pi}{192}$

29. (a) $\frac{1}{2}$ (b) 0.375 (c) $\frac{5}{48} \approx 0.1042$

31. (b) (i) $e^{-0.2} \approx 0.8187$

(ii) $1 + e^{-1.8} - e^{-0.8} - e^{-1} \approx 0.3481$ (c) 2, 5

33. (a) ≈ 0.500 (b) ≈ 0.632

35. (a) $\iint_D k \left[1 - \frac{1}{20} \sqrt{(x - x_0)^2 + (y - y_0)^2} \right] dA$, where D is the disk with radius 10 km centered at the center of the city
 (b) $200\pi k/3 \approx 209k$, $200(\pi/2 - \frac{8}{9})k \approx 136k$; on the edge

EXERCISES 15.5 ■ PAGE 1119

1. $\frac{13}{3}\sqrt{2}$ 3. $12\sqrt{35}$ 5. $3\sqrt{14}$

7. $(\pi/6)(13\sqrt{13} - 1)$ 9. $(\pi/6)(17\sqrt{17} - 5\sqrt{5})$

11. $(2\pi/3)(2\sqrt{2} - 1)$ 13. $a^2(\pi - 2)$ 15. 3.6258

17. (a) ≈ 1.83 (b) ≈ 1.8616

19. $\frac{45}{8}\sqrt{14} + \frac{15}{16}\ln[(11\sqrt{5} + 3\sqrt{70})/(3\sqrt{5} + \sqrt{70})]$

21. 3.3213 25. $(\pi/6)(101\sqrt{101} - 1)$

EXERCISES 15.6 ■ PAGE 1130

1. $\frac{27}{4}$ 3. $\frac{16}{15}$ 5. $\frac{5}{3}$ 7. $3\ln 3 + 3$

9. (a) $\int_{-1}^1 \int_0^{1-x^2} \int_0^{2-z} x dy dz dx$ (b) 0

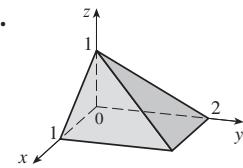
11. (a) $\int_0^2 \int_0^{2-x} \int_0^x (x+y) dy dz dx$ (b) $\frac{8}{3}$

13. $\frac{27}{2}$ 15. $\pi/8 - \frac{1}{3}$ 17. $\frac{65}{28}$

19. $\frac{8}{15}$ 21. $16\pi/3$ 23. $\frac{16}{3}$ 25. $\frac{8}{15}$

27. (a) $\int_0^1 \int_0^x \int_0^{\sqrt{1-y^2}} dz dy dx$ (b) $\frac{1}{4}\pi - \frac{1}{3}$

29. ≈ 0.985



31.

$$\begin{aligned} 33. & \int_{-2}^2 \int_0^{4-x^2} \int_{-\sqrt{4-x^2-y/2}}^{\sqrt{4-x^2-y/2}} f(x, y, z) dz dy dx \\ &= \int_0^4 \int_{-\sqrt{4-y}}^{\sqrt{4-y}} \int_{-\sqrt{4-x^2-y/2}}^{\sqrt{4-x^2-y/2}} f(x, y, z) dz dy dx \\ &= \int_{-1}^1 \int_{-4}^{4-x^2} \int_{-\sqrt{4-y-4z^2}}^{\sqrt{4-y-4z^2}} f(x, y, z) dx dy dz \\ &= \int_0^4 \int_{-\sqrt{4-y}}^{\sqrt{4-y}} \int_{-\sqrt{4-y-4z^2}}^{\sqrt{4-y-4z^2}} f(x, y, z) dx dz dy \\ &= \int_{-2}^2 \int_{-\sqrt{4-x^2}}^{\sqrt{4-x^2}} \int_0^{4-x^2-4z^2} f(x, y, z) dy dz dx \\ &= \int_{-1}^1 \int_{-\sqrt{4-4z^2}}^{\sqrt{4-4z^2}} \int_0^{4-x^2-4z^2} f(x, y, z) dy dx dz \end{aligned}$$

$$\begin{aligned} 35. & \int_{-2}^2 \int_{x^2}^{x^2-y^2} f(x, y, z) dz dy dx \\ &= \int_0^4 \int_{-\sqrt{y}}^{\sqrt{y}} \int_0^{x^2-y^2} f(x, y, z) dz dx dy \\ &= \int_0^2 \int_0^{4-2x} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dy dz \\ &= \int_0^4 \int_0^{2-y^2} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dz dy \\ &= \int_{-2}^2 \int_0^{2-x^2/2} \int_{x^2}^{4-2z} f(x, y, z) dy dz dx \\ &= \int_0^2 \int_{-\sqrt{4-2z}}^{\sqrt{4-2z}} \int_{x^2}^{4-2z} f(x, y, z) dy dx dz \end{aligned}$$

$$\begin{aligned} 37. & \int_0^1 \int_{-\sqrt{x}}^1 \int_{-\sqrt{1-y}}^y f(x, y, z) dz dy dx = \int_0^1 \int_0^y \int_{-\sqrt{1-y}}^y f(x, y, z) dz dx dy \\ &= \int_0^1 \int_0^1 \int_0^y f(x, y, z) dx dy dz = \int_0^1 \int_0^1 \int_0^y f(x, y, z) dx dz dy \\ &= \int_0^1 \int_0^1 \int_{-\sqrt{x}}^1 f(x, y, z) dy dz dx = \int_0^1 \int_0^1 \int_{(1-z)^2}^{1-z} f(x, y, z) dy dx dz \end{aligned}$$

$$\begin{aligned} 39. & \int_0^1 \int_y^1 \int_0^y f(x, y, z) dz dx dy = \int_0^1 \int_0^y \int_0^y f(x, y, z) dz dy dx \\ &= \int_0^1 \int_y^1 \int_y^1 f(x, y, z) dx dy dz = \int_0^1 \int_0^y \int_y^1 f(x, y, z) dx dz dy \\ &= \int_0^1 \int_0^x \int_z^x f(x, y, z) dy dz dx = \int_0^1 \int_z^1 \int_z^x f(x, y, z) dy dx dz \end{aligned}$$

41. 64π 43. $\frac{3}{2}\pi, (0, 0, \frac{1}{3})$

45. $a^5, (7a/12, 7a/12, 7a/12)$

47. $I_x = I_y = I_z = \frac{2}{3}kL^5$ 49. $\frac{1}{2}\pi kha^4$

51. (a) $m = \int_{-1}^1 \int_{x^2}^1 \int_0^{1-y} \sqrt{x^2 + y^2} dz dy dx$

(b) $(\bar{x}, \bar{y}, \bar{z})$, where

$\bar{x} = (1/m) \int_{-1}^1 \int_{x^2}^1 \int_0^{1-y} x \sqrt{x^2 + y^2} dz dy dx,$

$\bar{y} = (1/m) \int_{-1}^1 \int_{x^2}^1 \int_0^{1-y} y \sqrt{x^2 + y^2} dz dy dx,$

and $\bar{z} = (1/m) \int_{-1}^1 \int_{x^2}^1 \int_0^{1-y} z \sqrt{x^2 + y^2} dz dy dx$

(c) $\int_{-1}^1 \int_{x^2}^1 \int_0^{1-y} (x^2 + y^2)^{3/2} dz dy dx$

53. (a) $\frac{3}{32}\pi + \frac{11}{24}$

(b) $\left(\frac{28}{9\pi + 44}, \frac{30\pi + 128}{45\pi + 220}, \frac{45\pi + 208}{135\pi + 660} \right)$

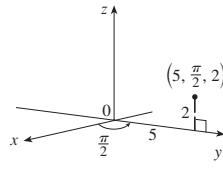
(c) $\frac{1}{240}(68 + 15\pi)$

55. (a) $\frac{1}{8}$ (b) $\frac{1}{64}$ (c) $\frac{1}{5760}$ 57. $L^3/8$

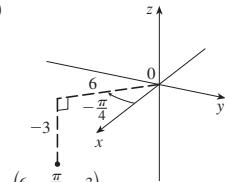
59. (a) The region bounded by the ellipsoid $x^2 + 2y^2 + 3z^2 = 1$
 (b) $4\sqrt{6}\pi/45$

EXERCISES 15.7 ■ PAGE 1138

1. (a)



(b)



(0, 5, 2)

$(3\sqrt{2}, -3\sqrt{2}, -3)$

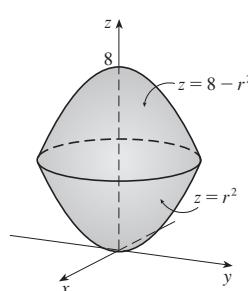
3. (a) $(4\sqrt{2}, \pi/4, -3)$ (b) $(10, -\pi/6, \sqrt{3})$

5. Circular cylinder with radius 2 and axis the z -axis

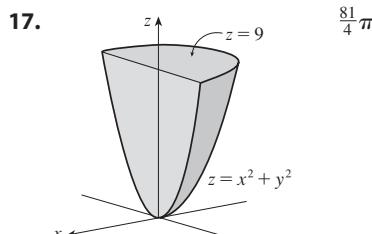
7. Sphere, radius 2, centered at the origin

9. (a) $z^2 = 1 + r \cos \theta - r^2$ (b) $z = r^2 \cos 2\theta$

11.

13. Cylindrical coordinates: $6 \leq r \leq 7$, $0 \leq \theta \leq 2\pi$, $0 \leq z \leq 20$

15. (a) $\int_0^\pi \int_0^1 \int_0^{r^2} r^3 dz dr d\theta$ (b) $\pi/3$



19. 384π 21. $\frac{8}{3}\pi + \frac{128}{15}$ 23. $2\pi/5$ 25. $\frac{4}{3}\pi(\sqrt{2} - 1)$

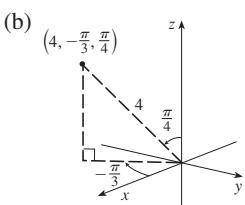
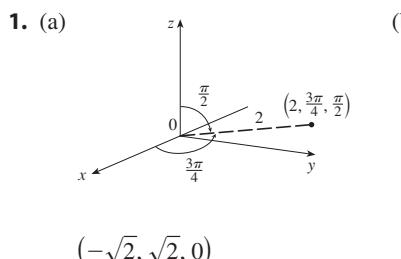
27. (a) $\frac{512}{3}\pi$ (b) $(0, 0, \frac{23}{2})$

29. $\pi K a^2/8, (0, 0, 2a/3)$ 31. 0

33. (a) $\iiint_C h(P)g(P) dV$, where C is the cone

(b) $\approx 4.4 \times 10^{18} \text{ J}$

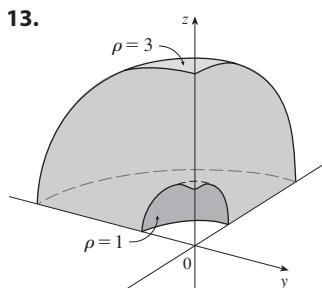
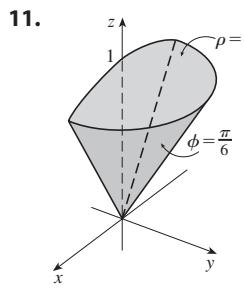
EXERCISES 15.8 ■ PAGE 1144



3. (a) $(3\sqrt{2}, \pi/4, \pi/2)$ (b) $(4, -\pi/3, \pi/6)$

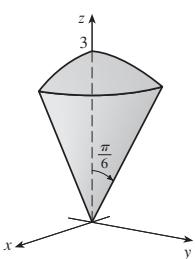
5. Bottom half of a cone 7. Horizontal plane

9. (a) $\rho = 3$ (b) $\rho^2(\sin^2\phi \cos 2\theta - \cos^2\phi) = 1$



15. $\pi/4 \leq \phi \leq \pi/2, 0 \leq \rho \leq 4 \cos \phi$

17. $(9\pi/4)(2 - \sqrt{3})$



19. $\int_0^{\pi/2} \int_0^3 \int_0^2 f(r \cos \theta, r \sin \theta, z) r dz dr d\theta$

21. (a) $\int_{\pi/2}^{\pi} \int_{\pi/2}^{3\pi/2} \int_2^3 \rho^3 \sin \phi d\rho d\theta d\phi$ (b) $\frac{65}{4}\pi$

23. $312,500\pi/7$ 25. $1688\pi/15$ 27. $\pi/8$

29. $(\sqrt{3} - 1)\pi a^3/3$ 31. (a) 10π (b) $(0, 0, 2.1)$

33. (a) $(0, 0, \frac{7}{12})$ (b) $11K\pi/960$

35. (a) $(0, 0, \frac{3}{8}a)$ (b) $4K\pi a^5/15$ (K is the density)

37. $\frac{1}{3}\pi(2 - \sqrt{2}), (0, 0, 3[\sqrt{8}(2 - \sqrt{2})])$

39. (a) $\pi K a^4 h/2$ (K is the density) (b) $\pi K a^2 h(3a^2 + 4h^2)/12$

41. $5\pi/6$ 43. $(4\sqrt{2} - 5)/15$ 45. $4096\pi/21$

47. 49. $136\pi/99$

EXERCISES 15.9 ■ PAGE 1154

1. (a) VI (b) I (c) IV (d) V (e) III (f) II

3. The parallelogram with vertices $(0, 0), (6, 3), (12, 1), (6, -2)$

5. The region bounded by the line $y = 1$, the y -axis, and $y = \sqrt{x}$

7. $x = \frac{1}{3}(v - u), y = \frac{1}{3}(u + 2v)$ is one possible transformation, where $S = \{(u, v) \mid -1 \leq u \leq 1, 1 \leq v \leq 3\}$

9. $x = u \cos v, y = u \sin v$ is one possible transformation, where $S = \{(u, v) \mid 1 \leq u \leq \sqrt{2}, 0 \leq v \leq \pi/2\}$

11. -6 13. s 15. $2uvw$

17. -3 19. 6π 21. $2 \ln 3$

23. (a) $\frac{4}{3}\pi abc$ (b) $1.083 \times 10^{12} \text{ km}^3$

(c) $\frac{4}{15}\pi(a^2 + b^2)abck$

25. $\frac{8}{5} \ln 8$ 27. $\frac{3}{2} \sin 1$ 29. $e - e^{-1}$

CHAPTER 15 REVIEW ■ PAGE 1156

True-False Quiz

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

Exercises

1. ≈ 64.0 3. $4e^2 - 4e + 3$ 5. $\frac{1}{2} \sin 1$ 7. $\frac{2}{3}$

9. $\int_0^\pi \int_2^4 f(r \cos \theta, r \sin \theta) r dr d\theta$

11. $(\sqrt{3}, 3, 2), (4, \pi/3, \pi/3)$

13. $(2\sqrt{2}, 2\sqrt{2}, 4\sqrt{3}), (4, \pi/4, 4\sqrt{3})$

15. (a) $r^2 + z^2 = 4, \rho = 2$ (b) $r = 2, \rho \sin \phi = 2$

17. The region inside the loop of the four-leaved rose $r = \sin 2\theta$ in the first quadrant

19. $\frac{1}{2} \sin 1$ 21. $\frac{1}{2}e^6 - \frac{7}{2}$ 23. $\frac{1}{4} \ln 2$ 25. 8

27. $81\pi/5$ 29. $\frac{81}{2}$ 31. $\pi/96$ 33. $\frac{64}{15}$

35. 176 37. $\frac{2}{3}$ 39. $2ma^3/9$

41. (a) $\frac{1}{4}$ (b) $(\frac{1}{3}, \frac{8}{15})$

(c) $I_x = \frac{1}{12}, I_y = \frac{1}{24}; \bar{y} = 1/\sqrt{3}, \bar{x} = 1/\sqrt{6}$

43. (a) $(0, 0, h/4)$ (b) $\pi a^5 h/15$

45. $\ln(\sqrt{2} + \sqrt{3}) + \sqrt{2}/3$ 47. $\frac{486}{5}$ 49. 0.0512
 51. (a) $\frac{1}{15}$ (b) $\frac{1}{3}$ (c) $\frac{1}{45}$
 53. $\int_0^1 \int_0^{1-z} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dy dz$ 55. $-\ln 2$ 57. 0

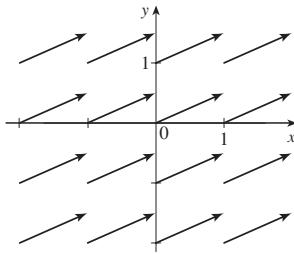
PROBLEMS PLUS ■ PAGE 1159

1. 30 3. $\frac{1}{2} \sin 1$ 7. (b) 0.90
 13. $abc\pi \left(\frac{2}{3} - \frac{8}{9\sqrt{3}} \right)$

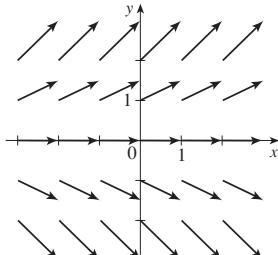
CHAPTER 16

EXERCISES 16.1 ■ PAGE 1167

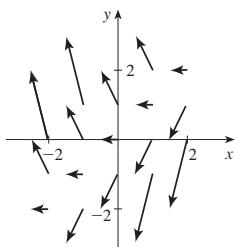
1.



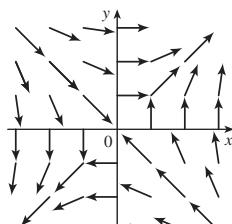
3.



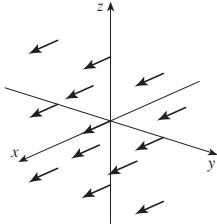
5.



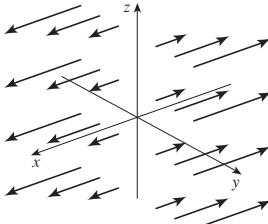
7.



9.



11.



13. IV

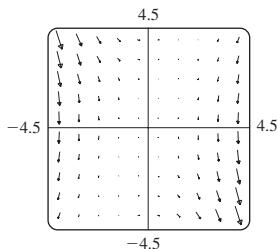
15. I

17. III

19. IV

21. III

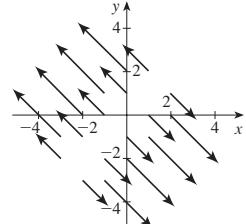
23.

The line $y = 2x$

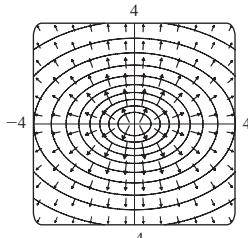
25. $\nabla f(x, y) = y^2 \cos(xy) \mathbf{i} + [xy \cos(xy) + \sin(xy)] \mathbf{j}$

27. $\nabla f(x, y, z) = \frac{x}{\sqrt{x^2 + y^2 + z^2}} \mathbf{i} + \frac{y}{\sqrt{x^2 + y^2 + z^2}} \mathbf{j} + \frac{z}{\sqrt{x^2 + y^2 + z^2}} \mathbf{k}$

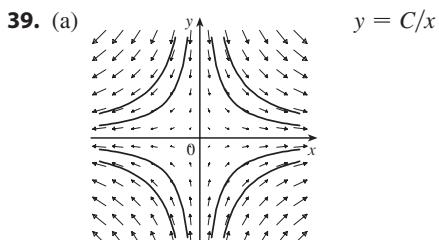
29. $\nabla f(x, y) = (x - y) \mathbf{i} + (y - x) \mathbf{j}$



31. III 33. II 35.



37. (2.04, 1.03)

(b) $y = 1/x, x > 0$

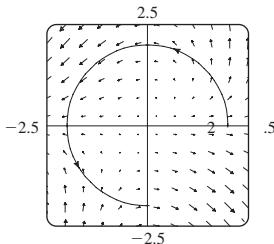
EXERCISES 16.2 ■ PAGE 1179

1. $\frac{4}{3}(10^{3/2} - 1)$ 3. 1638.4 5. $\frac{1}{3}\pi^6 + 2\pi$ 7. $\frac{5}{2}$
 9. $\sqrt{2}/3$ 11. $\frac{1}{12}\sqrt{14}(e^6 - 1)$ 13. $\frac{2}{5}(e - 1)$
 15. $\pi/2 - \frac{1}{6}\sqrt{2}$ 17. $\frac{35}{3}$

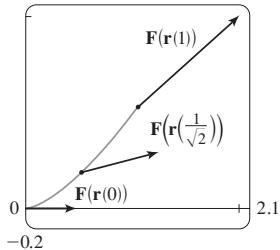
19. (a) Positive (b) Negative 21. $\frac{1}{20}$

23. $\frac{6}{5} - \cos 1 - \sin 1$ 25. 0.5424 27. 94.8231

29. $3\pi + \frac{2}{3}$



31. (a) $\frac{11}{8} - 1/e$ (b) 2.1



33. $\frac{172,704}{5,632,705}\sqrt{2}(1 - e^{-14\pi})$ 35. $2\pi k, (4/\pi, 0)$

37. (a) $\bar{x} = (1/m) \int_C x \rho(x, y, z) ds$,

$\bar{y} = (1/m) \int_C y \rho(x, y, z) ds$,

$\bar{z} = (1/m) \int_C z \rho(x, y, z) ds$, where $m = \int_C \rho(x, y, z) ds$

(b) $(0, 0, 3\pi)$

39. $I_x = k(\frac{1}{2}\pi - \frac{4}{3})$, $I_y = k(\frac{1}{2}\pi - \frac{2}{3})$ 41. $2\pi^2$ 43. $\frac{7}{3}$

45. (a) $2ma \mathbf{i} + 6mbt \mathbf{j}$, $0 \leq t \leq 1$ (b) $2ma^2 + \frac{9}{2}mb^2$

47. $\approx 2.26 \times 10^4 \text{ J}$ 49. (b) Yes 53. $\approx 22 \text{ J}$

EXERCISES 16.3 ■ PAGE 1189

1. 40 3. Not conservative

5. $f(x, y) = ye^{xy} + K$ 7. $f(x, y) = ye^x + x \sin y + K$

9. $f(x, y) = y^2 \sin x + x \cos y + K$

11. (b) 16 13. (a) 16 (b) $f(x, y) = x^3 + xy^2 + K$

15. (a) $f(x, y) = e^{xy} + K$ (b) $e^2 - 1$

17. (a) $f(x, y) = x^2 + 2y^2$ (b) -21

19. (a) $f(x, y) = \frac{1}{3}x^3y^3$ (b) -9

21. (a) $f(x, y, z) = x^2y + y^2z$ (b) 30

23. (a) $f(x, y, z) = ye^{xz}$ (b) 4 25. $4/e$

27. It doesn't matter which curve is chosen.

29. $\frac{31}{4}$ 31. No 33. Conservative

37. (a) Yes (b) Yes (c) Yes

39. (a) No (b) Yes (c) Yes

EXERCISES 16.4 ■ PAGE 1197

1. 120 3. $\frac{2}{3}$ 5. $4(e^3 - 1)$ 7. $-\frac{9}{5}$ 9. $\frac{1}{3}$

11. -24π 13. 14 15. $-\frac{16}{3}$ 17. 4π

19. $\frac{1}{15}\pi^4 - \frac{4144}{1125}\pi^2 + \frac{7,578,368}{253,125} \approx 0.0779$

21. $-\frac{1}{12}$ 23. 3π 25. (c) $\frac{9}{2}$

27. $(4a/3\pi, 4a/3\pi)$ if the region is the portion of the disk $x^2 + y^2 = a^2$ in the first quadrant

31. 0

EXERCISES 16.5 ■ PAGE 1206

1. (a) $\mathbf{0}$ (b) $y^2z^2 + x^2z^2 + x^2y^2$

3. (a) $ze^x \mathbf{i} + (xye^z - yze^x) \mathbf{j} - xe^z \mathbf{k}$ (b) $y(e^z + e^x)$

5. (a) $-\frac{\sqrt{z}}{(1+y)^2} \mathbf{i} - \frac{\sqrt{x}}{(1+z)^2} \mathbf{j} - \frac{\sqrt{y}}{(1+x)^2} \mathbf{k}$

(b) $\frac{1}{2\sqrt{x}(1+z)} + \frac{1}{2\sqrt{y}(1+x)} + \frac{1}{2\sqrt{z}(1+y)}$

7. (a) $\langle -e^y \cos z, -e^z \cos x, -e^x \cos y \rangle$

(b) $e^x \sin y + e^y \sin z + e^z \sin x$

9. (a) Negative (b) $\operatorname{curl} \mathbf{F} = \mathbf{0}$

11. (a) Zero (b) $\operatorname{curl} \mathbf{F}$ points in the negative z -direction.

15. $f(x, y, z) = x^2y^3z^2 + K$

17. $f(x, y, z) = x \ln y + y \ln z + K$

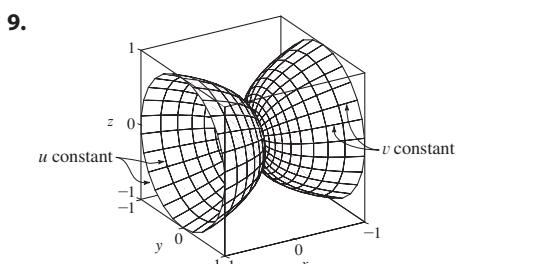
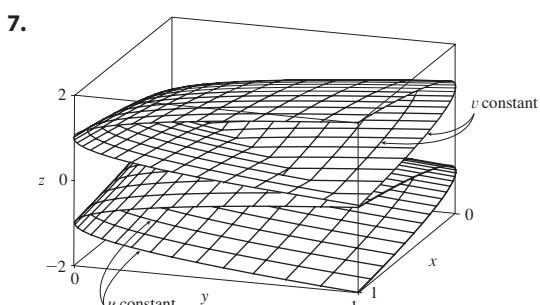
19. Not conservative 21. No

EXERCISES 16.6 ■ PAGE 1218

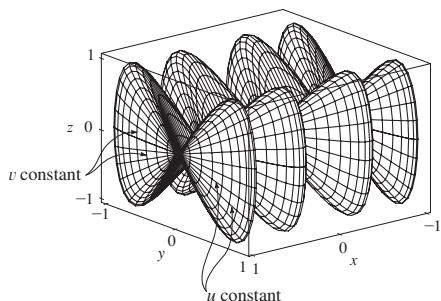
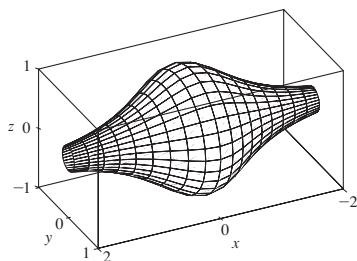
1. P: yes; Q: no

3. Plane through $(0, 3, 1)$ containing vectors $\langle 1, 0, 4 \rangle, \langle 1, -1, 5 \rangle$

5. Circular cone with axis the z -axis



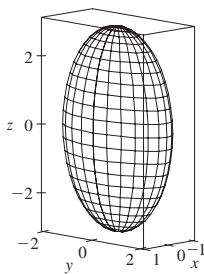
11.

13. IV 15. I 17. III 19. $x = u, y = v - u, z = -v$ 21. $y = y, z = z, x = \sqrt{1 + y^2 + \frac{1}{4}z^2}$ 23. $x = 2 \sin \phi \cos \theta, y = 2 \sin \phi \sin \theta,$ $z = 2 \cos \phi, 0 \leq \phi \leq \pi/4, 0 \leq \theta \leq 2\pi$ [or $x = x, y = y, z = \sqrt{4 - x^2 - y^2}, x^2 + y^2 \leq 2$]25. $x = 6 \sin \phi \cos \theta, y = 6 \sin \phi \sin \theta, z = 6 \cos \phi, \pi/6 \leq \phi \leq \pi/2, 0 \leq \theta \leq 2\pi$ 29. $x = x, y = \frac{1}{1+x^2} \cos \theta, y = \frac{1}{1+x^2} \sin \theta, -2 \leq x \leq 2, 0 \leq \theta \leq 2\pi$ 

31. (a) Direction reverses (b) Number of coils doubles

33. $3x - y + 3z = 3$ 35. $\frac{\sqrt{3}}{2}x - \frac{1}{2}y + z = \frac{\pi}{3}$ 37. $-x + 2z = 1$ 39. $3\sqrt{14}$ 41. $\sqrt{14}\pi$ 43. $\frac{4}{15}(3^{5/2} - 2^{7/2} + 1)$ 45. $(2\pi/3)(2\sqrt{2} - 1)$ 47. $(\pi/6)(65^{3/2} - 1)$ 49. 4 51. $\pi R^2 \leq A(S) \leq \sqrt{3}\pi R^2$ 53. 3.5618 55. (a) ≈ 24.2055 (b) 24.247657. $\frac{45}{8}\sqrt{14} + \frac{15}{16}\ln[(11\sqrt{5} + 3\sqrt{70})/(3\sqrt{5} + \sqrt{70})]$

59. (b)

(c) $\int_0^{2\pi} \int_0^\pi \sqrt{36 \sin^4 u \cos^2 v + 9 \sin^4 u \sin^2 v + 4 \cos^2 u \sin^2 u} du dv$ 61. 4π 63. $2a^2(\pi - 2)$

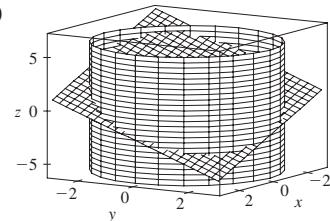
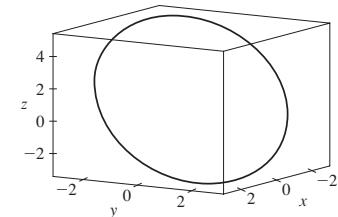
EXERCISES 16.7 ■ PAGE 1230

1. ≈ -6.93 3. 900π 5. $11\sqrt{14}$ 7. $\frac{2}{3}(2\sqrt{2} - 1)$ 9. $171\sqrt{14}$ 11. $\sqrt{21}/3$ 13. $(\pi/120)(25\sqrt{5} + 1)$ 15. $\frac{7}{4}\sqrt{21} - \frac{17}{12}\sqrt{17}$ 17. 16π 19. 0 21. 423. $\frac{713}{180}$ 25. $\frac{8}{3}\pi$ 27. 0 29. 48 31. $2\pi + \frac{8}{3}$

33. 4.5822 35. 3.4895

37. $\iint_S \mathbf{F} \cdot d\mathbf{S} = \iint_D [P(\partial h/\partial x) - Q + R(\partial h/\partial z)] dA$, where D = projection of S onto xz -plane39. $(0, 0, a/2)$ 41. (a) $I_z = \iint_S (x^2 + y^2)\rho(x, y, z) dS$ (b) $4329\sqrt{2}\pi/5$ 43. 0 kg/s 45. $\frac{8}{3}\pi a^3 \epsilon_0$ 47. 1248π

EXERCISES 16.8 ■ PAGE 1237

3. 16π 5. 0 7. -1 9. $-\frac{17}{20}$ 11. 8π 13. $\pi/2$ 15. (a) $81\pi/2$ (b)(c) $x = 3 \cos t, y = 3 \sin t, z = 1 - 3(\cos t + \sin t), 0 \leq t \leq 2\pi$ 17. -32π 19. $-\pi$ 21. 3

EXERCISES 16.9 ■ PAGE 1244

1. $\frac{9}{2}$ 3. $256\pi/3$ 5. $\frac{9}{2}$ 7. $9\pi/2$ 9. 011. π 13. 16 15. $\frac{1}{24}abc(a + 4)$ 17. 2π 19. $13\pi/20$ 21. Negative at P_1 , positive at P_2 23. $\operatorname{div} \mathbf{F} > 0$ in quadrants I, II; $\operatorname{div} \mathbf{F} < 0$ in quadrants III, IV

CHAPTER 16 REVIEW ■ PAGE 1247

True-False Quiz

1. False 3. True 5. False 7. False

9. True 11. True 13. False

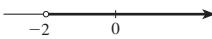
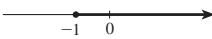
Exercises

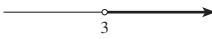
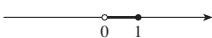
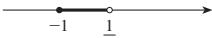
1. (a) Negative (b) Positive 3. $6\sqrt{10}$ 5. $\frac{4}{15}$
 7. $\frac{110}{3}$ 9. $\frac{11}{12} - 4/e$ 11. $f(x, y) = e^y + xe^{xy} + K$
 13. 0 15. 0 17. -8π 25. $\frac{1}{6}(27 - 5\sqrt{5})$
 27. $(\pi/60)(391\sqrt{17} + 1)$ 29. $-64\pi/3$ 31. 0
 33. $-\frac{1}{2}$ 35. 4π 37. -4 39. 21

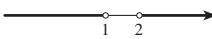
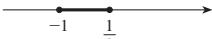
PROBLEMS PLUS ■ PAGE 1251

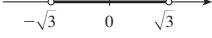
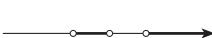
7. (d) $\frac{4\sqrt{2}\pi^2}{25}$ (e) $2\pi^2r^2R$

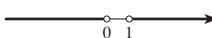
APPENDICES**EXERCISES A ■ PAGE A9**

1. 18 3. π 5. $5 - \sqrt{5}$ 7. $2 - x$
 9. $|x + 1| = \begin{cases} x + 1 & \text{for } x \geq -1 \\ -x - 1 & \text{for } x < -1 \end{cases}$ 11. $x^2 + 1$
 13. $(-2, \infty)$ 15. $[-1, \infty)$
- 
- 

17. $(3, \infty)$ 19. $(2, 6)$
- 
- 
21. $(0, 1]$ 23. $[-1, \frac{1}{2})$
- 
- 

25. $(-\infty, 1) \cup (2, \infty)$ 27. $[-1, \frac{1}{2}]$
- 
- 

29. $(-\infty, \infty)$ 31. $(-\sqrt{3}, \sqrt{3})$
- 
- 
33. $(-\infty, 1]$ 35. $(-1, 0) \cup (1, \infty)$
- 
- 

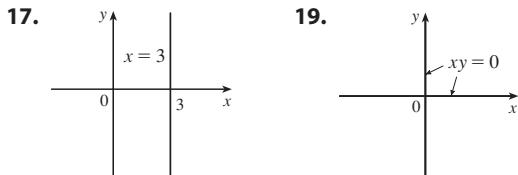
37. $(-\infty, 0) \cup (\frac{1}{4}, \infty)$
- 

39. $10 \leq C \leq 35$ 41. (a) $T = 20 - 10h$, $0 \leq h \leq 12$
 (b) $-30^\circ\text{C} \leq T \leq 20^\circ\text{C}$ 43. $\pm\frac{3}{2}$ 45. $2, -\frac{4}{3}$

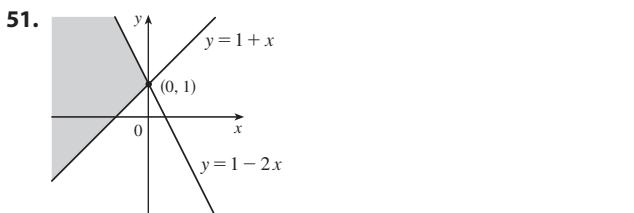
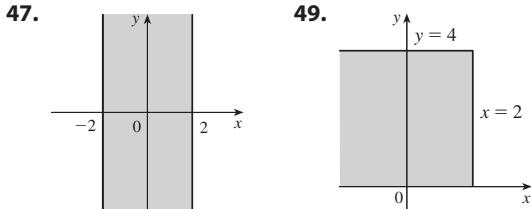
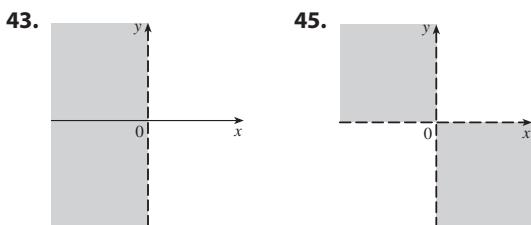
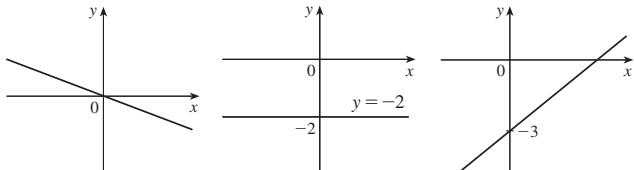
47. $(-3, 3)$ 49. $(3, 5)$ 51. $(-\infty, -7] \cup [-3, \infty)$
 53. $[1.3, 1.7]$ 55. $[-4, -1] \cup [1, 4]$
 57. $x \geq (a+b)c/(ab)$ 59. $x > (c-b)/a$

EXERCISES B ■ PAGE A15

1. 5 3. $\sqrt{74}$ 5. $2\sqrt{37}$ 7. 2 9. $-\frac{9}{2}$



21. $y = 6x - 15$ 23. $2x - 3y + 19 = 0$
 25. $5x + y = 11$ 27. $y = 3x - 2$ 29. $y = 3x - 3$
 31. $y = 5$ 33. $x + 2y + 11 = 0$ 35. $5x - 2y + 1 = 0$
 37. $m = -\frac{1}{3}$,
 $b = 0$ 39. $m = 0$,
 $b = -2$ 41. $m = \frac{3}{4}$,
 $b = -3$



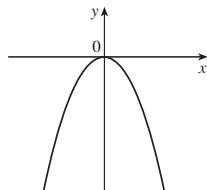
53. $(0, -4)$ 55. (a) $(4, 9)$ (b) $(3.5, -3)$ 57. $(1, -2)$

59. $y = x - 3$ 61. (b) $4x - 3y - 24 = 0$

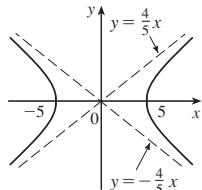
EXERCISES C ■ PAGE A23

1. $(x - 3)^2 + (y + 1)^2 = 25$ 3. $x^2 + y^2 = 65$
5. $(2, -5), 4$ 7. $(-\frac{1}{2}, 0), \frac{1}{2}$ 9. $(\frac{1}{4}, -\frac{1}{4}), \sqrt{10}/4$

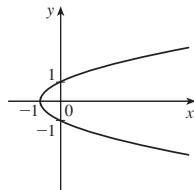
11. Parabola



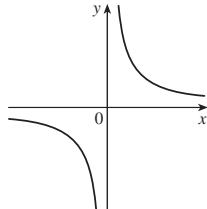
15. Hyperbola



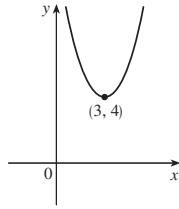
19. Parabola



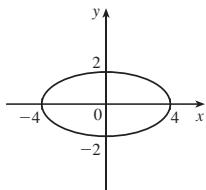
23. Hyperbola



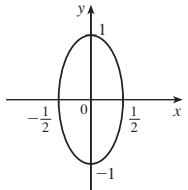
27. Parabola



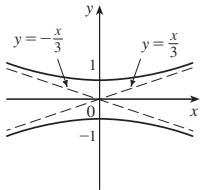
13. Ellipse



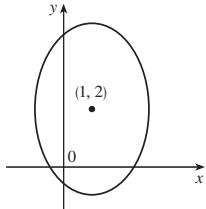
17. Ellipse



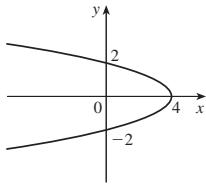
21. Hyperbola



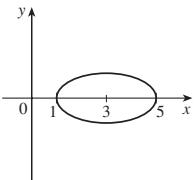
25. Ellipse



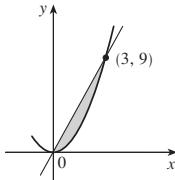
29. Parabola



31. Ellipse

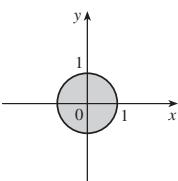


33.

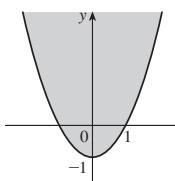


35. $y = x^2 - 2x$

37.

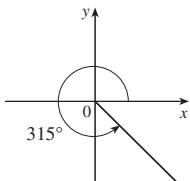


39.

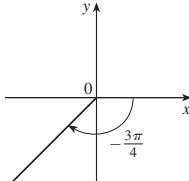
**EXERCISES D ■ PAGE A33**

1. $7\pi/6$ 3. $\pi/20$ 5. 5π 7. 720° 9. 75°
11. -67.5° 13. 3π cm 15. $\frac{2}{3}\text{ rad} = (120/\pi)^\circ$

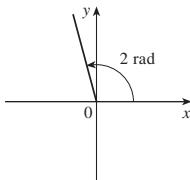
17.



19.



21.



23. $\sin(3\pi/4) = 1/\sqrt{2}$, $\cos(3\pi/4) = -1/\sqrt{2}$, $\tan(3\pi/4) = -1$,
 $\csc(3\pi/4) = \sqrt{2}$, $\sec(3\pi/4) = -\sqrt{2}$, $\cot(3\pi/4) = -1$

25. $\sin(9\pi/2) = 1$, $\cos(9\pi/2) = 0$, $\csc(9\pi/2) = 1$,
 $\cot(9\pi/2) = 0$, $\tan(9\pi/2)$ and $\sec(9\pi/2)$ undefined

27. $\sin(5\pi/6) = \frac{1}{2}$, $\cos(5\pi/6) = -\sqrt{3}/2$, $\tan(5\pi/6) = -1/\sqrt{3}$,
 $\csc(5\pi/6) = 2$, $\sec(5\pi/6) = -2/\sqrt{3}$, $\cot(5\pi/6) = -\sqrt{3}$

29. $\cos \theta = \frac{4}{5}$, $\tan \theta = \frac{3}{4}$, $\csc \theta = \frac{5}{3}$, $\sec \theta = \frac{5}{4}$, $\cot \theta = \frac{4}{3}$

31. $\sin \phi = \sqrt{5}/3$, $\cos \phi = -\frac{2}{3}$, $\tan \phi = -\sqrt{5}/2$,
 $\csc \phi = 3/\sqrt{5}$, $\cot \phi = -2/\sqrt{5}$

33. $\sin \beta = -1/\sqrt{10}$, $\cos \beta = -3/\sqrt{10}$, $\tan \beta = \frac{1}{3}$,
 $\csc \beta = -\sqrt{10}$, $\sec \beta = -\sqrt{10}/3$

35. 5.73576 cm 37. 24.62147 cm

59. $\frac{1}{15}(4 + 6\sqrt{2})$

61. $\frac{1}{15}(3 + 8\sqrt{2})$

63. $\frac{24}{25}$

65. $\pi/3, 5\pi/3$

67. $\pi/4, 3\pi/4, 5\pi/4, 7\pi/4$

69. $\pi/6, \pi/2, 5\pi/6, 3\pi/2$

71. $0, \pi, 2\pi$

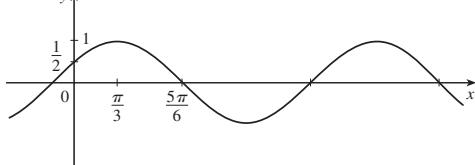
73. $0 \leq x \leq \pi/6$ and $5\pi/6 \leq x \leq 2\pi$

75. $0 \leq x < \pi/4, 3\pi/4 < x < 5\pi/4, 7\pi/4 < x \leq 2\pi$

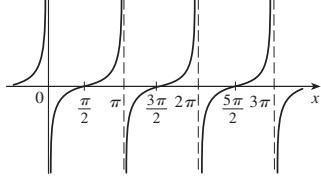
77. $\angle C = 62^\circ, a \approx 199.55, b \approx 241.52$

79. ≈ 1355 m 81. 14.34457 cm 2

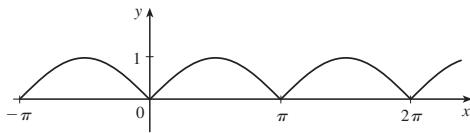
83.



85.



87.



EXERCISES E ■ PAGE A40

1. $\sqrt{1} + \sqrt{2} + \sqrt{3} + \sqrt{4} + \sqrt{5}$

3. $3^4 + 3^5 + 3^6$

5. $-1 + \frac{1}{3} + \frac{3}{5} + \frac{5}{7} + \frac{7}{9}$

7. $1^{10} + 2^{10} + 3^{10} + \dots + n^{10}$

9. $1 - 1 + 1 - 1 + \dots + (-1)^{n-1}$

11. $\sum_{i=1}^{10} i$

13. $\sum_{i=1}^{19} \frac{i}{i+1}$

15. $\sum_{i=1}^n 2i$

17. $\sum_{i=0}^5 2^i$

19. $\sum_{i=1}^n x^i$

21. 80 23. 3276 25. 0 27. 61 29. $n(n + 1)$

31. $n(n^2 + 6n + 17)/3$

33. $n(n^2 + 6n + 11)/3$

35. $n(n^3 + 2n^2 - n - 10)/4$

41. (a) n^4 (b) $5^{100} - 1$ (c) $\frac{97}{300}$ (d) $a_n - a_0$

43. $\frac{1}{3}$ 45. 14 49. $2^{n+1} + n^2 + n - 2$