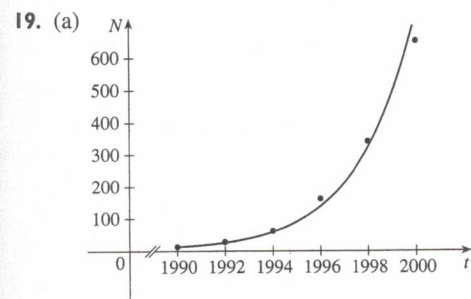
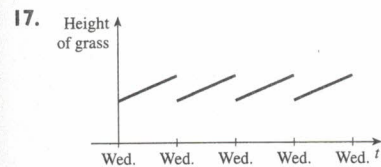
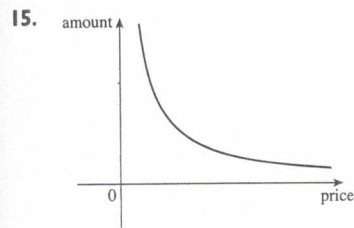
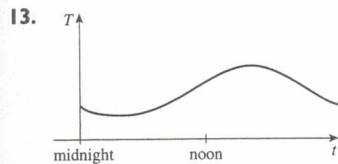
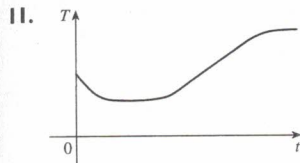


**H** ANSWERS TO ODD-NUMBERED EXERCISES

**CHAPTER 1**

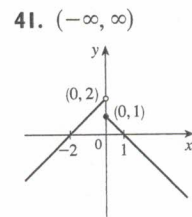
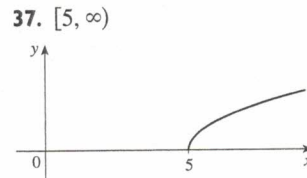
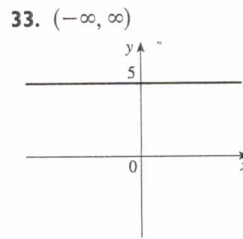
**EXERCISES 1.1 ■ PAGE 20**

1. (a) -2 (b) 2.8 (c) -3, 1 (d) -2.5, 0.3  
 (e) [-3, 3], [-2, 3] (f) [-1, 3]  
 3. [-85, 115] 5. No  
 7. Yes, [-3, 2], [-3, -2) ∪ [-1, 3]  
 9. Diet, exercise, or illness



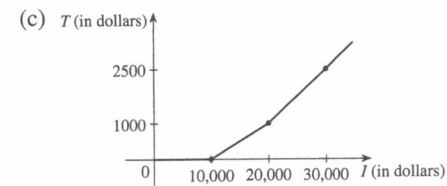
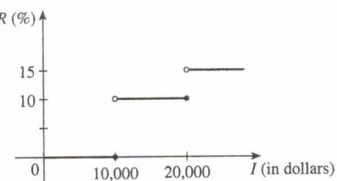
(b) In millions:  
92; 485

21. 12, 16,  $3a^2 - a + 2$ ,  $3a^2 + a + 2$ ,  $3a^2 + 5a + 4$ ,  
 $6a^2 - 2a + 4$ ,  $12a^2 - 2a + 2$ ,  $3a^4 - a^2 + 2$ ,  
 $9a^4 - 6a^3 + 13a^2 - 4a + 4$ ,  $3a^2 + 6ah + 3h^2 - a - h + 2$   
 23.  $-3 - h$  25.  $-1/(ax)$   
 27.  $\{x | x \neq \frac{1}{3}\} = (-\infty, \frac{1}{3}) \cup (\frac{1}{3}, \infty)$   
 29.  $[0, \infty)$  31.  $(-\infty, 0) \cup (5, \infty)$



45.  $f(x) = \frac{5}{2}x - \frac{11}{2}$ ,  $1 \leq x \leq 5$  47.  $f(x) = 1 - \sqrt{-x}$   
 49.  $f(x) = \begin{cases} -x + 3 & \text{if } 0 \leq x \leq 3 \\ 2x - 6 & \text{if } 3 < x \leq 5 \end{cases}$

51.  $A(L) = 10L - L^2$ ,  $0 < L < 10$   
 53.  $A(x) = \sqrt{3}x^2/4$ ,  $x > 0$  55.  $S(x) = x^2 + (8/x)$ ,  $x > 0$   
 57.  $V(x) = 4x^3 - 64x^2 + 240x$ ,  $0 < x < 6$   
 59. (a)  $R(\%)$  (b) \$400, \$1900

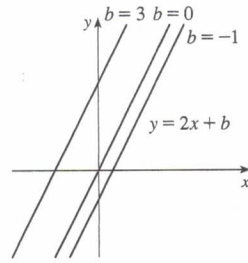


61.  $f$  is odd,  $g$  is even  
 63. (a)  $(-5, 3)$  (b)  $(-5, -3)$   
 65. Odd 67. Neither 69. Even

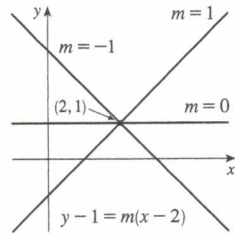
**EXERCISES 1.2 ■ PAGE 34**

1. (a) Root (b) Algebraic (c) Polynomial (degree 9)  
 (d) Rational (e) Trigonometric (f) Logarithmic  
 3. (a)  $h$  (b)  $f$  (c)  $g$

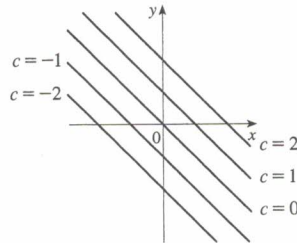
5. (a)  $y = 2x + b$ , where  $b$  is the y-intercept.



(b)  $y = mx + 1 - 2m$ , where  $m$  is the slope. See graph at right.  
 (c)  $y = 2x - 3$



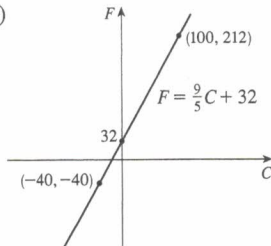
7. Their graphs have slope  $-1$ .



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

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

13. (a)



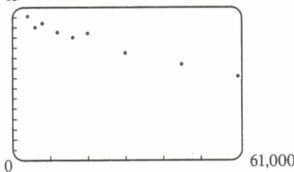
(b)  $\frac{9}{5}$ , change in  $^{\circ}\text{F}$  for every  $1^{\circ}\text{C}$  change; 32, Fahrenheit temperature corresponding to  $0^{\circ}\text{C}$

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

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

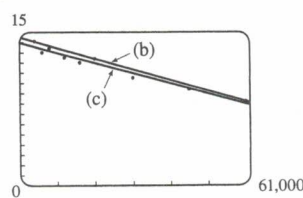
19. (a) Cosine (b) Linear

21. (a) 15



Linear model is appropriate

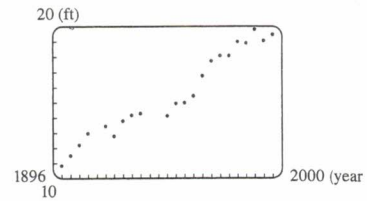
(b)  $y = -0.000105x + 14.521$



(c)  $y = -0.00009979x + 13.951$  [See graph in (b).]

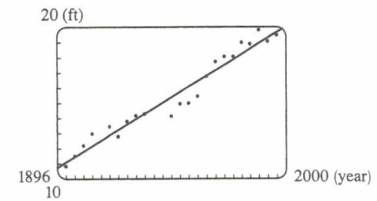
(d) About 11.5 per 100 population (e) About 6% (f) No

23. (a)



Linear model is appropriate

(b)  $y = 0.08912x - 158.24$  (c) 20 ft (d) No



25.  $y \approx 0.0012937x^3 - 7.06142x^2 + 12,823x - 7,743,770$ ; 1914 million

EXERCISES 1.3 ■ PAGE 43

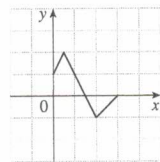
1. (a)  $y = f(x) + 3$  (b)  $y = f(x) - 3$  (c)  $y = f(x - 3)$

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

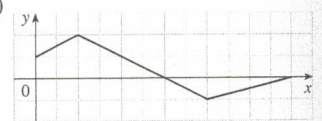
(g)  $y = 3f(x)$  (h)  $y = \frac{1}{3}f(x)$

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

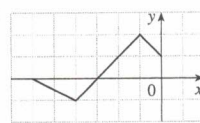
5. (a)



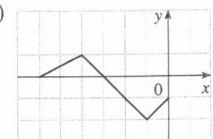
(b)



(c)

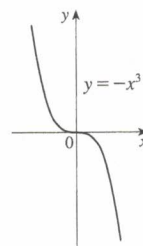


(d)

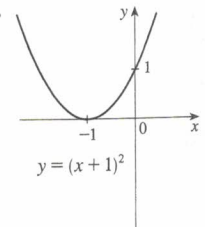


7.  $y = -\sqrt{-x^2 - 5x - 4} - 1$

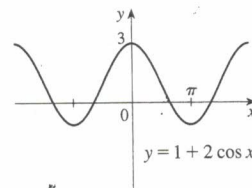
9.

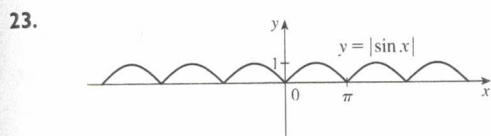
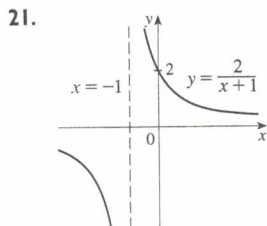
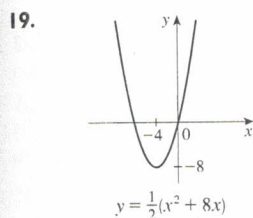
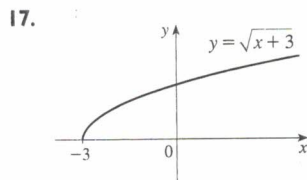
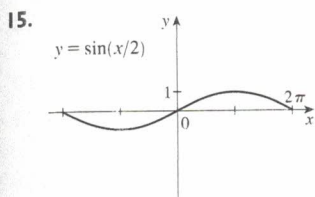


11.



13.

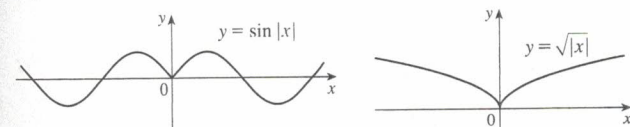




25.  $L(t) = 12 + 2 \sin\left[\frac{2\pi}{365}(t - 80)\right]$

27. (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)



29.  $(f + g)(x) = x^3 + 5x^2 - 1, (-\infty, \infty)$   
 $(f - g)(x) = x^3 - x^2 + 1, (-\infty, \infty)$   
 $(fg)(x) = 3x^5 + 6x^4 - x^3 - 2x^2, (-\infty, \infty)$   
 $(f/g)(x) = (x^3 + 2x^2)/(3x^2 - 1), \{x | x \neq \pm 1/\sqrt{3}\}$

31. (a)  $(f \circ g)(x) = 4x^2 + 4x, (-\infty, \infty)$   
 (b)  $(g \circ f)(x) = 2x^2 - 1, (-\infty, \infty)$   
 (c)  $(f \circ f)(x) = x^4 - 2x^2, (-\infty, \infty)$   
 (d)  $(g \circ g)(x) = 4x + 3, (-\infty, \infty)$

33. (a)  $(f \circ g)(x) = 1 - 3 \cos x, (-\infty, \infty)$   
 (b)  $(g \circ f)(x) = \cos(1 - 3x), (-\infty, \infty)$   
 (c)  $(f \circ f)(x) = 9x - 2, (-\infty, \infty)$   
 (d)  $(g \circ g)(x) = \cos(\cos x), (-\infty, \infty)$

35. (a)  $(f \circ g)(x) = (2x^2 + 6x + 5)/[(x + 2)(x + 1)], \{x | x \neq -2, -1\}$   
 (b)  $(g \circ f)(x) = (x^2 + x + 1)/(x + 1)^2, \{x | x \neq -1, 0\}$   
 (c)  $(f \circ f)(x) = (x^4 + 3x^2 + 1)/[x(x^2 + 1)], \{x | x \neq 0\}$   
 (d)  $(g \circ g)(x) = (2x + 3)/(3x + 5), \{x | x \neq -2, -5/3\}$

37.  $(f \circ g \circ h)(x) = 2x - 1$

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

41.  $g(x) = x^2 + 1, f(x) = x^{10}$

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

45.  $g(t) = \cos t, f(t) = \sqrt{t}$

47.  $h(x) = x^2, g(x) = 3^x, f(x) = 1 - x$

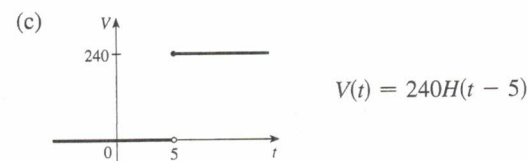
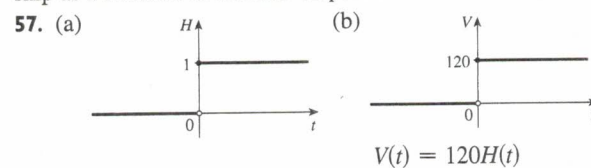
49.  $h(x) = \sqrt{x}, g(x) = \sec x, f(x) = x^4$

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

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

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

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



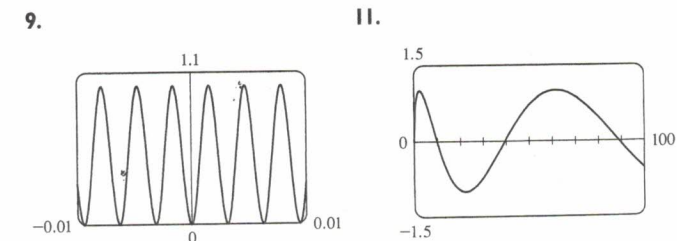
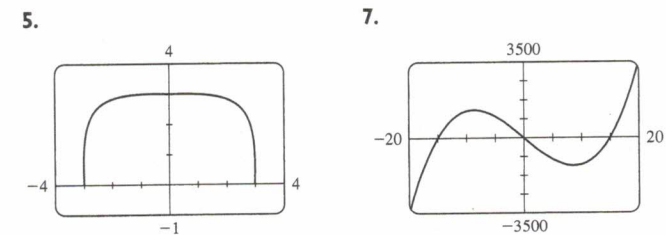
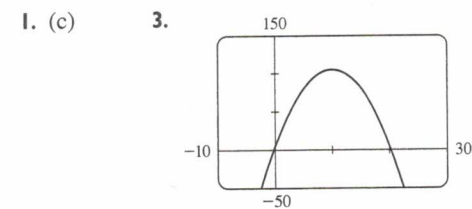
59. Yes;  $m_1 m_2$

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

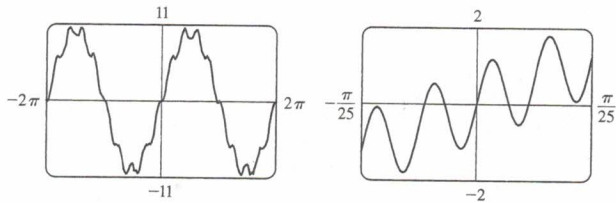
63. (a) Even; even (b) Odd; even

65. Yes

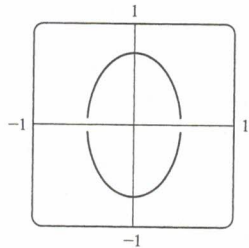
#### EXERCISES 1.4 ■ PAGE 51



13.



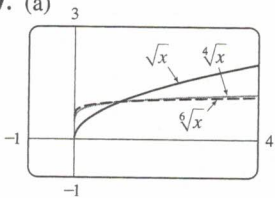
15.



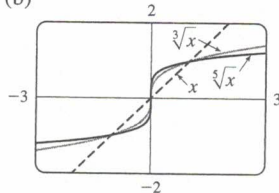
17. No    19. 9.05    21. 0, 0.88    23.  $g$

25.  $-0.85 < x < 0.85$

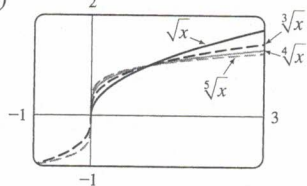
27. (a)



(b)

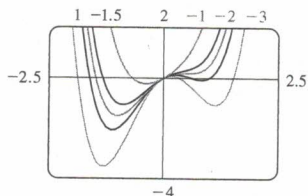


(c)



(d) Graphs of even roots are similar to  $\sqrt{x}$ , graphs of odd roots are similar to  $\sqrt[3]{x}$ . As  $n$  increases, the graph of  $y = \sqrt[n]{x}$  becomes steeper near 0 and flatter for  $x > 1$ .

29.



If  $c < -1.5$ , the graph has three humps: two minimum points and a maximum point. These humps get flatter as  $c$  increases until at  $c = -1.5$  two of the humps disappear and there is only one minimum point. This single hump then moves to the right and approaches the origin as  $c$  increases.

31. The hump gets larger and moves to the right.

33. If  $c < 0$ , the loop is to the right of the origin; if  $c > 0$ , the loop is to the left. The closer  $c$  is to 0, the larger the loop.

CHAPTER 1 REVIEW ■ PAGE 52

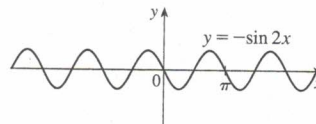
True-False Quiz

1. False    3. False    5. True

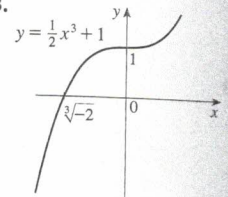
Exercises

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.  $\mathbb{R}, [0, 2]$   
 9. (a) Shift the graph 8 units upward.  
 (b) Shift the graph 8 units to the left.  
 (c) Stretch the graph vertically by a factor of 2, then shift it 1 unit upward.  
 (d) Shift the graph 2 units to the right and 2 units downward.  
 (e) Reflect the graph about the  $x$ -axis.  
 (f) Reflect the graph about the line  $x$ -axis, then shift it 3 units upward.

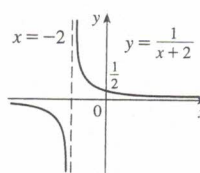
11.



13.



15.



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

19. (a)  $(f \circ g)(x) = \sqrt{\sin x}$ ,  $\{x \mid x \in [2n\pi, \pi + 2n\pi], n \text{ an integer}\}$

(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. All have domain  $\mathbb{R}$ . The range is  $[-1, 1]$  for  $n$  odd and  $[0, 1]$  for  $n$  even. The spikes become sharper as  $n \rightarrow \infty$ .

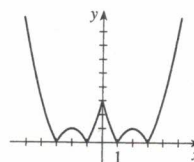
23.  $y = 0.2493x - 423.4818$ ; about 77.6 years

PRINCIPLES OF PROBLEM SOLVING ■ PAGE 59

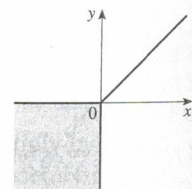
1.  $a = 4\sqrt{h^2 - 16}/h$ , where  $a$  is the length of the altitude and  $h$  is the length of the hypotenuse

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

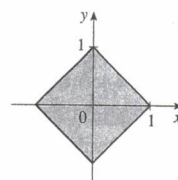
5.



7.



9.



11. 40 mi/h

15.  $f_n(x) = x^{2n+1}$

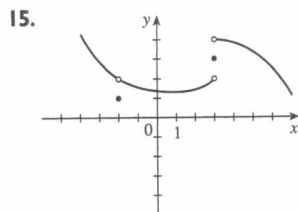
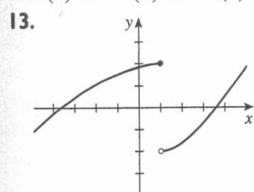
CHAPTER 2

EXERCISES 2.1 ■ PAGE 65

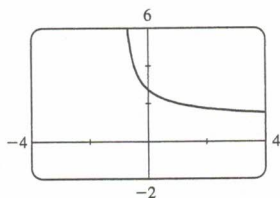
1. (a)  $-44.4, -38.8, -27.8, -22.2, -16.6$   
 (b)  $-33.3$  (c)  $-33\frac{1}{3}$   
 3. (a) (i) 0.333333 (ii) 0.263158 (iii) 0.251256  
 (iv) 0.250125 (v) 0.2 (vi) 0.238095 (vii) 0.248756  
 (viii) 0.249875 (b)  $\frac{1}{4}$  (c)  $y = \frac{1}{4}x + \frac{1}{4}$   
 5. (a) (i)  $-32$  ft/s (ii)  $-25.6$  ft/s (iii)  $-24.8$  ft/s  
 (iv)  $-24.16$  ft/s (b)  $-24$  ft/s  
 7. (a) (i) 4.65 m/s (ii) 5.6 m/s (iii) 7.55 m/s  
 (iv) 7 m/s (b) 6.3 m/s  
 9. (a) 0, 1.7321,  $-1.0847, -2.7433, 4.3301, -2.8173, 0,$   
 $-2.1651, -2.6061, -5, 3.4202$ ; no (c)  $-31.4$

EXERCISES 2.2 ■ PAGE 74

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) 3 (c) Does not exist (d) 4  
 (e) Does not exist  
 7. (a)  $-1$  (b)  $-2$  (c) Does not exist (d) 2 (e) 0  
 (f) Does not exist (g) 1 (h) 3  
 9. (a)  $-\infty$  (b)  $\infty$  (c)  $\infty$  (d)  $-\infty$  (e)  $\infty$   
 (f)  $x = -7, x = -3, x = 0, x = 6$   
 11. (a) 1 (b) 0 (c) Does not exist



17.  $\frac{2}{3}$  19.  $\frac{1}{2}$  21.  $\frac{1}{4}$  23.  $\frac{3}{5}$  25.  $-\infty$   
 27.  $\infty$  29.  $-\infty$  31.  $-\infty$  33.  $-\infty; \infty$   
 35. (a) 2.71828 (b)

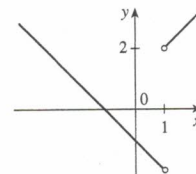


37. (a) 0.998000, 0.638259, 0.358484, 0.158680, 0.038851, 0.008928, 0.001465; 0  
 (b) 0.000572,  $-0.000614, -0.000907, -0.000978, -0.000993,$   
 $-0.001000; -0.001$   
 39. No matter how many times we zoom in toward the origin, the graph appears to consist of almost-vertical lines. This indicates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

EXERCISES 2.3 ■ PAGE 84

1. (a)  $-6$  (b)  $-8$  (c) 2 (d)  $-6$   
 (e) Does not exist (f) 0  
 3. 59 5. 390 7.  $\frac{1}{8}$  9. 0 11. 5  
 13. Does not exist 15.  $\frac{6}{5}$  17. 8 19.  $\frac{1}{12}$  21. 6  
 23.  $\frac{1}{6}$  25.  $-\frac{1}{16}$  27.  $\frac{1}{128}$  29.  $-\frac{1}{2}$  31. (a), (b)  $\frac{2}{3}$   
 35. 7 39. 6 41.  $-4$  43. Does not exist  
 45. (a) (b) (i) 1  
 (ii)  $-1$   
 (iii) Does not exist  
 (iv) 1

47. (a) (i) 2 (ii)  $-2$  (b) No (c)



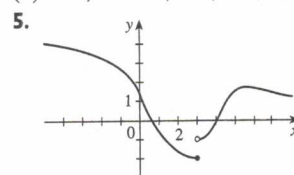
49. (a) (i)  $-2$  (ii) Does not exist (iii)  $-3$   
 (b) (i)  $n - 1$  (ii)  $n$  (c)  $a$  is not an integer.  
 55. 8 61. 15;  $-1$

EXERCISES 2.4 ■ PAGE 95

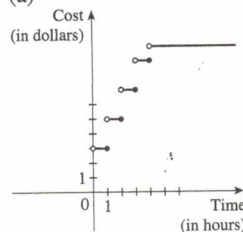
1.  $\frac{4}{7}$  (or any smaller positive number)  
 3. 1.44 (or any smaller positive number)  
 5. 0.0906 (or any smaller positive number)  
 7. 0.11, 0.012 (or smaller positive numbers)  
 9. (a) 0.031 (b) 0.010  
 11. (a)  $\sqrt{1000/\pi}$  cm (b) Within approximately 0.0445 cm  
 (c) Radius; area;  $\sqrt{1000/\pi}; 1000; 5; \approx 0.0445$   
 13. (a) 0.025 (b) 0.0025  
 35. (a) 0.093 (b)  $\delta = (B^{2/3} - 12)/(6B^{1/3}) - 1$ , where  
 $B = 216 + 108\epsilon + 12\sqrt{336 + 324\epsilon + 81\epsilon^2}$   
 41. Within 0.1

EXERCISES 2.5 ■ PAGE 105

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

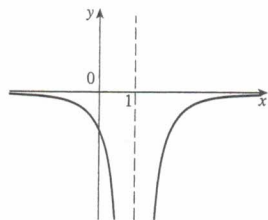


7. (a) (b) Discontinuous at  $t = 1, 2, 3, 4$

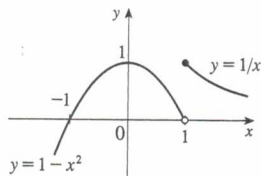


9. 6

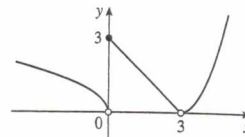
15.  $f(1)$  is not defined.



17.  $\lim_{x \rightarrow 1} f(x)$  does not exist.



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

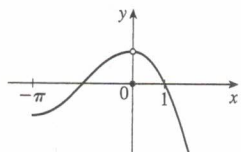


25.  $[0, \infty)$  29. 0

PROBLEMS PLUS = PAGE 110

1.  $\frac{2}{3}$  3. -4 5. (a) Does not exist. (b) 1  
7.  $a = \frac{1}{2} \pm \frac{1}{2}\sqrt{5}$   
9.  $\frac{3}{4}$  11. (b) Yes (c) Yes; no

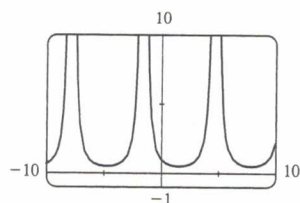
19.  $\lim_{x \rightarrow 0} f(x) \neq f(0)$



21.  $\{x \mid x \neq -3, -2\}$  23.  $[\frac{1}{2}, \infty)$

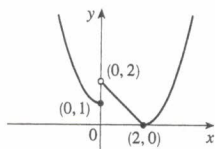
25.  $\mathbb{R}$  27.  $[0, \infty)$

29.  $x = (-\pi/2) + 2n\pi, n$  an integer

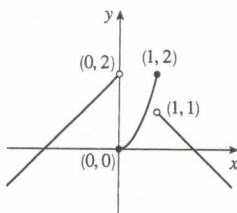


31.  $\frac{7}{3}$  33.  $\pi/8$

37. 0, left



39. 0, right; 1, left



41.  $\frac{2}{3}$

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

51. (b) (0.86, 0.87) 53. (b) 1.434

59. None 61. Yes

CHAPTER 2 REVIEW = PAGE 108

True-False Quiz

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

Exercises

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

(b)  $x = 0, x = 2$  (c) -3, 0, 2, 4

3. 1 5.  $\frac{3}{2}$  7. 3 9.  $\infty$  11.  $\frac{4}{7}$  13.  $-\frac{1}{8}$

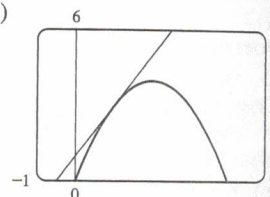
15. 0 17. 1

CHAPTER 3

EXERCISES 3.1 = PAGE 119

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

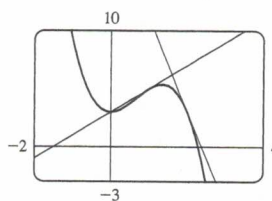
3. (a) 2 (b)  $y = 2x + 1$  (c)



5.  $y = -x + 5$  7.  $y = \frac{1}{2}x + \frac{1}{2}$

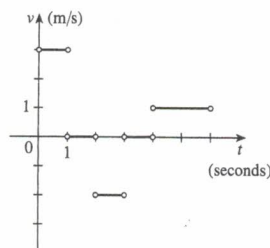
9. (a)  $8a - 6a^2$  (b)  $y = 2x + 3, y = -8x + 19$

(c)



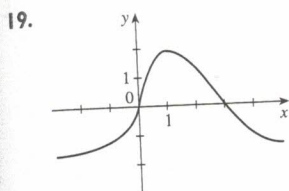
11. (a) Right:  $0 < t < 1$  and  $4 < t < 6$ ; left:  $2 < t < 3$ ;  
standing still:  $1 < t < 2$  and  $3 < t < 4$

(b)

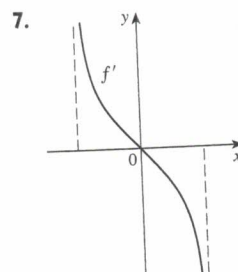
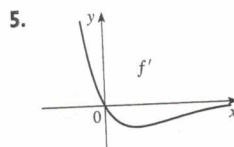


13. -24 ft/s 15.  $-2/a^3$  m/s; -2 m/s;  $-\frac{1}{4}$  m/s;  $-\frac{2}{27}$  m/s

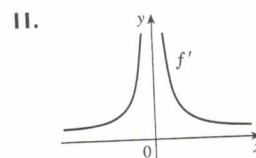
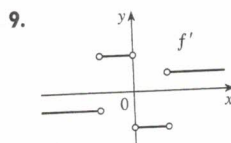
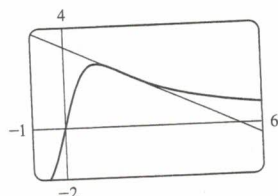
17.  $g'(0), 0, g'(4), g'(2), g'(-2)$



21.  $7; y = 7x - 12$



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



25.  $-2 + 8a$     27.  $\frac{5}{(a+3)^2}$     29.  $\frac{-1}{2(a+2)^{3/2}}$

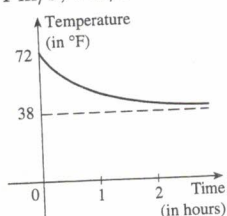
31.  $f(x) = x^{10}, a = 1$  or  $f(x) = (1+x)^{10}, a = 0$

33.  $f(x) = 2^x, a = 5$

35.  $f(x) = \cos x, a = \pi$  or  $f(x) = \cos(\pi + x), a = 0$

37. 1 m/s; 1 m/s

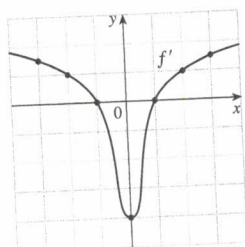
39. Greater (in magnitude)



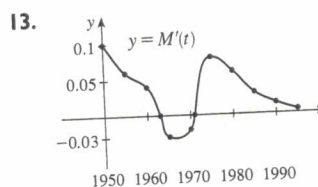
41. (a) (i) 11 percent/year    (ii) 13 percent/year  
 (iii) 16 percent/year  
 (b) 14.5 percent/year    (c) 15 percent/year  
 43. (a) (i) \$20.25/unit    (ii) \$20.05/unit    (b) \$20/unit  
 45. (a) The rate at which the cost is changing per ounce of gold produced; dollars per ounce  
 (b) When the 800th ounce of gold is produced, the cost of production is \$17/oz.  
 (c) Decrease in the short term; increase in the long term  
 47. The rate at which the temperature is changing at 10:00 AM; 4°F/h  
 49. (a) The rate at which the oxygen solubility changes with respect to the water temperature; (mg/L)/°C  
 (b)  $S'(16) \approx -0.25$ ; as the temperature increases past 16°C, the oxygen solubility is decreasing at a rate of 0.25 (mg/L)/°C.  
 51. Does not exist

EXERCISES 3.2 ■ PAGE 131

1. (a) 1.5  
 (b) 1  
 (c) 0  
 (d) -4  
 (e) 0  
 (f) 1  
 (g) 1.5



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

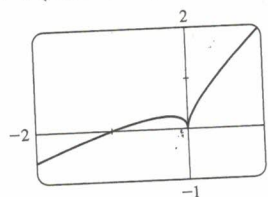


1963 to 1971

15. (a) 0, 1, 2, 4    (b) -1, -2, -4    (c)  $f'(x) = 2x$   
 17.  $f'(x) = \frac{1}{2}, \mathbb{R}, \mathbb{R}$     19.  $f'(t) = 5 - 18t, \mathbb{R}, \mathbb{R}$   
 21.  $f'(x) = 3x^2 - 3, \mathbb{R}, \mathbb{R}$   
 23.  $g'(x) = 1/\sqrt{1+2x}, [-\frac{1}{2}, \infty), (-\frac{1}{2}, \infty)$   
 25.  $G'(t) = \frac{4}{(t+1)^2}, (-\infty, -1) \cup (-1, \infty), (-\infty, -1) \cup (-1, \infty)$   
 27.  $f'(x) = 4x^3, \mathbb{R}, \mathbb{R}$     29. (a)  $f'(x) = 4x^3 + 2$   
 31. (a) The rate at which the unemployment rate is changing, in percent unemployed per year  
 (b)

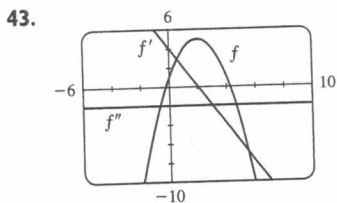
$t$	$U'(t)$	$t$	$U'(t)$
1993	-0.80	1998	-0.35
1994	-0.65	1999	-0.25
1995	-0.35	2000	0.25
1996	-0.35	2001	0.90
1997	-0.45	2002	1.10

33. -4 (corner); 0 (discontinuity)  
 35. -1 (vertical tangent); 4 (corner)  
 37.

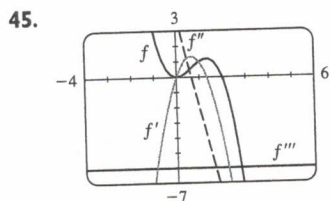


Differentiable at -1;  
 not differentiable at 0

39.  $a = f', b = f', c = f''$   
 41.  $a =$  acceleration,  $b =$  velocity,  $c =$  position



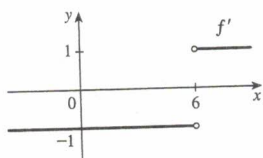
43.  $f'(x) = 4 - 2x,$   
 $f''(x) = -2$



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

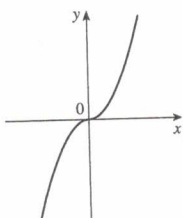
47. (a)  $\frac{1}{3}a^{-2/3}$

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



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

51. (a)



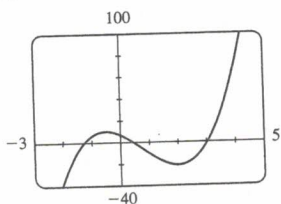
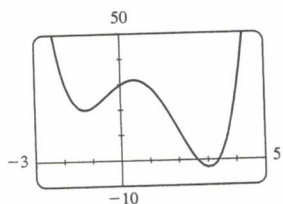
(b) All  $x$   
(c)  $f'(x) = 2|x|$

55.  $63^\circ$

EXERCISES 3.3 ■ PAGE 144

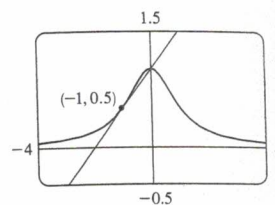
1.  $f'(x) = 0$     3.  $f'(t) = -\frac{2}{3}$     5.  $f'(x) = 3x^2 - 4$   
7.  $f'(t) = t^3$     9.  $V'(r) = 4\pi r^2$     11.  $Y'(t) = -54t^{-10}$   
13.  $F'(x) = \frac{5}{32}x^4$     15.  $A'(s) = 60/s^6$     17.  $y' = 0$   
19.  $u' = \frac{1}{5}t^{-4/5} + 10t^{3/2}$     21.  $y' = 5x^4 + 3x^2 + 2x$   
23.  $V'(x) = 14x^6 - 4x^3 - 6$     25.  $F'(y) = 5 + 14/y^2 + 9/y^4$   
27.  $g'(x) = 5/(2x + 1)^2$     29.  $y' = \frac{x^2(3 - x^2)}{(1 - x^2)^2}$   
31.  $y' = 2v - 1/\sqrt{v}$     33.  $y' = \frac{2t(-t^4 - 4t^2 + 7)}{(t^4 - 3t^2 + 1)^2}$

35.  $y' = 2ax + b$     37.  $y' = \frac{r(4 + 3\sqrt{r})}{2(1 + \sqrt{r})^2}$   
39.  $y' = (7t^3 + 4t^2 - 2)/(3t^{5/3})$     41.  $f'(x) = 2cx/(x^2 + c)^2$   
43.  $P'(x) = na_nx^{n-1} + (n-1)a_{n-1}x^{n-2} + \dots + 2a_2x + a_1$   
45.  $45x^{14} - 15x^2$   
47. (a) (c)  $4x^3 - 9x^2 - 12x + 7$



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

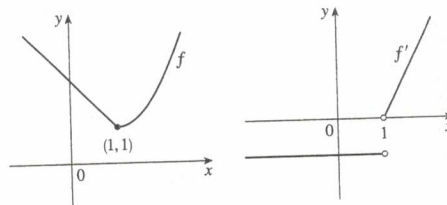
51. (a)  $y = \frac{1}{2}x + 1$  (b)



53.  $y = \frac{3}{2}x + \frac{1}{2}, y = -\frac{2}{3}x + \frac{8}{3}$     55.  $y = -\frac{1}{2}x + \frac{5}{2}, y = 2x$   
57.  $f'(x) = 4x^3 - 9x^2 + 16, f''(x) = 12x^2 - 18x$

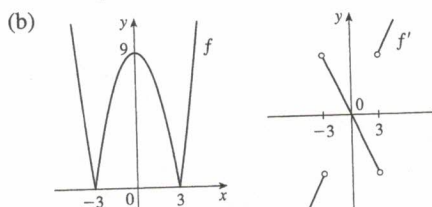
59.  $\frac{2x^2 + 2x}{(1 + 2x)^2}, \frac{2}{(1 + 2x)^3}$   
61. (a)  $v(t) = 3t^2 - 3, a(t) = 6t$  (b) 12 m/s<sup>2</sup>  
(c)  $a(1) = 6 \text{ m/s}^2$

63. (a) -16 (b)  $-\frac{20}{9}$  (c) 20  
65. 16    67. (a) 0 (b)  $-\frac{2}{3}$   
69. (a)  $y' = xg'(x) + g(x)$  (b)  $y' = [g(x) - xg'(x)]/[g(x)]^2$   
(c)  $y' = [xg'(x) - g(x)]/x^2$   
71. (-2, 21), (1, -6)    75.  $y = 12x - 15, y = 12x + 17$   
77.  $y = \frac{1}{3}x - \frac{1}{3}$     79. ( $\pm 2, 4$ )  
81. (c)  $3(x^4 + 3x^3 + 17x + 82)^2(4x^3 + 9x^2 + 17)$   
83.  $P(x) = x^2 - x + 3$     85.  $y = \frac{3}{16}x^3 - \frac{9}{4}x + 3$   
87. \$1.627 billion/year  
89. No



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

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



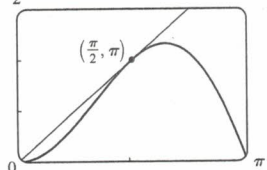
93.  $a = -\frac{1}{2}, b = 2$     95. 6    99. 1000    101. 3, 1

EXERCISES 3.4 ■ PAGE 154

1.  $f'(x) = 6x + 2 \sin x$     3.  $f'(x) = \cos x - \frac{1}{2} \csc^2 x$   
5.  $g'(t) = 3t^2 \cos t - t^3 \sin t$   
7.  $h'(\theta) = \csc \theta - \theta \csc \theta \cot \theta + \csc^2 \theta$   
9.  $y' = \frac{2 - \tan x + x \sec^2 x}{(2 - \tan^4 x)^2}$     11.  $f'(\theta) = \frac{\sec \theta \tan \theta}{(1 + \sec \theta)^2}$   
13.  $y' = (x \cos x - 2 \sin x)/x^3$     15.  $y' = \sec \theta (\sec^2 \theta + \tan^2 \theta)$   
21.  $y = 2\sqrt{3}x - \frac{2}{3}\sqrt{3}\pi + 2$     23.  $y = x + 1$



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



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

29.  $\theta \cos \theta + \sin \theta; 2 \cos \theta - \theta \sin \theta$

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

33.  $(2n + 1)\pi \pm \frac{1}{3}\pi, n$  an integer

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

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

37. 5 ft/rad 39. 3 41. 3 43.  $\sin 1$

45.  $\frac{1}{2}$  47.  $-\sqrt{2}$

49. (a)  $\sec^2 x = 1/\cos^2 x$  (b)  $\sec x \tan x = (\sin x)/\cos^2 x$

(c)  $\cos x - \sin x = (\cot x - 1)/\csc x$

51. 1

## EXERCISES 3.5 = PAGE 161

1.  $4 \cos 4x$  3.  $-20x(1 - x^2)^9$  5.  $\frac{\cos x}{2\sqrt{\sin x}}$

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

9.  $F'(x) = \frac{2 + 3x^2}{4(1 + 2x + x^3)^{3/4}}$  11.  $g'(t) = -\frac{12t^3}{(t^4 + 1)^4}$

13.  $y' = -3x^2 \sin(a^3 + x^3)$  15.  $y' = \sec kx(kx \tan kx + 1)$

17.  $g'(x) = 4(1 + 4x)^4(3 + x - x^2)^7(17 + 9x - 21x^2)$

19.  $y' = 8(2x - 5)^3(8x^2 - 5)^{-4}(-4x^2 + 30x - 5)$

21.  $y' = \frac{-12x(x^2 + 1)^2}{(x^2 - 1)^4}$

23.  $y' = (\cos x - x \sin x) \cos(x \cos x)$

25.  $F'(z) = 1/[(z - 1)^{1/2}(z + 1)^{3/2}]$

27.  $y' = (r^2 + 1)^{-3/2}$  29.  $y' = 2 \cos(\tan 2x) \sec^2(2x)$

31.  $y' = (x \cos \sqrt{1 + x^2})/\sqrt{1 + x^2}$  33.  $y' = 4 \sec^2 x \tan x$

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

37.  $y' = -2 \cos \theta \cot(\sin \theta) \csc^2(\sin \theta)$

39.  $y' = 3[x^2 + (1 - 3x)^5]^2[2x - 15(1 - 3x)^4]$

41.  $y' = \frac{1 + 1/(2\sqrt{x})}{2\sqrt{x} + \sqrt{x}}$

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

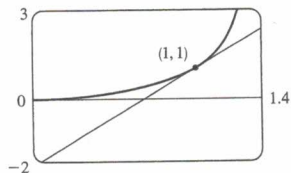
45.  $y' = \frac{-\pi \cos(\tan \pi x) \sec^2(\pi x) \sin \sqrt{\sin(\tan \pi x)}}{2\sqrt{\sin(\tan \pi x)}}$

47.  $h'(x) = x/\sqrt{x^2 + 1}, h''(x) = 1/(x^2 + 1)^{3/2}$

49.  $H'(t) = 3 \sec^2 3t, H''(t) = 18 \sec^2 3t \tan 3t$

51.  $y = 20x + 1$  53.  $y = -x + \pi$

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



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

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

61. 24

63. (a) 30 (b) 36

65. (a)  $\frac{3}{4}$  (b) Does not exist (c) -2

67. (a)  $F'(x) = -\sin x f'(\cos x)$  (b)  $G'(x) = -\sin(f(x))f'(x)$

69. 120 71. 96 73.  $2^{103} \sin 2x$

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

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

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

81. (b) The factored form

85. (b)  $-n \cos^{n-1} x \sin[(n + 1)x]$

## EXERCISES 3.6 = PAGE 169

1. (a)  $y' = -(y + 2 + 6x)/x$

(b)  $y = (4/x) - 2 - 3x, y' = -(4/x^2) - 3$

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

5.  $y' = -x^2/y^2$

7.  $y' = \frac{2x + y}{2y - x}$  9.  $y' = \frac{3y^2 - 5x^4 - 4x^3y}{x^4 + 3y^2 - 6xy}$

11.  $y' = \frac{-2xy^2 - \sin y}{2x^2y + x \cos y}$  13.  $y' = \tan x \tan y$

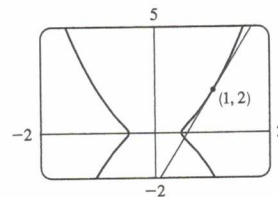
15.  $y' = \frac{y \sec^2(x/y) - y^2}{y^2 + x \sec^2(x/y)}$  17.  $y' = \frac{4xy\sqrt{xy} - y}{x - 2x^2\sqrt{xy}}$

19.  $y' = \frac{y \sin x + y \cos(xy)}{\cos x - x \cos(xy)}$  21.  $-\frac{16}{13}$

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

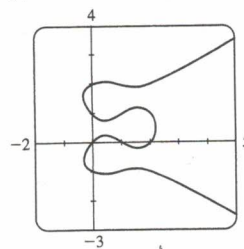
27.  $y = x + \frac{1}{2}$  29.  $y = -\frac{9}{13}x + \frac{40}{13}$

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



33.  $-81/y^3$  35.  $-2x/y^5$

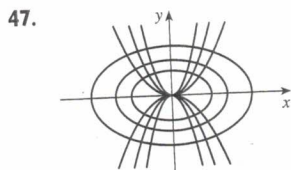
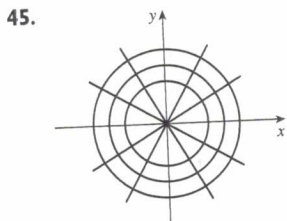
37. (a)



Eight;  $x \approx 0.42, 1.58$

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

39.  $(\pm \frac{5}{4}\sqrt{3}, \pm \frac{5}{4})$  41.  $(x_0/a^2) - (y_0/b^2) = 1$

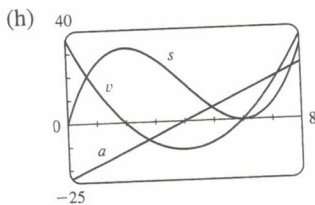
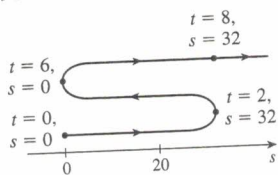


49.  $(\pm\sqrt{3}, 0)$     51.  $(-1, -1), (1, 1)$     53. 2

EXERCISES 3.7 ■ PAGE 179

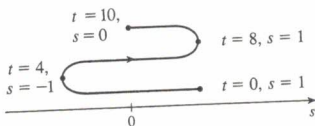
1. (a)  $3t^2 - 24t + 36$     (b)  $-9$  ft/s    (c)  $t = 2, 6$   
 (d)  $0 \leq t < 2, t > 6$   
 (e) 96 ft  
 (f)

(g)  $6t - 24; -6$  m/s<sup>2</sup>

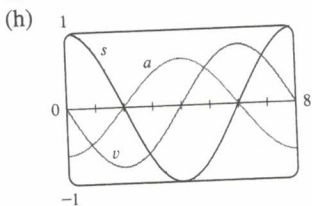


- (i) Speeding up when  $2 < t < 4$  or  $t > 6$ ;  
 slowing down when  $0 \leq t < 2$  or  $4 < t < 6$

3. (a)  $-\frac{\pi}{4} \sin\left(\frac{\pi t}{4}\right)$     (b)  $-\frac{1}{8}\pi\sqrt{2}$  ft/s    (c)  $t = 0, 4, 8$   
 (d)  $4 < t < 8$     (e) 4 ft



(g)  $-\frac{1}{16}\pi^2 \cos(\pi t/4); \frac{1}{32}\pi^2\sqrt{2}$  ft/s<sup>2</sup>



- (i) Speeding up when  $0 < t < 2, 4 < t < 6, 8 < t < 10$ ;  
 slowing down when  $2 < t < 4, 6 < t < 8$

5. (a) Speeding up when  $0 < t < 1$  or  $2 < t < 3$ ;  
 slowing down when  $1 < t < 2$   
 (b) Speeding up when  $1 < t < 2$  or  $3 < t < 4$ ;  
 slowing down when  $0 < t < 1$  or  $2 < t < 3$

7. (a)  $t = 4$  s  
 (b)  $t = 1.5$  s; the velocity has an absolute minimum.  
 9. (a) 5.02 m/s    (b)  $\sqrt{17}$  m/s

11. (a) 30 mm<sup>2</sup>/mm; the rate at which the area is increasing with respect to side length as  $x$  reaches 15 mm  
 (b)  $\Delta A \approx 2x \Delta x$

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

15. (a) 8π ft<sup>2</sup>/ft    (b) 16π ft<sup>2</sup>/ft    (c) 24π ft<sup>2</sup>/ft  
 The rate increases as the radius increases.

17. (a) 6 kg/m    (b) 12 kg/m    (c) 18 kg/m  
 At the right end; at the left end

19. (a) 4.75 A    (b) 5 A;  $t = \frac{2}{3}$  s

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

23. (a) 16 million/year; 78.5 million/year  
 (b)  $P(t) = at^3 + bt^2 + ct + d$ , where  $a \approx 0.00129371$ ,  
 $b \approx -7.061422$ ,  $c \approx 12,822.979$ ,  $d \approx -7,743,770$   
 (c)  $P'(t) = 3at^2 + 2bt + c$   
 (d) 14.48 million/year; 75.29 million/year (smaller)  
 (e) 81.62 million/year

25. (a) 0.926 cm/s; 0.694 cm/s; 0  
 (b) 0;  $-92.6$  (cm/s)/cm;  $-185.2$  (cm/s)/cm  
 (c) At the center; at the edge

27. (a)  $C'(x) = 12 - 0.2x + 0.0015x^2$   
 (b) \$32/yd; the cost of producing the 201st yard  
 (c) \$32.20

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

31.  $-0.2436$  K/min

33. (a) 0 and 0    (b)  $C = 0$

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

EXERCISES 3.8 ■ PAGE 186

1.  $dV/dt = 3x^2 dx/dt$     3. 48 cm<sup>2</sup>/s    5.  $3/(25\pi)$  m/min

7. 70    9.  $\pm \frac{46}{13}$

11. (a) The plane's altitude is 1 mi and its speed is 500 mi/h.  
 (b) The rate at which the distance from the plane to the station is increasing when the plane is 2 mi from the station

- (c)    (d)  $y^2 = x^2 + 1$   
 (e)  $250\sqrt{3}$  mi/h

13. (a) The height of the pole (15 ft), the height of the man (6 ft), and the speed of the man (5 ft/s)  
 (b) The rate at which the tip of the man's shadow is moving when he is 40 ft from the pole

- (c)    (d)  $\frac{15}{6} = \frac{x+y}{y}$     (e)  $\frac{25}{3}$  ft/s

15. 65 mi/h    17.  $837/\sqrt{8674} \approx 8.99$  ft/s

19.  $-1.6$  cm/min    21.  $\frac{720}{13} \approx 55.4$  km/h

23.  $(10,000 + 800,000\pi/9) \approx 2.89 \times 10^5$  cm<sup>3</sup>/min

25.  $\frac{10}{3}$  cm/min    27.  $6/(5\pi) \approx 0.38$  ft/min    29. 0.3 m<sup>2</sup>/s

31. 80 cm<sup>3</sup>/min    33.  $\frac{107}{810} \approx 0.132$  Ω/s    35. 0.396 m/min

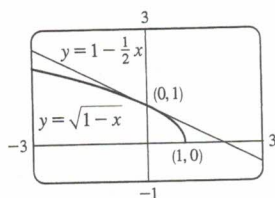
37. (a) 360 ft/s    (b) 0.096 rad/s    39.  $\frac{10}{9}\pi$  km/min

41.  $1650/\sqrt{31} \approx 296$  km/h    43.  $\frac{7}{4}\sqrt{15} \approx 6.78$  m/s

EXERCISES 3.9 = PAGE 193

1.  $L(x) = -10x - 6$     3.  $L(x) = -x + \pi/2$

5.  $\sqrt{1-x} \approx 1 - \frac{1}{2}x$ ;  
 $\sqrt{0.9} \approx 0.95$ ,  
 $\sqrt{0.99} \approx 0.995$



7.  $-1.204 < x < 0.706$     9.  $-0.045 < x < 0.055$

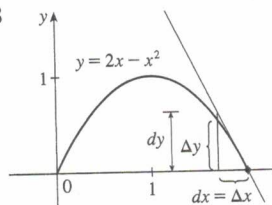
11. (a)  $dy = 2x(x \cos 2x + \sin 2x) dx$     (b)  $dy = \frac{t}{\sqrt{1+t^2}} dt$

13. (a)  $dy = \frac{-2}{(u-1)^2} du$     (b)  $dy = -\frac{6r^2}{(1+r^3)^3} dr$

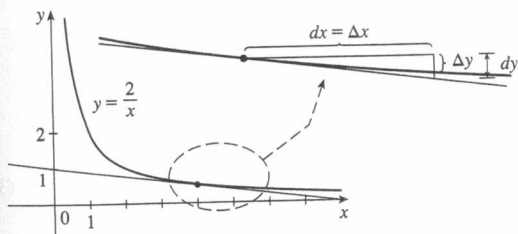
15. (a)  $dy = 5/(2\sqrt{4+5x}) dx$     (b) 0.05

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

19.  $\Delta y = 0.64, dy = 0.8$



21.  $\Delta y = -0.1, dy = -0.125$



23. 32.08    25. 4.02    27.  $1 - \pi/90 \approx 0.965$

31. (a) 270 cm<sup>3</sup>, 0.01, 1%    (b) 36 cm<sup>3</sup>, 0.006, 0.6%

33. (a)  $84/\pi \approx 27$  cm<sup>2</sup>;  $\frac{1}{84} \approx 0.012$

(b)  $1764/\pi^2 \approx 179$  cm<sup>3</sup>;  $\frac{1}{56} \approx 0.018$

35. (a)  $2\pi rh \Delta r$     (b)  $\pi(\Delta r)^2 h$

41. (a) 4.8, 5.2    (b) Too large

CHAPTER 3 REVIEW = PAGE 196

True-False Quiz

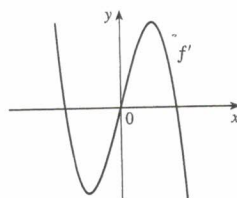
I. False    3. False    5. True    7. False    9. True

11. False

Exercises

I. (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

3.



5.  $a = f, c = f', b = f''$

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. The rate at which the total value of US currency in circulation is changing in billions of dollars per year; \$22.2 billion/year

11.  $f'(x) = 3x^2 + 5$     13.  $6x(x^4 - 3x^2 + 5)^2(2x^2 - 3)$

15.  $\frac{1}{2\sqrt{x}} - \frac{4}{3\sqrt[3]{x^7}}$     17.  $\frac{2(2x^2 + 1)}{\sqrt{x^2 + 1}}$     19.  $\frac{t^2 + 1}{(1 - t^2)^2}$

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

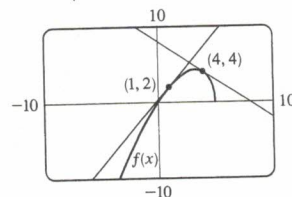
39.  $\cos(\tan \sqrt{1+x^3})(\sec^2 \sqrt{1+x^3}) \frac{3x^2}{2\sqrt{1+x^3}}$     41.  $-\frac{4}{27}$

43.  $-5x^4/y^{11}$     45. 1    47.  $y = 2\sqrt{3}x + 1 - \pi\sqrt{3}/3$

49.  $y = 2x + 1$

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) 2    (b) 44    61.  $2xg(x) + x^2g'(x)$     63.  $2g(x)g'(x)$

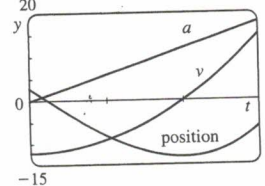
65.  $f'(x) = g'(g(x))g'(x)$     67.  $f'(x) = g'(\sin x) \cdot \cos x$

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

71.  $f'(g(\sin 4x))g'(\sin 4x)(\cos 4x)(4)$

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.  $\frac{4}{3}$  cm<sup>2</sup>/min    79. 13 ft/s    81. 400 ft/h

83. (a)  $L(x) = 1 + x; \sqrt[3]{1 + 3x} \approx 1 + x; \sqrt[3]{1.03} \approx 1.01$   
 (b)  $-0.23 < x < 0.40$   
 85.  $12 + \frac{3}{2}\pi \approx 16.7 \text{ cm}^2$     87.  $\frac{1}{32}$     89.  $\frac{1}{4}$     91.  $\frac{1}{8}x^2$

PROBLEMS PLUS ■ PAGE 200

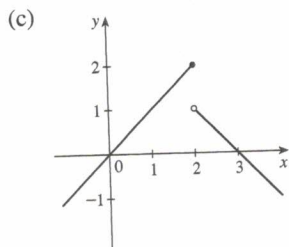
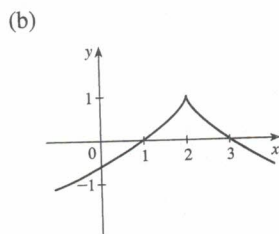
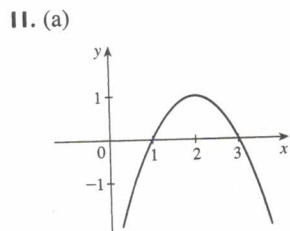
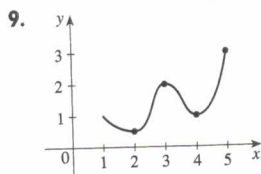
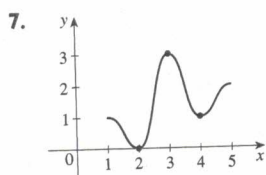
1.  $(\pm\frac{1}{2}\sqrt{3}, \frac{1}{4})$   
 5. (a) 0    (b) 1    (c)  $f'(x) = x^2 + 1$   
 9.  $(0, \frac{5}{4})$   
 11. (a)  $4\pi\sqrt{3}/\sqrt{11} \text{ rad/s}$     (b)  $40(\cos\theta + \sqrt{8 + \cos^2\theta}) \text{ cm}$   
 (c)  $-480\pi \sin\theta(1 + \cos\theta/\sqrt{8 + \cos^2\theta}) \text{ cm/s}$   
 13.  $x_T \in (3, \infty), y_T \in (2, \infty), x_N \in (0, \frac{5}{3}), y_N \in (-\frac{5}{2}, 0)$   
 15. (b) (i)  $53^\circ$  (or  $127^\circ$ )    (ii)  $63^\circ$  (or  $117^\circ$ )  
 17.  $R$  approaches the midpoint of the radius  $AO$ .  
 19.  $-\sin a$     21.  $(1, -2), (-1, 0)$   
 23.  $\sqrt{29}/58$     25.  $2 + \frac{375}{128}\pi \approx 11.204 \text{ cm}^3/\text{min}$

CHAPTER 4

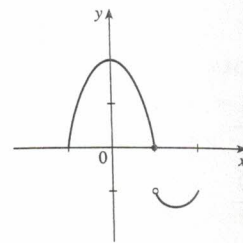
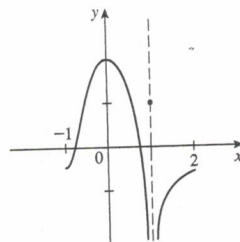
EXERCISES 4.1 ■ PAGE 211

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

1. Absolute minimum: smallest function value on the entire domain of the function; local minimum 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  $r$   
 5. Abs. max.  $f(4) = 5$ , loc. max.  $f(4) = 5$  and  $f(6) = 4$ , loc. min.  $f(2) = 2$  and  $f(1) = f(5) = 3$



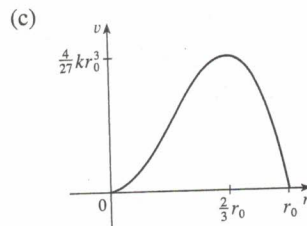
13. (a)    (b)



15. Abs. max.  $f(1) = 5$     17. None  
 19. Abs. min.  $f(0) = 0$   
 21. Abs. max.  $f(-3) = 9$ , abs. and loc. min.  $f(0) = 0$   
 23. None    25. Abs. max.  $f(0) = 1$   
 27. Abs. max.  $f(3) = 2$     29.  $-\frac{2}{5}$     31.  $-4, 2$   
 33.  $0, \frac{1}{2}(-1 \pm \sqrt{5})$     35.  $0, 2$     37.  $0, \frac{4}{9}$     39.  $0, \frac{8}{7}, 4$   
 41.  $n\pi$  ( $n$  an integer)    43.  $10$     45.  $f(0) = 5, f(2) = -7$   
 47.  $f(-1) = 8, f(2) = -19$   
 49.  $f(3) = 66, f(\pm 1) = 2$     51.  $f(1) = \frac{1}{2}, f(0) = 0$   
 53.  $f(\sqrt{2}) = 2, f(-1) = -\sqrt{3}$   
 55.  $f(\pi/6) = \frac{3}{2}\sqrt{3}, f(\pi/2) = 0$

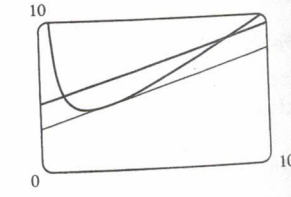
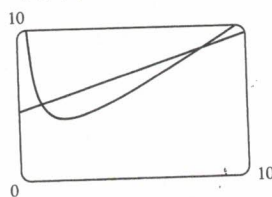
57.  $f\left(\frac{a}{a+b}\right) = \frac{a^a b^b}{(a+b)^{a+b}}$

59. (a) 2.19, 1.81    (b)  $\frac{6}{25}\sqrt{\frac{3}{5}} + 2, -\frac{6}{25}\sqrt{\frac{3}{5}} + 2$   
 61. (a) 0.32, 0.00    (b)  $\frac{3}{16}\sqrt{3}, 0$     63.  $\approx 3.9665^\circ\text{C}$   
 65. Cheapest,  $t \approx 0.855$  (June 1994); most expensive,  $t \approx 4.618$  (March 1998)  
 67. (a)  $r = \frac{2}{3}r_0$     (b)  $v = \frac{4}{27}kr_0^3$



EXERCISES 4.2 ■ PAGE 219

1. 2    3.  $\frac{9}{4}$     5.  $f$  is not differentiable on  $(-1, 1)$   
 7. 0.8, 3.2, 4.4, 6.1  
 9. (a), (b)    (c)  $2\sqrt{2}$



11. 0    13.  $\sqrt{3}/9$     15.  $f$  is not continuous at 3  
 23. 16    25. No    31. No

## EXERCISES 4.3 ■ PAGE 227

Abbreviations: inc., increasing; dec., decreasing; CD, concave downward; CU, concave upward; HA, horizontal asymptote; VA, vertical asymptote; IP, inflection point(s)

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 (1, 5); dec. on (0, 1) and (5, 6)  
 (b) Loc. max. at  $x = 5$ , loc. min. at  $x = 1$

7.  $x = 1, 7$

9. (a) Inc. on  $(-\infty, -3)$ ,  $(2, \infty)$ ; dec. on  $(-3, 2)$   
 (b) Loc. max.  $f(-3) = 81$ ; loc. min.  $f(2) = -44$   
 (c) CU on  $(-\frac{1}{2}, \infty)$ ; CD on  $(-\infty, -\frac{1}{2})$ ; IP  $(-\frac{1}{2}, \frac{37}{2})$

11. (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  $(\pm\sqrt{3}/3, \frac{22}{9})$

13. (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  $(3\pi/4, 0)$ ,  $(7\pi/4, 0)$

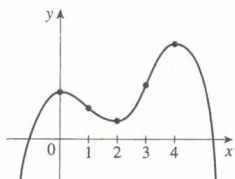
15. Loc. max.  $f(-1) = 7$ , loc. min.  $f(1) = -1$

17. Loc. max.  $f(\frac{3}{4}) = \frac{5}{4}$

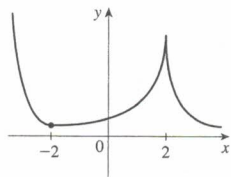
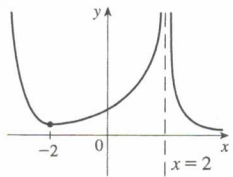
19. (a)  $f$  has a local maximum at 2.

- (b)  $f$  has a horizontal tangent at 6.

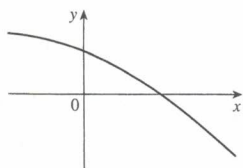
21.



23.



25.



27. (a) Inc. on (0, 2), (4, 6), (8,  $\infty$ );  
 dec. on (2, 4), (6, 8)

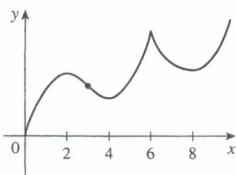
- (b) Loc. max. at  $x = 2, 6$ ;

- loc. min. at  $x = 4, 8$

- (c) CU on (3, 6), (6,  $\infty$ );

- CD on (0, 3)

- (d) 3 (e) See graph at right.



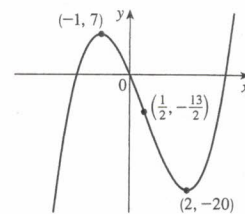
29. (a) Inc. on  $(-\infty, -1)$ ,  $(2, \infty)$ ;  
 dec. on  $(-1, 2)$

- (b) Loc. max.  $f(-1) = 7$ ;

- loc. min.  $f(2) = -20$

- (c) CU on  $(\frac{1}{2}, \infty)$ ; CD on  $(-\infty, \frac{1}{2})$ ;  
 IP  $(\frac{1}{2}, -\frac{13}{2})$

- (d) See graph at right.



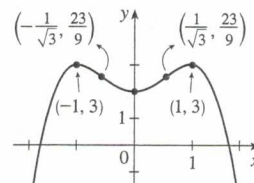
31. (a) Inc. on  $(-\infty, -1)$ ,  $(0, 1)$ ;  
 dec. on  $(-1, 0)$ ,  $(1, \infty)$

- (b) Loc. max.  $f(-1) = 3, f(1) = 3$ ;

- loc. min.  $f(0) = 2$

- (c) CU on  $(-1/\sqrt{3}, 1/\sqrt{3})$ ;  
 CD on  $(-\infty, -1/\sqrt{3})$ ,  $(1/\sqrt{3}, \infty)$ ;  
 IP  $(\pm 1/\sqrt{3}, \frac{23}{9})$

- (d) See graph at right.



33. (a) Inc. on  $(-\infty, -2)$ ,  $(0, \infty)$ ;  
 dec. on  $(-2, 0)$

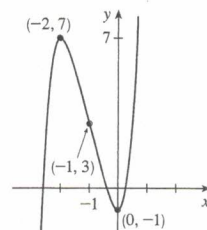
- (b) Loc. max.  $h(-2) = 7$ ;

- loc. min.  $h(0) = -1$

- (c) CU on  $(-1, \infty)$ ;

- CD on  $(-\infty, -1)$ ; IP  $(-1, 3)$

- (d) See graph at right.



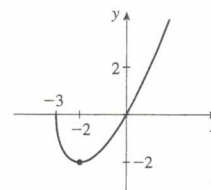
35. (a) Inc. on  $(-2, \infty)$ ;

- dec. on  $(-3, -2)$

- (b) Loc. min.  $A(-2) = -2$

- (c) CU on  $(-3, \infty)$

- (d) See graph at right.



37. (a) Inc. on  $(-1, \infty)$ ;

- dec. on  $(-\infty, -1)$

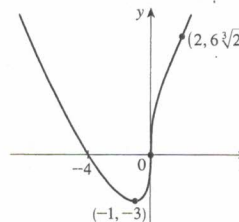
- (b) Loc. min.  $C(-1) = -3$

- (c) CU on  $(-\infty, 0)$ ,  $(2, \infty)$ ;

- CD on  $(0, 2)$ ;

- IPs  $(0, 0)$ ,  $(2, 6\sqrt[3]{2})$

- (d) See graph at right.



39. (a) Inc. on  $(\pi, 2\pi)$ ;

- dec. on  $(0, \pi)$

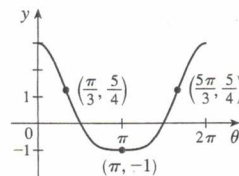
- (b) Loc. min.  $f(\pi) = -1$

- (c) CU on  $(\pi/3, 5\pi/3)$ ;

- CD on  $(0, \pi/3)$ ,  $(5\pi/3, 2\pi)$ ;

- IP  $(\pi/3, \frac{5}{4})$ ,  $(5\pi/3, \frac{5}{4})$

- (d) See graph at right.



41.  $(3, \infty)$

43. (a) Loc. and abs. max.  $f(1) = \sqrt{2}$ , no min.

- (b)  $\frac{1}{4}(3 - \sqrt{17})$

45. (b) CU on  $(0.94, 2.57)$ ,  $(3.71, 5.35)$ ;

- CD on  $(0, 0.94)$ ,  $(2.57, 3.71)$ ,  $(5.35, 2\pi)$ ;

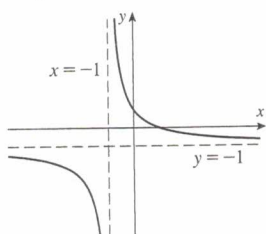
- IP  $(0.94, 0.44)$ ,  $(2.57, -0.63)$ ,  $(3.71, -0.63)$ ,  $(5.35, 0.44)$

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

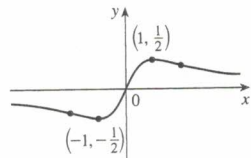
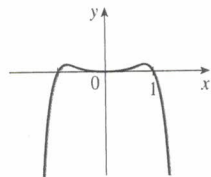
49. (a) The rate of increase is initially very small, increases to a maximum at  $t \approx 8$  h, then decreases toward 0.  
 (b) When  $t = 8$  (c) CU on  $(0, 8)$ ; CD on  $(8, 18)$  (d)  $(8, 350)$   
 51.  $K(3) - K(2)$ ; CD 53.  $f(x) = \frac{1}{9}(2x^3 + 3x^2 - 12x + 7)$

EXERCISES 4.4 ■ PAGE 240

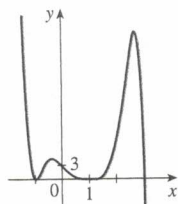
1. (a) As  $x$  becomes large,  $f(x)$  approaches 5.  
 (b) As  $x$  becomes large negative,  $f(x)$  approaches 3.  
 3. (a)  $\infty$  (b)  $\infty$  (c)  $-\infty$  (d) 1 (e) 2  
 (f)  $x = -1, x = 2, y = 1, y = 2$   
 5. 0 7.  $\frac{3}{2}$  9. 0 11.  $-\frac{1}{2}$  13.  $\frac{1}{2}$  15. 2  
 17. 3 19.  $\frac{1}{6}$  21.  $\frac{1}{2}(a - b)$  23.  $\infty$  25.  $-\infty$   
 27.  $\infty$  29. 1  
 31. (a), (b)  $-\frac{1}{2}$  33.  $y = 2; x = 2$   
 35.  $y = 2; x = -2, x = 1$  37.  $x = 5$  39.  $y = 3$   
 41.  $f(x) = \frac{2 - x}{x^2(x - 3)}$   
 43.  $y = -1$  45.  $y = 0$



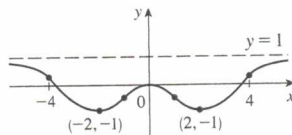
47.  $-\infty, -\infty$



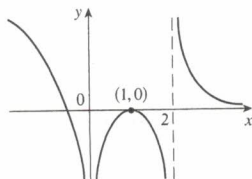
49.  $-\infty, \infty$



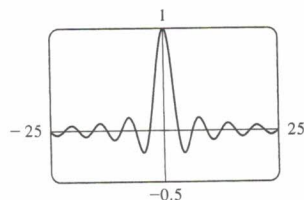
51.



53.



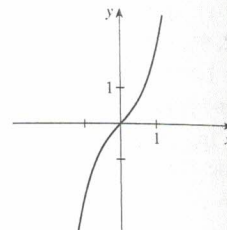
55. (a) 0 (b) An infinite number of times



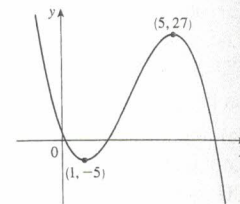
57. (a) 0 (b)  $\pm\infty$  59. 4  
 61.  $N \geq 15$  63.  $N \leq -6, N \leq -22$  65. (a)  $x > 100$

EXERCISES 4.5 ■ PAGE 248

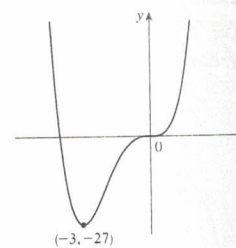
1. A.  $\mathbb{R}$  B. y-int. 0; x-int. 0  
 C. About  $(0, 0)$  D. None  
 E. Inc. on  $(-\infty, \infty)$  F. None  
 G. CU on  $(0, \infty)$ ; CD on  $(-\infty, 0)$ ;  
 IP  $(0, 0)$   
 H. See graph at right.



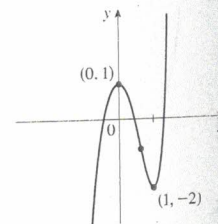
3. A.  $\mathbb{R}$  B. y-int. 2; x-int. 2,  $\frac{1}{2}(7 \pm 3\sqrt{5})$   
 C. None D. None  
 E. Inc. on  $(1, 5)$ ;  
 dec. on  $(-\infty, 1), (5, \infty)$   
 F. Loc. min.  $f(1) = -5$ ;  
 loc. max.  $f(5) = 27$   
 G. CU on  $(-\infty, 3)$ ;  
 CD on  $(3, \infty)$ ; IP  $(3, 11)$   
 H. See graph at right.



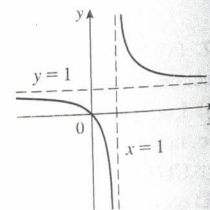
5. A.  $\mathbb{R}$  B. y-int. 0; x-int.  $-4, 0$   
 C. None D. None  
 E. Inc. on  $(-3, \infty)$ ;  
 dec. on  $(-\infty, -3)$   
 F. Loc. min.  $f(-3) = -27$   
 G. CU on  $(-\infty, -2), (0, \infty)$ ;  
 CD on  $(-2, 0)$ ; IP  $(0, 0), (-2, -16)$   
 H. See graph at right.



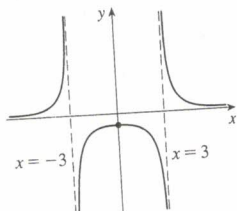
7. A.  $\mathbb{R}$  B. y-int. 1  
 C. None D. None  
 E. Inc. on  $(-\infty, 0), (1, \infty)$ ;  
 dec. on  $(0, 1)$   
 F. Loc. max.  $f(0) = 1$ ;  
 loc. min.  $f(1) = -2$   
 G. CU on  $(1/\sqrt[3]{4}, \infty)$ ;  
 CD on  $(-\infty, 1/\sqrt[3]{4})$ ;  
 IP  $(1/\sqrt[3]{4}, 1 - 9/(2\sqrt[3]{16}))$   
 H. See graph at right.



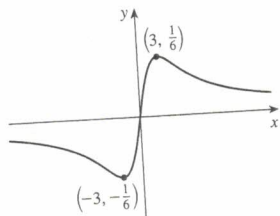
9. A.  $\{x \mid x \neq 1\}$  B. y-int. 0; x-int. 0  
 C. None D. VA  $x = 1$ , HA  $y = 1$   
 E. Dec. on  $(-\infty, 1), (1, \infty)$   
 F. None  
 G. CU on  $(1, \infty)$ ; CD on  $(-\infty, 1)$   
 H. See graph at right.



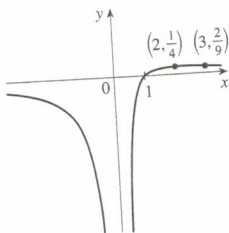
11. A.  $\{x \mid x \neq \pm 3\}$  B. y-int.  $-\frac{1}{9}$   
 C. About y-axis D. VA  $x = \pm 3$ , HA  $y = 0$   
 E. Inc. on  $(-\infty, -3)$ ,  $(-3, 0)$ ;  
 dec. on  $(0, 3)$ ,  $(3, \infty)$   
 F. Loc. max.  $f(0) = -\frac{1}{9}$   
 G. CU on  $(-\infty, -3)$ ,  $(3, \infty)$ ;  
 CD on  $(-3, 3)$   
 H. See graph at right.



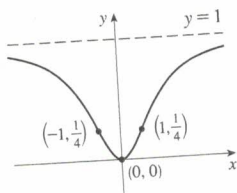
13. A.  $\mathbb{R}$  B. y-int. 0; x-int. 0  
 C. About (0, 0) D. HA  $y = 0$   
 E. Inc. on  $(-3, 3)$ ;  
 dec. on  $(-\infty, -3)$ ,  $(3, \infty)$   
 F. Loc. min.  $f(-3) = -\frac{1}{6}$ ;  
 loc. max.  $f(3) = \frac{1}{6}$ ;  
 G. CU on  $(-3\sqrt{3}, 0)$ ,  $(3\sqrt{3}, \infty)$ ;  
 CD on  $(-\infty, -3\sqrt{3})$ ,  $(0, 3\sqrt{3})$ ;  
 IP  $(0, 0)$ ,  $(\pm 3\sqrt{3}, \pm \sqrt{3}/12)$   
 H. See graph at right.



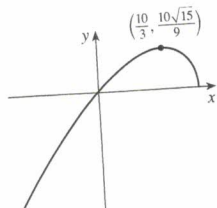
15. A.  $(-\infty, 0) \cup (0, \infty)$  B. x-int. 1  
 C. None D. HA  $y = 0$ ; VA  $x = 0$   
 E. Inc. on  $(0, 2)$ ;  
 dec. on  $(-\infty, 0)$ ,  $(2, \infty)$   
 F. Loc. max.  $f(2) = \frac{1}{4}$   
 G. CU on  $(3, \infty)$ ;  
 CD on  $(-\infty, 0)$ ,  $(0, 3)$ ; IP  $(3, \frac{2}{9})$   
 H.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



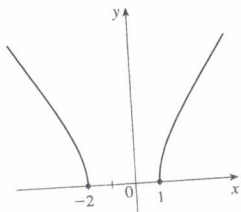
17. A.  $\mathbb{R}$  B. y-int. 0, x-int. 0  
 C. About y-axis D. HA  $y = 1$   
 E. Inc. on  $(0, \infty)$ ; dec. on  $(-\infty, 0)$   
 F. Loc. min.  $f(0) = 0$   
 G. CU on  $(-1, 1)$ ;  
 CD on  $(-\infty, -1)$ ,  $(1, \infty)$ ; IP  $(\pm 1, \frac{1}{4})$   
 H. See graph at right



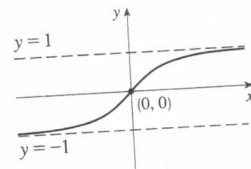
19. A.  $(-\infty, 5]$  B. y-int. 0; x-int. 0, 5  
 C. None D. None  
 E. Inc. on  $(-\infty, \frac{10}{3})$ ; dec. on  $(\frac{10}{3}, 5)$   
 F. Loc. max.  $f(\frac{10}{3}) = \frac{10}{9}\sqrt{15}$   
 G. CD on  $(-\infty, 5)$   
 H. See graph at right.



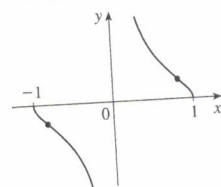
21. A.  $(-\infty, -2) \cup (1, \infty)$   
 B. x-int. -2, 1  
 C. None D. None  
 E. Inc. on  $(1, \infty)$ ; dec. on  $(-\infty, -2)$   
 F. None  
 G. CD on  $(-\infty, -2)$ ,  $(1, \infty)$   
 H. See graph at right.



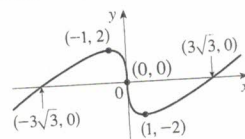
23. A.  $\mathbb{R}$  B. y-int. 0; x-int. 0  
 C. About the origin  
 D. HA  $y = \pm 1$   
 E. Inc. on  $(-\infty, \infty)$  F. None  
 G. CU on  $(-\infty, 0)$ ;  
 CD on  $(0, \infty)$ ; IP  $(0, 0)$   
 H. See graph at right.



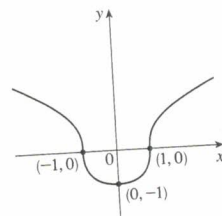
25. A.  $\{x \mid |x| \leq 1, x \neq 0\} = [-1, 0) \cup (0, 1]$   
 B. x-int.  $\pm 1$  C. About (0, 0)  
 D. VA  $x = 0$   
 E. Dec. on  $(-1, 0)$ ,  $(0, 1)$   
 F. None  
 G. CU on  $(-1, -\sqrt{2}/3)$ ,  $(0, \sqrt{2}/3)$ ;  
 CD on  $(-\sqrt{2}/3, 0)$ ,  $(\sqrt{2}/3, 1)$ ;  
 IP  $(\pm \sqrt{2}/3,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



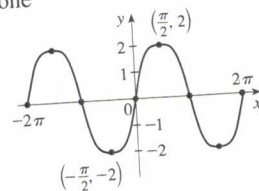
27. A.  $\mathbb{R}$  B. y-int. 0; x-int. 0,  $\pm 3\sqrt{3}$  C. About the origin  
 D. None E. Inc. on  $(-\infty, -1)$ ,  $(1, \infty)$ ; dec. on  $(-1, 1)$   
 F. Loc. max.  $f(-1) = 2$ ;  
 loc. min.  $f(1) = -2$   
 G. CU on  $(0, \infty)$ ; CD on  $(-\infty, 0)$ ;  
 IP  $(0, 0)$   
 H. See graph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



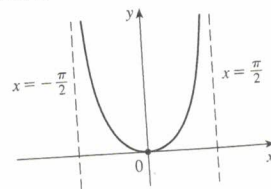
29. A.  $\mathbb{R}$  B. y-int. -1; x-int.  $\pm 1$   
 C. About y-axis D. None  
 E. Inc. on  $(0, \infty)$ ; dec. on  $(-\infty, 0)$   
 F. Loc. min.  $f(0) = -1$   
 G. CU on  $(-1, 1)$ ;  
 CD on  $(-\infty, -1)$ ,  $(1, \infty)$ ;  
 IP  $(\pm 1, 0)$   
 H. See graph at right.



31. A.  $\mathbb{R}$  B. y-int. 0; x-int.  $n\pi$  ( $n$  an integer)  
 C. About the origin, period  $2\pi$  D. None  
 E. Inc. on  $(2n\pi - \pi/2, 2n\pi + \pi/2)$ ;  
 dec. on  $(2n\pi + \pi/2, 2n\pi + 3\pi/2)$   
 F. Loc. max.  $f(2n\pi + \pi/2) = 2$ ;  
 loc. min.  $f(2n\pi + 3\pi/2) = -2$   
 G. CU on  $((2n-1)\pi, 2n\pi)$ ;  
 CD on  $(2n\pi, (2n+1)\pi)$ ; IP  $(n\pi, 0)$   
 H. See graph at right.



33. 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.



35. A.  $(0, 3\pi)$  C. None D. None

E. Inc. on  $(\pi/3, 5\pi/3), (7\pi/3, 3\pi)$ ;

dec. on  $(0, \pi/3), (5\pi/3, 7\pi/3)$

F. Loc. min.  $f(\pi/3) = (\pi/6) - \frac{1}{2}\sqrt{3}, f(7\pi/3) = (7\pi/6) - \frac{1}{2}\sqrt{3}$ ;

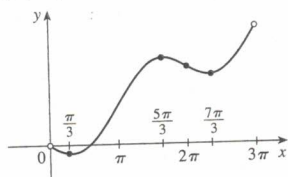
loc. max.  $f(5\pi/3) = (5\pi/6) + \frac{1}{2}\sqrt{3}$

G. CU on  $(0, \pi), (2\pi, 3\pi)$ ;

CD on  $(\pi, 2\pi)$ ;

IP  $(\pi, \pi/2), (2\pi, \pi)$

H. See graph at right.



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

B.  $y$ -int. 0;  $x$ -int.  $2n\pi$

C. About the origin, period  $2\pi$

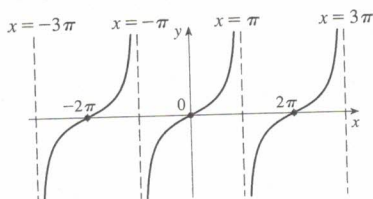
D. VA  $x = (2n + 1)\pi$

E. Inc. on  $((2n - 1)\pi, (2n + 1)\pi)$  F. None

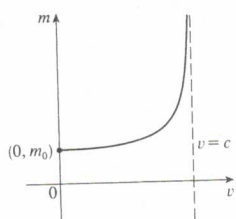
G. CU on  $(2n\pi, (2n + 1)\pi)$ ; CD on  $((2n - 1)\pi, 2n\pi)$ ;

IP  $(2n\pi, 0)$

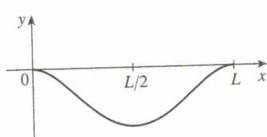
H.



39.



41.



43.  $y = x - 1$

45.  $y = 2x - 2$

47. A.  $(-\infty, \frac{1}{2}) \cup (\frac{1}{2}, \infty)$

B.  $y$ -int. 1;  $x$ -int.  $\frac{1}{4}(5 \pm \sqrt{17})$

C. None

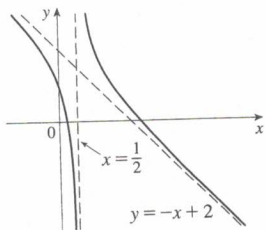
D. VA  $x = \frac{1}{2}$ ; SA  $y = -x + 2$

E. Dec. on  $(-\infty, \frac{1}{2}), (\frac{1}{2}, \infty)$

F. None

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

H. See graph at right



49. A.  $\{x | x \neq 0\}$  B. None

C. About  $(0, 0)$  D. VA  $x = 0$ ; SA  $y = x$

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

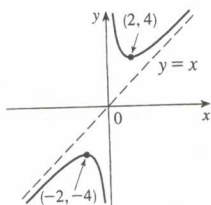
dec. on  $(-2, 0), (0, 2)$

F. Loc. max.  $f(-2) = -4$ ;

loc. min.  $f(2) = 4$

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

H. See graph at right.



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

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

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

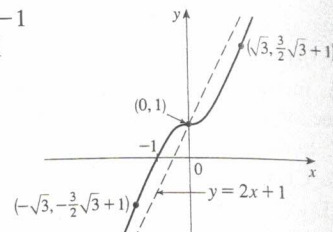
G. CU on  $(-\infty, -\sqrt{3}),$

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

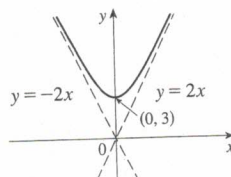
CD on  $(-\sqrt{3}, 0), (\sqrt{3}, \infty)$ ;

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

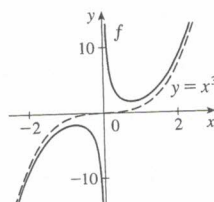
H. See graph at right.



53.



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



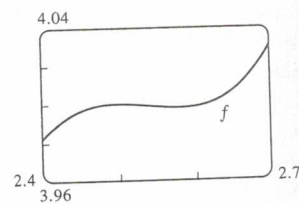
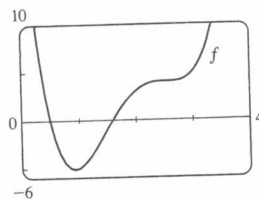
EXERCISES 4.6 = PAGE 255

1. Inc. on  $(0.92, 2.5), (2.58, \infty)$ ; dec. on  $(-\infty, 0.92), (2.5, 2.58)$ ;

loc. max.  $f(2.5) \approx 4$ ; loc. min.  $f(0.92) \approx -5.12, f(2.58) \approx 3.998$ ;

CU on  $(-\infty, 1.46), (2.54, \infty)$ ;

CD on  $(1.46, 2.54)$ ; IP  $(1.46, -1.40), (2.54, 3.999)$



3. Inc. on  $(-15, 4.40), (18.93, \infty)$ ;

dec. on  $(-\infty, -15), (4.40, 18.93)$ ;

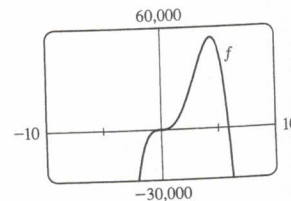
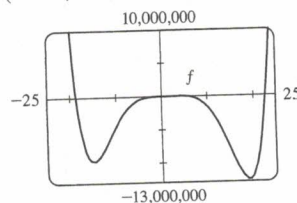
loc. max.  $f(4.40) \approx 53,800$ ; loc. min.  $f(-15) \approx -9,700,000$ ,

$f(18.93) \approx -12,700,000$ ; CU on  $(-\infty, -11.34), (0, 2.92),$

$(15.08, \infty)$ ; CD on  $(-11.34, 0), (2.92, 15.08)$ ;

IP  $(0, 0), \approx (-11.34, -6,250,000), (2.92, 31,800),$

$(15.08, -8,150,000)$

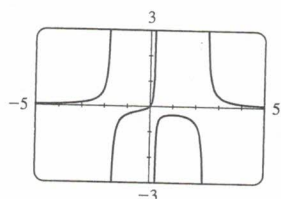


5. Inc. on  $(-\infty, -1.7), (-1.7, 0.24), (0.24, 1)$ ;

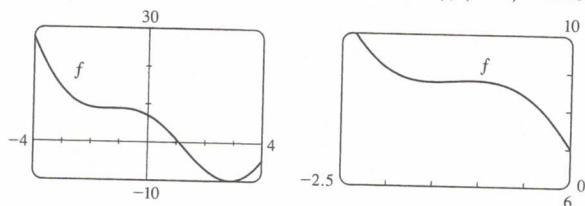
dec. on  $(1, 2.46), (2.46, \infty)$ ; loc. max.  $f(1) = -\frac{1}{3}$ ;



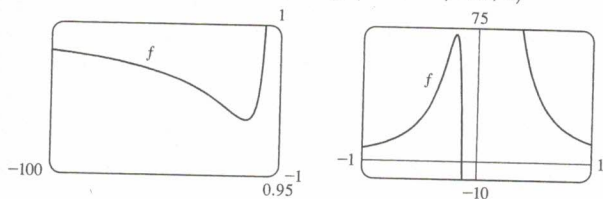
CU on  $(-\infty, -1.7)$ ,  $(-0.506, 0.24)$ ,  $(2.46, \infty)$ ;  
 CD on  $(-1.7, -0.506)$ ,  $(0.24, 2.46)$ ; IP  $(-0.506, -0.192)$



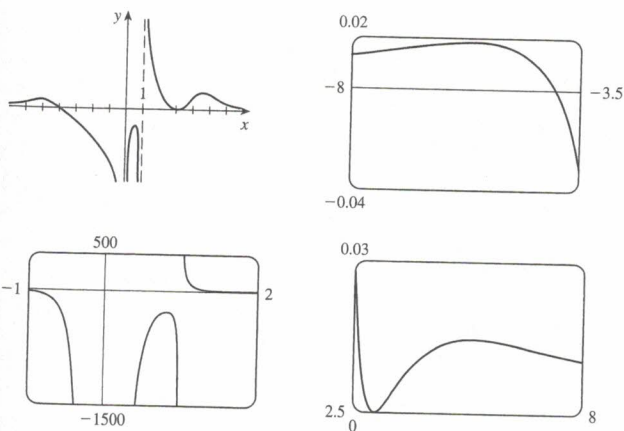
7. Inc. on  $(-1.49, -1.07)$ ,  $(2.89, 4)$ ; dec. on  $(-4, -1.49)$ ,  
 $(-1.07, 2.89)$ ; loc. max.  $f(-1.07) \approx 8.79$ ; loc. min.  
 $f(-1.49) \approx 8.75$ ,  $f(2.89) \approx -9.99$ ; CU on  $(-4, -1.28)$ ,  
 $(1.28, 4)$ ; CD on  $(-1.28, 1.28)$ ; IP  $(-1.28, 8.77)$ ,  $(1.28, -1.48)$



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.  $f(3) = 0$

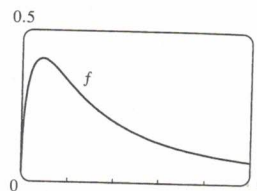


$$13. f'(x) = -\frac{x(x+1)^2(x^3+18x^2-44x-16)}{(x-2)^3(x-4)^5}$$

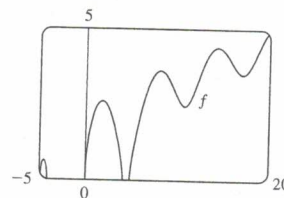
$$f''(x) = 2\frac{(x+1)(x^6+36x^5+6x^4-628x^3+684x^2+672x+64)}{(x-2)^4(x-4)^6}$$

CU on  $(-35.3, -5.0)$ ,  $(-1, -0.5)$ ,  $(-0.1, 2)$ ,  $(2, 4)$ ,  $(4, \infty)$ ;  
 CD on  $(-\infty, -35.3)$ ,  $(-5.0, -1)$ ,  $(-0.5, -0.1)$ ;  
 IP  $(-35.3, -0.015)$ ,  $(-5.0, -0.005)$ ,  $(-1, 0)$ ,  $(-0.5, 0.000001)$ ,  
 $(-0.1, 0.0000066)$

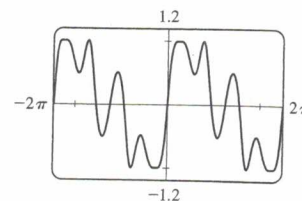
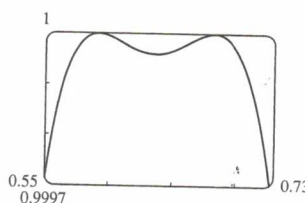
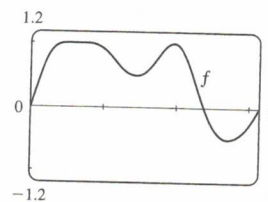
15. Inc. on  $(0, 0.43)$ ; dec. on  $(0.43, \infty)$ ; loc. max.  $f(0.43) \approx 0.41$ ;  
 CU on  $(0.94, \infty)$ ; CD on  $(0, 0.94)$ ;  
 IP  $(0.94, 0.34)$



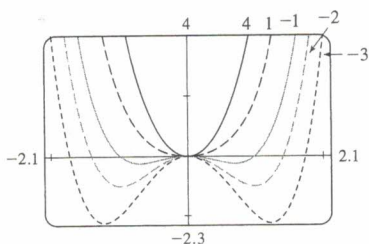
17. Inc. on  $(-4.91, -4.51)$ ,  $(0, 1.77)$ ,  $(4.91, 8.06)$ ,  $(10.79, 14.34)$ ,  
 $(17.08, 20)$ ;  
 dec. on  $(-4.51, -4.10)$ ,  $(1.77, 4.10)$ ,  $(8.06, 10.79)$ ,  $(14.34, 17.08)$ ;  
 loc. max.  $f(-4.51) \approx 0.62$ ,  $f(1.77) \approx 2.58$ ,  $f(8.06) \approx 3.60$ ,  
 $f(14.34) \approx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



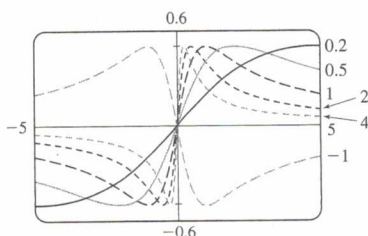
19. Max.  $f(0.59) \approx 1$ ,  $f(0.68) \approx 1$ ,  $f(1.96) \approx 1$ ;  
 min.  $f(0.64) \approx 0.99996$ ,  $f(1.46) \approx 0.49$ ,  $f(2.73) \approx -0.51$ ;  
 IP  $(0.61, 0.99998)$ ,  $(0.66, 0.99998)$ ,  $(1.17, 0.72)$ ,  
 $(1.75, 0.77)$ ,  $(2.28, 0.34)$



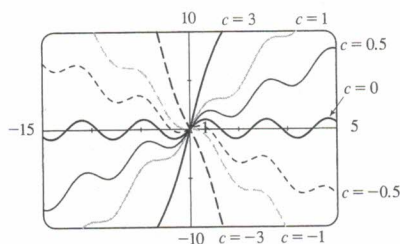
21. For  $c \geq 0$ , there is no IP and only one extreme point, the origin. For  $c < 0$ , there is a maximum point at the origin, two minimum points, and two IPs, which move downward and away from the origin as  $c \rightarrow -\infty$ .



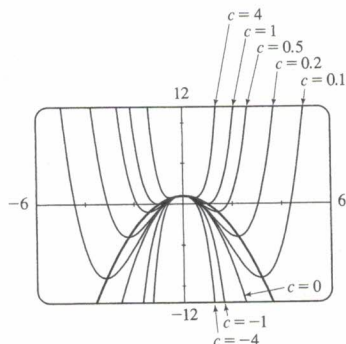
23. For  $c > 0$ , the maximum and minimum values are always  $\pm \frac{1}{2}$ , but the extreme points and IPs move closer to the y-axis as  $c$  increases.  $c = 0$  is a transitional value: when  $c$  is replaced by  $-c$ , the curve is reflected in the  $x$ -axis.



25. For  $|c| < 1$ , the graph has local maximum and minimum 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.

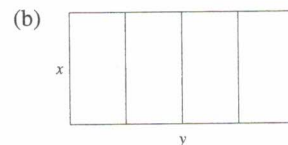
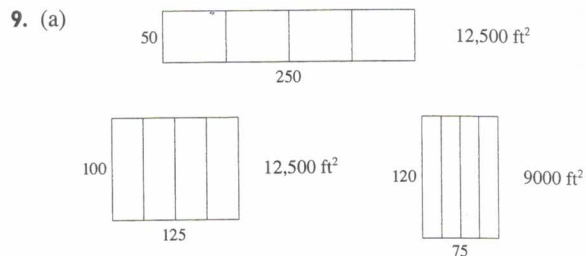


27. (a) Positive (b)



EXERCISES 4.7 ■ PAGE 262

1. (a) 11, 12 (b) 11.5, 11.5 3. 10, 10  
5. 25 m by 25 m 7.  $N = 1$



- (c)  $A = xy$  (d)  $5x + 2y = 750$  (e)  $A(x) = 375x - \frac{5}{2}x^2$   
(f) 14,062.5 ft<sup>2</sup>

11. 1000 ft by 1500 ft 13. 4000 cm<sup>3</sup> 15. \$191.28  
17.  $(-\frac{28}{17}, \frac{7}{17})$  19.  $(-\frac{1}{3}, \pm \frac{4}{3}\sqrt{2})$  21. Square, side  $\sqrt{2}r$   
23.  $L/2, \sqrt{3}L/4$  25. Base  $\sqrt{3}r$ , height  $3r/2$   
27.  $4\pi r^3/(3\sqrt{3})$  29.  $\pi r^2(1 + \sqrt{5})$  31. 24 cm, 36 cm  
33. (a) Use all of the wire for the square  
(b)  $40\sqrt{3}/(9 + 4\sqrt{3})$  m for the square

35. Height = radius =  $\sqrt[3]{V/\pi}$  cm 37.  $V = 2\pi R^3/(9\sqrt{3})$   
41.  $E^2/(4r)$   
43. (a)  $\frac{3}{2}s^2 \csc \theta (\csc \theta - \sqrt{3} \cot \theta)$  (b)  $\cos^{-1}(1/\sqrt{3}) \approx 55^\circ$   
(c)  $6s[h + s/(2\sqrt{2})]$

45. Row directly to B 47.  $\approx 4.85$  km east of the refinery  
49.  $10\sqrt[3]{3}/(1 + \sqrt[3]{3})$  ft from the stronger source  
51.  $(a^{2/3} + b^{2/3})^{3/2}$   
53. (b) (i) \$342,491; \$342/unit; \$390/unit (ii) 400  
(iii) \$320/unit  
55. (a)  $p(x) = 19 - \frac{1}{3000}x$  (b) \$9.50  
57. (a)  $p(x) = 550 - \frac{1}{10}x$  (b) \$175 (c) \$100  
61. 9.35 m 65.  $x = 6$  in. 67.  $\pi/6$  69.  $\frac{1}{2}(L + W)^2$   
71. (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)  $\approx 1.07$ ; no such value (d)  $\sqrt{41}/4 \approx 1.6$

EXERCISES 4.8 ■ PAGE 272

1. (a)  $x_2 \approx 2.3, x_3 \approx 3$  (b) No 3.  $\frac{4}{5}$  5. 1.1797  
7. 1.1785 9. -1.25 11. 1.82056420 13. 1.217562  
15. 0.876726 17. -0.724492, 1.220744  
19. -0.471074, 1.461070 21. 0.641714  
23. -1.93822883, -1.21997997, 1.13929375, 2.98984102  
25. -1.97806681, -0.82646233  
27. (b) 31.622777  
33. (a) -1.293227, -0.441731, 0.507854 (b) -2.0212  
35. (0.164419, 0.990958)  
37. (0.410245, 0.347810)  
39. 0.76286%

EXERCISES 4.9 ■ PAGE 279

1.  $F(x) = \frac{1}{2}x^2 - 3x + C$     3.  $F(x) = \frac{1}{2}x + \frac{1}{4}x^3 - \frac{1}{5}x^4 + C$   
 5.  $F(x) = \frac{2}{3}x^3 + \frac{1}{2}x^2 - x + C$     7.  $F(x) = 4x^{5/4} - 4x^{7/4} + C$   
 9.  $F(x) = 4x^{3/2} - \frac{6}{7}x^{7/6} + C$

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

13.  $F(u) = \frac{1}{3}u^3 - 6u^{-1/2} + C$

15.  $G(\theta) = \sin \theta + 5 \cos \theta + C$

17.  $F(t) = 2 \sec t + t^{1/2} + C_n$

19.  $F(x) = x^5 - \frac{1}{3}x^6 + 4$     21.  $x^3 + x^4 + Cx + D$

23.  $\frac{3}{20}x^{8/3} + Cx + D$     25.  $t^5 + \frac{1}{2}Ct^2 + Dt + E$

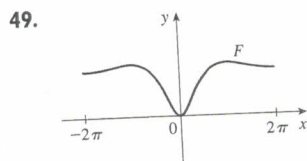
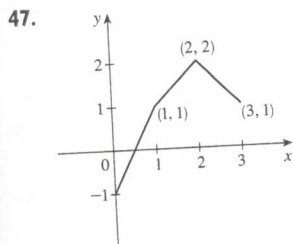
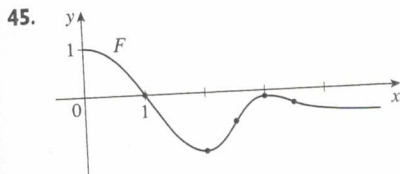
27.  $x - 3x^2 + 8$     29.  $4x^{3/2} + 2x^{5/2} + 4$

31.  $2 \sin t + \tan t + 4 - 2\sqrt{3}$

33.  $2x^4 + \frac{1}{3}x^3 + 5x^2 - 22x + \frac{59}{3}$

35.  $-\sin \theta - \cos \theta + 5\theta + 4$     37.  $x^2 - 2x^3 + 9x + 9$

39.  $x^2 - \cos x - \frac{1}{2}\pi x$     41. 10    43. b



51.  $s(t) = 1 - \cos t - \sin t$     53.  $s(t) = \frac{1}{6}t^3 - t^2 + 3t + 1$

55.  $s(t) = -10 \sin t - 3 \cos t + (6/\pi)t + 3$

57. (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

61. 225 ft    63. \$742.08    65.  $\frac{130}{11} \approx 11.8$  s

67.  $\frac{88}{15} \approx 5.87$  ft/s<sup>2</sup>    69.  $62,500 \text{ km/h}^2 \approx 4.82 \text{ m/s}^2$

71. (a) 22.9125 mi    (b) 21.675 mi    (c) 30 min 33 s  
 (d) 55.425 mi

CHAPTER 4 REVIEW ■ PAGE 282

True-False Quiz

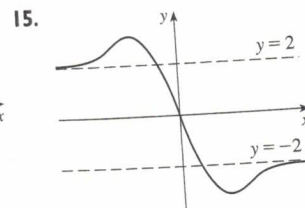
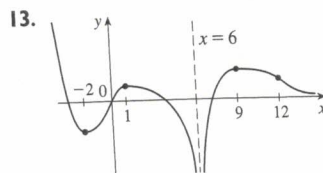
1. False    3. False    5. True    7. False    9. True  
 11. True    13. False    15. True    17. True    19. True

Exercises

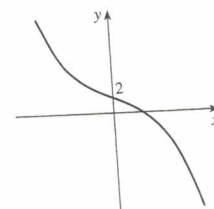
1. Abs. max.  $f(4) = 5$ , abs. and loc. min.  $f(3) = 1$ ;  
 loc. min.  $f(3) = 1$   
 3. Abs. max.  $f(2) = \frac{2}{5}$ , abs. and loc. min.  $f(-\frac{1}{3}) = -\frac{9}{2}$

5. Abs. max.  $f(\pi) = \pi$ ; abs. min.  $f(0) = 0$ ; loc. max.  
 $f(\pi/3) = (\pi/3) + \frac{1}{2}\sqrt{3}$ ; loc. min.  $f(2\pi/3) = (2\pi/3) - \frac{1}{2}\sqrt{3}$

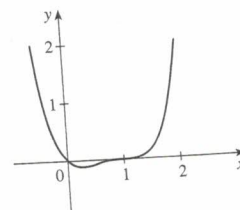
7.  $\frac{1}{2}$     9.  $-\frac{2}{3}$     11.  $\frac{3}{4}$



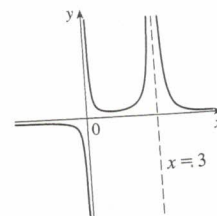
17. A.  $\mathbb{R}$     B. y-int. 2  
 C. None    D. None  
 E. Dec. on  $(-\infty, \infty)$     F. None  
 G. CU on  $(-\infty, 0)$ ;  
 CD on  $(0, \infty)$ ; IP  $(0, 2)$   
 H. See graph at right.



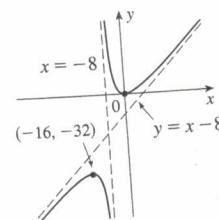
19. A.  $\mathbb{R}$     B. y-int. 0; x-int. 0, 1  
 C. None    D. None  
 E. Inc. on  $(\frac{1}{4}, \infty)$ , dec. on  $(-\infty, \frac{1}{4})$   
 F. Loc. min.  $f(\frac{1}{4}) = -\frac{27}{256}$   
 G. CU on  $(-\infty, \frac{1}{2})$ ,  $(1, \infty)$ ;  
 CD on  $(\frac{1}{2}, 1)$ ; IP  $(\frac{1}{2}, -\frac{1}{16})$ ,  $(1, 0)$   
 H. See graph at right.



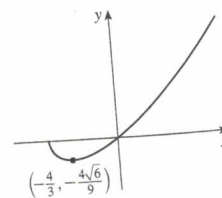
21. A.  $\{x \mid x \neq 0, 3\}$   
 B. None    C. None  
 D. HA  $y = 0$ ; VA  $x = 0, x = 3$   
 E. Inc. on  $(1, 3)$ ; dec. on  $(-\infty, 0)$ ,  
 $(0, 1)$ ,  $(3, \infty)$   
 F. Loc. min.  $f(1) = \frac{1}{4}$   
 G. CU on  $(0, 3)$ ,  $(3, \infty)$ ; CD on  $(-\infty, 0)$   
 H. See graph at right.



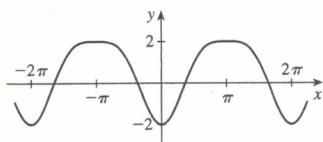
23. A.  $\{x \mid x \neq -8\}$   
 B. y-int. 0, x-int. 0    C. None  
 D. VA  $x = -8$ ; SA  $y = x - 8$   
 E. Inc. on  $(-\infty, -16)$ ,  $(0, \infty)$ ;  
 dec. on  $(-16, -8)$ ,  $(-8, 0)$   
 F. Loc. max.  $f(-16) = -32$ ;  
 loc. min.  $f(0) = 0$   
 G. CU on  $(-8, \infty)$ ; CD on  $(-\infty, -8)$   
 H. See graph at right.



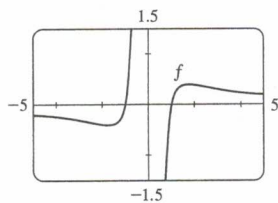
25. A.  $[-2, \infty)$   
 B. y-int. 0; x-int.  $-2, 0$   
 C. None    D. None  
 E. Inc. on  $(-\frac{4}{3}, \infty)$ , dec. on  $(-2, -\frac{4}{3})$   
 F. Loc. min.  $f(-\frac{4}{3}) = -\frac{4}{9}\sqrt{6}$   
 G. CU on  $(-2, \infty)$   
 H. See graph at right.



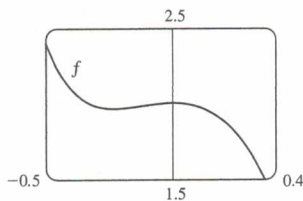
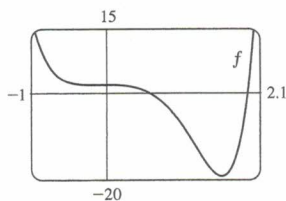
27. A.  $\mathbb{R}$  B. y-int.  $-2$   
 C. About y-axis, period  $2\pi$  D. None  
 E. Inc. on  $(2n\pi, (2n+1)\pi)$ ,  $n$  an integer; dec. on  $((2n-1)\pi, 2n\pi)$   
 F. Loc. max.  $f((2n+1)\pi) = 2$ ; loc. min.  $f(2n\pi) = -2$   
 G. CU on  $(2n\pi - (\pi/3), 2n\pi + (\pi/3))$ ;  
 CD on  $(2n\pi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



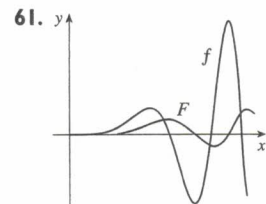
29. Inc. on  $(-\sqrt{3}, 0)$ ,  $(0, \sqrt{3})$ ;  
 dec. on  $(-\infty, -\sqrt{3})$ ,  $(\sqrt{3}, \infty)$ ;  
 loc. max.  $f(\sqrt{3}) = \frac{2}{9}\sqrt{3}$ ;  
 loc. min.  $f(-\sqrt{3}) = -\frac{2}{9}\sqrt{3}$ ;  
 CU on  $(-\sqrt{6}, 0)$ ,  $(\sqrt{6}, \infty)$ ;  
 CD on  $(-\infty, -\sqrt{6})$ ,  $(0, \sqrt{6})$ ;  
 IP  $(\sqrt{6}, \frac{5}{36}\sqrt{6})$ ,  $(-\sqrt{6}, -\frac{5}{36}\sqrt{6})$



31. Inc. on  $(-0.23, 0)$ ,  $(1.62, \infty)$ ; dec. on  $(-\infty, -0.23)$ ,  $(0, 1.62)$ ;  
 loc. max.  $f(0) = 2$ ; loc. min.  $f(-0.23) \approx 1.96$ ,  $f(1.62) \approx -19.2$ ;  
 CU on  $(-\infty, -0.12)$ ,  $(1.24, \infty)$ ;  
 CD on  $(-0.12, 1.24)$ ; IP  $(-0.12, 1.98)$ ,  $(1.24, -12.1)$



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.  $f(x) = \frac{2}{5}x^{5/2} + \frac{3}{5}x^{5/3} + C$   
 55.  $f(t) = t^2 + 3 \cos t + 2$   
 57.  $f(x) = \frac{1}{2}x^2 - x^3 + 4x^4 + 2x + 1$   
 59.  $s(t) = t^2 + \cos t + 2$



63. No  
 65. (b) About 8.5 in. by 2 in. (c)  $20/\sqrt{3}$  in.,  $20\sqrt{2/3}$  in.

PROBLEMS PLUS ■ PAGE 286

5.  $(-2, 4)$ ,  $(2, -4)$  7.  $\frac{4}{3}$  9.  $(m/2, m^2/4)$   
 11.  $-3.5 < a < -2.5$  13. (a)  $x/(x^2 + 1)$  (b)  $\frac{1}{2}$

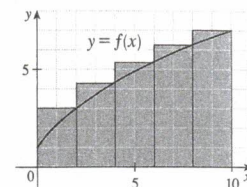
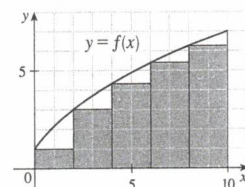
15. (a)  $-\tan \theta \left[ \frac{1}{c} \frac{dc}{dt} + \frac{1}{b} \frac{db}{dt} \right]$   
 (b)  $\frac{b \frac{db}{dt} + c \frac{dc}{dt} - \left( b \frac{dc}{dt} + c \frac{db}{dt} \right) \sec \theta}{\sqrt{b^2 + c^2} - 2bc \cos \theta}$

17. (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  
 21.  $3/(\sqrt[3]{2} - 1) \approx 11\frac{1}{2} h$

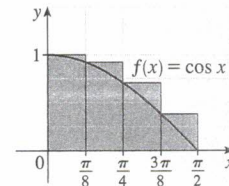
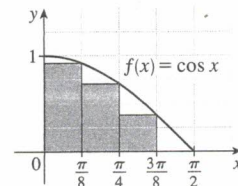
CHAPTER 5

EXERCISES 5.1 ■ PAGE 298

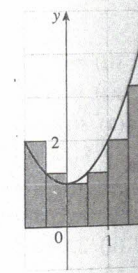
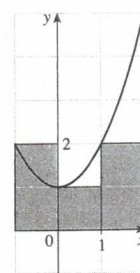
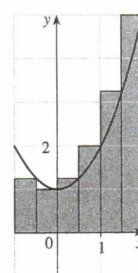
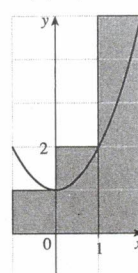
1. (a) 40, 52 (b) 43.2, 49.2



3. (a) 0.7908, underestimate (b) 1.1835, overestimate

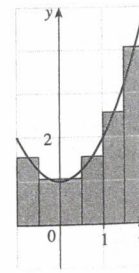
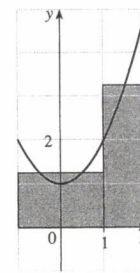


5. (a) 8, 6.875



- (b) 5, 5.375

- (c) 5.75, 5.9375

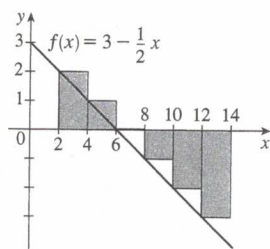


- (d)  $M_6$

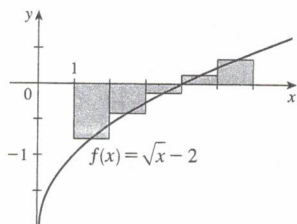
7. 0.2533, 0.2170, 0.2101, 0.2050; 0.2  
 9. (a) Left: 0.8100, 0.7937, 0.7904; right: 0.7600, 0.7770, 0.7804  
 11. 34.7 ft, 44.8 ft    13. 63.2 L, 70 L    15. 155 ft  
 17.  $\lim_{n \rightarrow \infty} \sum_{i=1}^n \sqrt[4]{1 + 15i/n} \cdot (15/n)$     19.  $\lim_{n \rightarrow \infty} \sum_{i=1}^n \left( \frac{i\pi}{2n} \cos \frac{i\pi}{2n} \right) \frac{\pi}{2n}$   
 21. The region under the graph of  $y = \tan x$  from 0 to  $\pi/4$   
 23. (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)  $\frac{32}{3}$   
 25.  $\sin b, 1$

EXERCISES 5.2 ■ PAGE 310

1. -6  
 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. -0.856759  
 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.



5. (a) 4    (b) 6    (c) 10    7. -475, -85    9. 124.1644  
 11. 0.3084    13. 0.30843908, 0.30981629, 0.31015563

15.

$n$	$R_n$
5	1.933766
10	1.983524
50	1.999342
100	1.999836

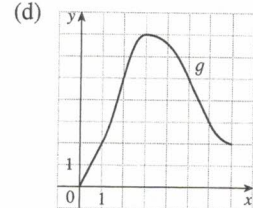
The values of  $R_n$  appear to be approaching 2.

17.  $\int_2^6 \frac{1-x^2}{4+x^2} dx$     19.  $\int_1^8 \sqrt{2x+x^2} dx$     21. 42  
 23.  $\frac{4}{3}$     25. 3.75    29.  $\lim_{n \rightarrow \infty} \sum_{i=1}^n \frac{2+4i/n}{1+(2+4i/n)^5} \cdot \frac{4}{n}$   
 31.  $\lim_{n \rightarrow \infty} \sum_{i=1}^n \left( \sin \frac{5\pi i}{n} \right) \frac{\pi}{n} = \frac{2}{5}$   
 33. (a) 4    (b) 10    (c) -3    (d) 2    35.  $-\frac{3}{4}$   
 37.  $3 + \frac{9}{4}\pi$     39. 2.5    41. 0    43. 3    45. 22.5  
 47.  $\int_{-1}^5 f(x) dx$     49. 122  
 51.  $2m \leq \int_0^2 f(x) dx \leq 2M$  by Comparison Property 8  
 55.  $3 \leq \int_1^4 \sqrt{x} dx \leq 6$     57.  $\frac{\pi}{12} \leq \int_{\pi/4}^{\pi/3} \tan x dx \leq \frac{\pi}{12} \sqrt{3}$   
 59.  $2 \leq \int_{-1}^1 \sqrt{1+x^4} dx \leq 2\sqrt{2}$     69.  $\int_0^1 x^4 dx$     71.  $\frac{1}{2}$

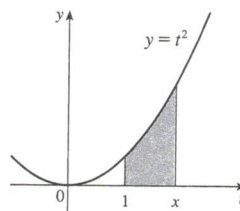
EXERCISES 5.3 ■ PAGE 321

1. One process undoes what the other one does. See the Fundamental Theorem of Calculus, page 320.

3. (a) 0, 2, 5, 7, 3  
 (b) (0, 3)  
 (c)  $x = 3$



5. (a), (b)  $x^2$

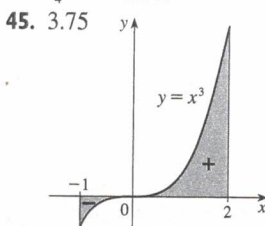


7.  $g'(x) = 1/(x^3 + 1)$   
 9.  $g'(y) = y^2 \sin y$     11.  $F'(x) = -\sqrt{1 + \sec x}$   
 13.  $h'(x) = -\sin^4(1/x)/x^2$     15.  $y' = \sqrt{\tan x} + \sqrt{\tan x} \sec^2 x$   
 17.  $y' = \frac{3(1-3x)^3}{1+(1-3x)^2}$     19.  $\frac{3}{4}$     21. 63  
 23.  $\frac{5}{9}$     25.  $\frac{7}{8}$     27.  $\frac{156}{7}$     29.  $\frac{40}{3}$     31. 1    33.  $\frac{49}{3}$   
 35. 0

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

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

41.  $\frac{243}{4}$     43. 2



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

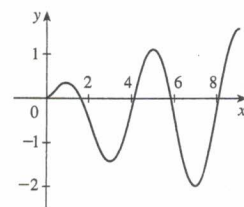
49.  $y' = 3x^{7/2} \sin(x^3) - \frac{\sin \sqrt{x}}{2\sqrt{x}}$     51.  $\sqrt{257}$

53. (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

55. (a) Loc. max. at 1 and 5; loc. min. at 3 and 7

- (b)  $x = 9$   
 (c)  $(\frac{1}{2}, 2), (4, 6), (8, 9)$

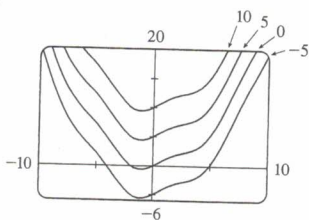
(d) See graph at right.



57.  $\frac{1}{4}$     65.  $f(x) = x^{3/2}, a = 9$   
 67. (b) Average expenditure over  $[0, t]$ ; minimize average expenditure  
 69.  $\ln 3$     71.  $\pi$     73.  $e^2 - 1$

EXERCISES 5.4 ■ PAGE 329

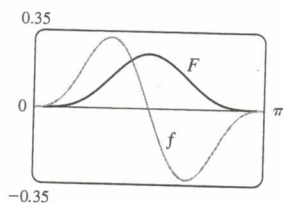
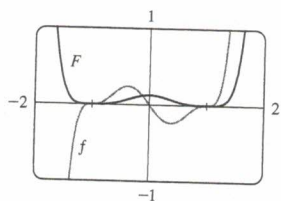
5.  $\frac{1}{3}x^3 - (1/x) + C$     7.  $\frac{1}{5}x^5 - \frac{1}{8}x^4 + \frac{1}{8}x^2 - 2x + C$   
 9.  $2t - t^2 + \frac{1}{3}t^3 - \frac{1}{4}t^4 + C$     11.  $\frac{1}{3}x^3 - 4\sqrt{x} + C$   
 13.  $\frac{1}{2}\theta^2 + \csc \theta + C$     15.  $\tan \alpha + C$   
 17.  $\sin x + \frac{1}{4}x^2 + C$



19. 18    21. 231    23. 52    25.  $\frac{256}{15}$     27.  $-\frac{63}{4}$     29.  $\frac{55}{63}$   
 31.  $2\sqrt{5}$     33. 8    35.  $1 + \pi/4$     37.  $\frac{256}{5}$     39. 1  
 41. -3.5    43. 0, 1.32; 0.84    45.  $\frac{4}{3}$   
 47. The increase in the child's weight (in pounds) between the ages of 5 and 10  
 49. Number of gallons of oil leaked in the first 2 hours  
 51. Increase in revenue when production is increased from 1000 to 5000 units  
 53. Newton-meters (or joules)    55. (a)  $-\frac{3}{2}$  m    (b)  $\frac{41}{6}$  m  
 57. (a)  $v(t) = \frac{1}{2}t^2 + 4t + 5$  m/s    (b)  $416\frac{2}{3}$  m  
 59.  $46\frac{2}{3}$  kg    61. 1.4 mi    63. \$58,000  
 65. (b) At most 40%;  $\frac{5}{36}$     67.  $-\cos x + \cosh x + C$   
 69.  $\frac{1}{3}x^3 + x + \tan^{-1}x + C$     71.  $\pi/6$

EXERCISES 5.5 ■ PAGE 338

1.  $\frac{1}{3} \sin 3x + C$     3.  $\frac{2}{9}(x^3 + 1)^{3/2} + C$     5.  $-\frac{1}{4} \cos^4 \theta + C$   
 7.  $-\frac{1}{2} \cos(x^2) + C$     9.  $\frac{1}{63}(3x - 2)^{21} + C$   
 11.  $\frac{1}{5}(2x + x^2)^{3/2} + C$     13.  $-(1/\pi) \cos \pi t + C$   
 15.  $\frac{2}{3}\sqrt{3ax + bx^3} + C$     17.  $2 \sin \sqrt{t} + C$     19.  $\frac{1}{7} \sin^7 \theta + C$   
 21.  $\frac{1}{2}(1 + z^3)^{2/3} + C$     23.  $-\frac{2}{3}(\cot x)^{3/2} + C$   
 25.  $\frac{1}{3} \sec^3 x + C$     27.  $-1/(\sin x) + C$   
 29.  $\frac{4}{7}(x + 2)^{7/4} - \frac{8}{3}(x + 2)^{3/4} + C$   
 31.  $\frac{1}{8}(x^2 - 1)^4 + C$     33.  $\frac{1}{4} \sin^4 x + C$



35. 0    37.  $\frac{182}{9}$     39. 4    41. 0    43. 3  
 45.  $\frac{1}{3}(2\sqrt{2} - 1)a^3$     47.  $\frac{16}{15}$     49.  $\frac{1}{2}(\sin 4 - \sin 1)$   
 51.  $\sqrt{3} - \frac{1}{3}$     53.  $6\pi$     55.  $\frac{5}{4\pi} \left(1 - \cos \frac{2\pi t}{5}\right) L$     57. 5

65.  $-\frac{1}{3} \ln|5 - 3x| + C$     67.  $\frac{1}{3}(\ln x)^3 + C$   
 69.  $\frac{2}{3}(1 + e^x)^{3/2} + C$     71.  $e^{\tan x} + C$   
 73.  $\tan^{-1}x + \frac{1}{2} \ln(1 + x^2) + C$     75.  $-\ln(1 + \cos^2 x) + C$   
 77.  $\ln|\sin x| + C$     79. 2    81.  $\ln(e + 1)$     83.  $\pi^2/4$

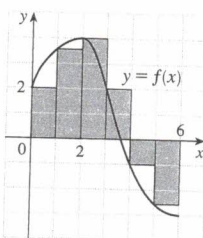
CHAPTER 5 REVIEW ■ PAGE 341

True-False Quiz

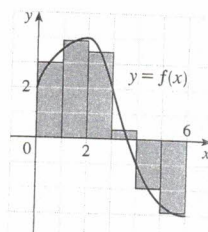
1. True    3. True    5. False    7. True    9. True  
 11. False    13. False    15. False

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. 37    11.  $\frac{9}{10}$     13. -76    15.  $\frac{21}{4}$     17. Does not exist  
 19.  $\frac{1}{3} \sin 1$     21. 0    23.  $[1/(2\pi)] \sin^2 \pi t + C$   
 25.  $\frac{1}{2}\sqrt{2} - \frac{1}{2}$     27.  $\frac{23}{3}$     29.  $2\sqrt{1 + \sin x} + C$     31.  $\frac{64}{5}$   
 33.  $F'(x) = x^2/(1 + x^3)$     35.  $g'(x) = 4x^3 \cos(x^8)$   
 37.  $y' = \frac{(2 \cos x - \cos \sqrt{x})}{(2x)}$     39.  $4 \leq \int_1^3 \sqrt{x^2 + 3} dx \leq 4\sqrt{3}$   
 43. 0.280981  
 45. Number of barrels of oil consumed from Jan. 1, 2000, through Jan. 1, 2008  
 47. 72,400    49. 3    51.  $(1 + x^2)(x \cos x + \sin x)/x^2$

PROBLEMS PLUS ■ PAGE 345

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

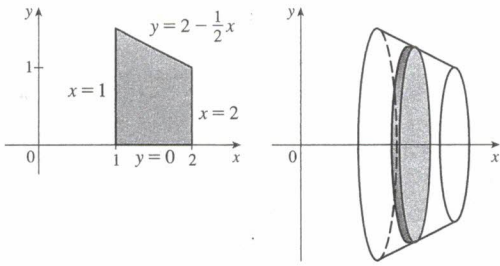
CHAPTER 6

EXERCISES 6.1 ■ PAGE 352

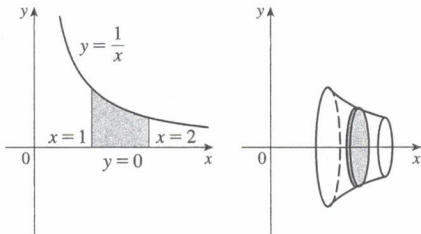
1.  $\frac{32}{3}$     3.  $\frac{4}{3}$     5. 19.5    7.  $\frac{1}{6}$     9.  $\frac{4}{3}$     11.  $\frac{1}{3}$     13. 72  
 15.  $6\sqrt{3}$     17.  $\frac{59}{12}$     19.  $\frac{32}{3}$     21.  $\frac{8}{3}$     23.  $\frac{1}{2}$   
 25.  $2 - \pi/2$     27.  $\frac{3}{4}$     29. 6.5    31.  $\frac{3}{2}\sqrt{3} - 1$   
 33. 0.6407    35. 0, 0.90; 0.04    37. 8.38    39.  $12\sqrt{6} - 9$   
 41.  $117\frac{1}{3}$  ft    43. 4232 cm<sup>2</sup>  
 45. (a) Car A    (b) The distance by which A is ahead of B after 1 minute    (c) Car A    (d)  $t \approx 2.2$  min  
 47.  $\frac{24}{5}\sqrt{3}$     49.  $4^{2/3}$     51.  $\pm 6$     53.  $\ln 2 - \frac{1}{2}$   
 55.  $2 - 2 \ln 2$

EXERCISES 6.2 ■ PAGE 362

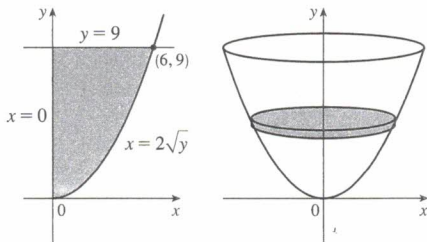
1.  $19\pi/12$



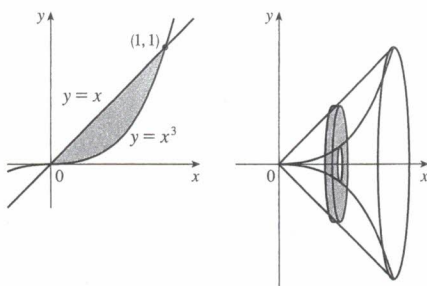
3.  $\pi/2$



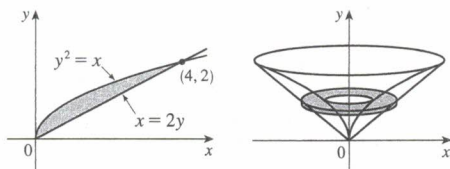
5.  $162\pi$



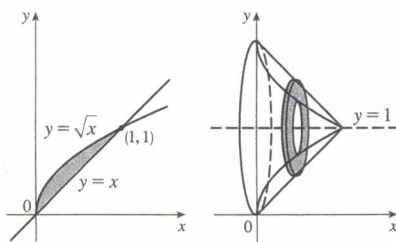
7.  $4\pi/21$



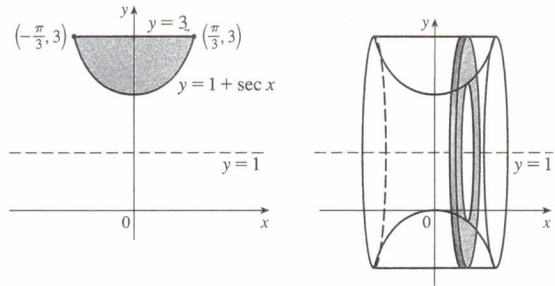
9.  $64\pi/15$



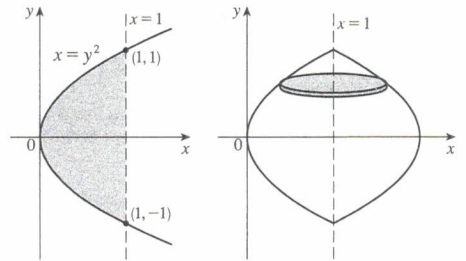
11.  $\pi/6$



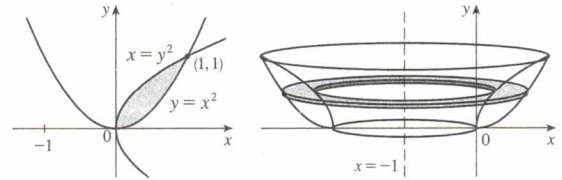
13.  $2\pi(\frac{4}{3}\pi - \sqrt{3})$



15.  $16\pi/15$



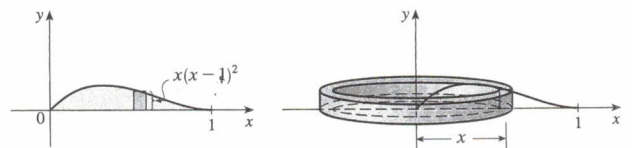
17.  $29\pi/30$



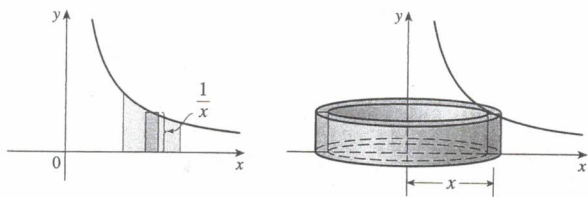
19.  $\pi/7$     21.  $\pi/10$     23.  $\pi/2$     25.  $7\pi/15$   
 27.  $5\pi/14$     29.  $13\pi/30$     31.  $\pi \int_0^{\pi/4} (1 - \tan^3 x)^2 dx$   
 33.  $\pi \int_0^{\pi} [1^2 - (1 - \sin x)^2] dx$   
 35.  $\pi \int_{-2\sqrt{2}}^{2\sqrt{2}} [5^2 - (\sqrt{1+y^2} + 2)^2] dy$   
 37.  $-1.288, 0.884; 23.780$     39.  $\frac{11}{8}\pi^2$   
 41. Solid obtained by rotating the region  $0 \leq y \leq \cos x$ ,  $0 \leq x \leq \pi/2$  about the  $x$ -axis  
 43. Solid obtained by rotating the region above the  $x$ -axis bounded by  $x = y^2$  and  $x = y^4$  about the  $y$ -axis  
 45.  $1110 \text{ cm}^3$     47. (a) 196    (b) 838    49.  $\frac{1}{3}\pi r^2 h$   
 51.  $\pi h^2(r - \frac{1}{3}h)$     53.  $\frac{2}{3}b^2 h$     55.  $10 \text{ cm}^3$     57. 24  
 59.  $\frac{1}{3}$     61.  $\frac{8}{15}$   
 63. (a)  $8\pi R \int_0^r \sqrt{r^2 - y^2} dy$     (b)  $2\pi^2 r^2 R$   
 65. (b)  $\pi r^2 h$     67.  $\frac{5}{12}\pi r^3$     69.  $8 \int_0^r \sqrt{R^2 - y^2} \sqrt{r^2 - y^2} dy$

EXERCISES 6.3 ■ PAGE 368

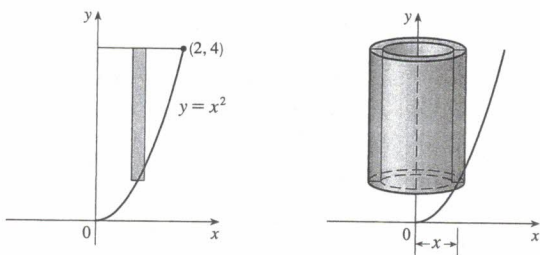
1. Circumference =  $2\pi x$ , height =  $x(x-1)^2$ ;  $\pi/15$



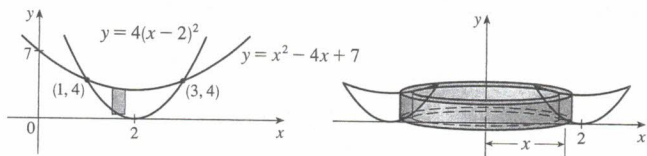
3.  $2\pi$



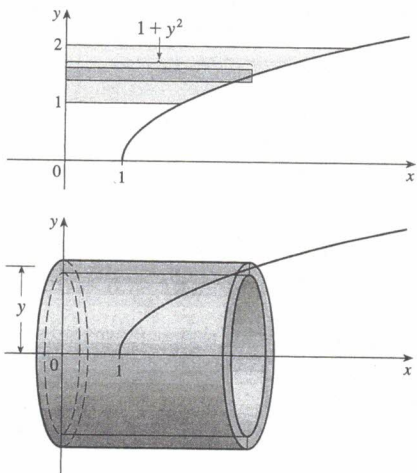
5.  $8\pi$



7.  $16\pi$



9.  $21\pi/2$



11.  $768\pi/7$  13.  $16\pi/3$  15.  $7\pi/15$  17.  $8\pi/3$

19.  $5\pi/14$  21.  $\int_{2\pi}^{3\pi} 2\pi x \sin x \, dx$

23.  $\int_0^1 2\pi(x+1)[\sin(\pi x/2) - x^4] \, dx$

25.  $\int_0^\pi 2\pi(4-y)\sqrt{\sin y} \, dy$  27. 3.68

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

31. Solid obtained by rotating the region bounded by (i)  $x = 1 - y^2$ ,  $x = 0$ , and  $y = 0$ , or (ii)  $x = y^2$ ,  $x = 1$ , and  $y = 0$  about the line  $y = 3$

33. 0, 1.32; 4.05 35.  $\frac{1}{32}\pi^3$  37.  $8\pi$  39.  $\frac{63}{2}\pi$

41.  $\frac{4}{3}\pi$  43.  $\frac{4}{3}\pi r^3$  45.  $\frac{1}{3}\pi r^2 h$

EXERCISES 6.4 ■ PAGE 373

1. 588 J 3. 9 ft-lb 5. 180 J 7.  $\frac{15}{4}$  ft-lb

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

13. (a) 625 ft-lb (b)  $\frac{1875}{4}$  ft-lb 15. 650,000 ft-lb

17. 3857 J 19. 2450 J 21.  $\approx 1.06 \times 10^6$  J

23.  $\approx 1.04 \times 10^5$  ft-lb 25. 2.0 m 29.  $Gm_1m_2\left(\frac{1}{a} - \frac{1}{b}\right)$

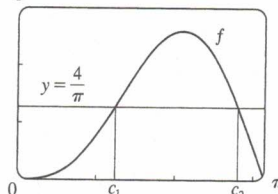
EXERCISES 6.5 ■ PAGE 377

1.  $\frac{8}{3}$  3.  $\frac{45}{28}$  5.  $\frac{1}{15}(26^{3/2} - 1)$  7.  $2/(5\pi)$

9. (a) 1 (b) 2, 4 (c) 

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

(c) 3



15.  $38\frac{1}{3}$  17.  $(50 + 28/\pi)^\circ\text{F} \approx 59^\circ\text{F}$  19. 6 kg/m

21.  $5/(4\pi) \approx 0.4$  L

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Exercises

1.  $\frac{8}{3}$  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. (a)  $2\pi/15$  (b)  $\pi/6$  (c)  $8\pi/15$

17. (a) 0.38 (b) 0.87

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

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

23. 36 25.  $\frac{125}{3}\sqrt{3} \, \text{m}^3$  27. 3.2 J

29. (a)  $8000\pi/3 \approx 8378$  ft-lb (b) 2.1 ft 31.  $f(x)$

PROBLEMS PLUS ■ PAGE 380

1. (a)  $f(t) = 3t^2$  (b)  $f(x) = \sqrt{2x/\pi}$  3.  $\frac{32}{27}$

5. (b) 0.2261 (c) 0.6736 m

(d) (i)  $1/(105\pi) \approx 0.003$  in/s (ii)  $370\pi/3 \, \text{s} \approx 6.5$  min

9.  $y = \frac{32}{9}x^2$

11. (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.

13.  $b = 2a$  15.  $B = 16A$



CHAPTER 7

EXERCISES 7.1 ■ PAGE 391

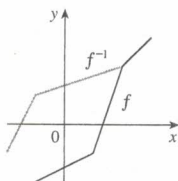
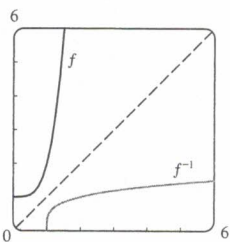
1. (a) See Definition 1.  
 (b) It must pass the Horizontal Line Test.  
 3. No    5. Yes    7. No    9. No    11. Yes    13. No  
 15. No    17. 2    19. 4

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

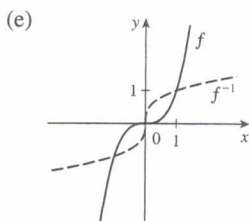
23.  $f^{-1}(x) = \frac{3}{2} - \frac{1}{2}x$     25.  $f^{-1}(x) = -\frac{1}{3}x^2 + \frac{10}{3}, x \geq 0$

27.  $y = \left(\frac{1-x}{1+x}\right)^2, -1 < x \leq 1$

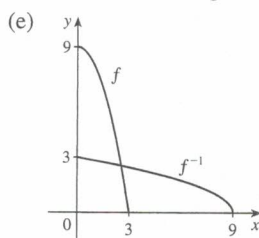
29.  $f^{-1}(x) = \sqrt[4]{x-1}$     31.



33. (b)  $\frac{1}{12}$   
 (c)  $f^{-1}(x) = \sqrt[3]{x}$ ,  
 domain =  $\mathbb{R}$  = range



35. (b)  $-\frac{1}{2}$   
 (c)  $f^{-1}(x) = \sqrt{9-x}$ ,  
 domain =  $[0, 9]$ , range =  $[0, 3]$



37.  $\frac{1}{7}$     39.  $2/\pi$     41.  $\frac{3}{2}$

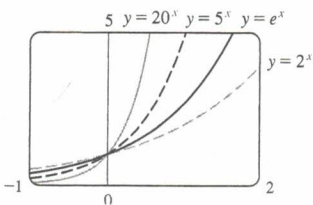
43.  
 $f^{-1}(x) = -(\sqrt[3]{4/6})(\sqrt[3]{D - 27x^2 + 20} - \sqrt[3]{D + 27x^2 - 20} + \sqrt[3]{2})$ ,  
 where  $D = 3\sqrt{3}\sqrt{27x^4 - 40x^2 + 16}$ ; two of the expressions are complex.

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

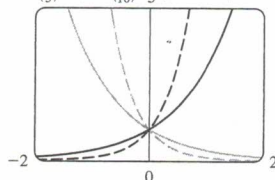
EXERCISES 7.2 ■ PAGE 402

1. (a)  $f(x) = a^x, a > 0$     (b)  $\mathbb{R}$     (c)  $(0, \infty)$   
 (d) See Figures 6(c), 6(b), and 6(a), respectively.

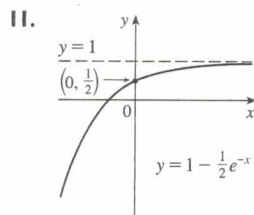
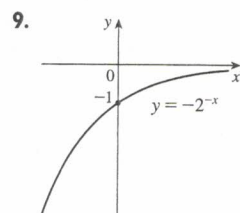
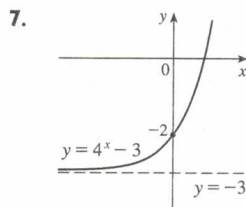
3.  $y = 20^x, y = 5^x, y = e^x$     All approach 0 as  $x \rightarrow -\infty$ ,  
 all pass through  $(0, 1)$ , and  
 all are increasing. The larger  
 the base, the faster the rate of  
 increase.



5.  $y = (\frac{1}{3})^x, y = (\frac{1}{10})^x, y = 10^x, y = 3^x$



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)  $(-\infty, \infty)$     (b)  $(-\infty, 0) \cup (0, \infty)$

17.  $f(x) = 3 \cdot 2^x$     21. At  $x \approx 35.8$     23.  $\infty$     25. 1

27. 0    29. 0    31.  $f'(x) = e^x(x^3 + 3x^2 + 2x + 2)$

33.  $y' = 3ax^2e^{ax^3}$     35.  $f'(u) = (-1/u^2)e^{1/u}$

37.  $F'(t) = e^t \sin 2t (2t \cos 2t + \sin 2t)$

39.  $y' = 3e^{3x}/\sqrt{1+2e^{3x}}$     41.  $y' = e^{e^x}e^x$

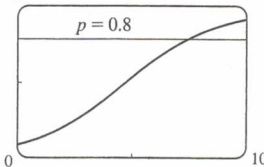
43.  $y' = \frac{(ad - bc)e^x}{(ce^x + d)^2}$     45.  $y' = \frac{4e^{2x}}{(1 + e^{2x})^2} \sin \frac{1 - e^{2x}}{1 + e^{2x}}$

47.  $y = 2x + 1$     49.  $y' = (1 - 2xye^{x^2y})/(x^2e^{x^2y} - 1)$

53. -4, -2    55.  $f^{(n)}(x) = 2^n e^{2x}$     57. (b) -0.567143

59. (a) 1    (b)  $kae^{-kt}/(1 + ae^{-kt})^2$

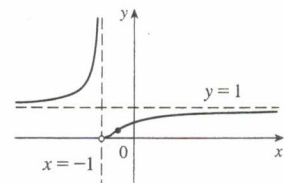
(c) 1     $t \approx 7.4$  h



61. -1    63.  $f(2) = 2/\sqrt{e}, f(-1) = -1/\sqrt[8]{e}$

65. (a) Inc. on  $(2, \infty)$ ; dec. on  $(-\infty, 2)$   
 (b) CU on  $(-\infty, 3)$ ; CD on  $(3, \infty)$     (c)  $(3, -2e^{-3})$

67. 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

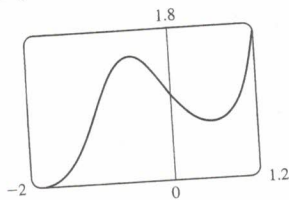


69. 28.57 min, when the rate of increase of drug level in the blood-stream is greatest; 85.71 min, when rate of decrease is greatest

71. 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  $(-0.15, 1.15), (-1.09, 0.82)$



73.  $\frac{1}{3}(1 - e^{-15})$     75.  $\frac{2}{3}(1 + e^x)^{3/2} + C$

77.  $\frac{1}{2}e^{2x} + 2x - \frac{1}{2}e^{-2x} + C$     79.  $-e^{\cos x} + C$

81.  $2e^{\sqrt{x}} + C$     83. 4.644    85.  $\pi(e^2 - 1)/2$     89.  $\frac{1}{2}$

EXERCISES 7.3 ■ PAGE 409

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

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

3. (a) 3    (b) -3    5. (a) -2    (b) 15

7. (a) 3    (b) -2

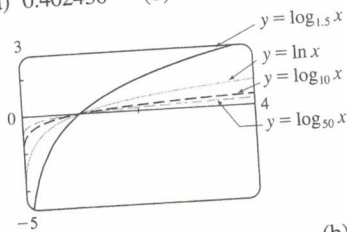
9.  $3 \log_2 x + \log_2 y - 2 \log_2 z$     11.  $10 \ln u + 10 \ln v$

13.  $\log_{10}(ac/b)$     15.  $\ln 1215$

17.  $\ln \frac{(1+x^2)\sqrt{x}}{\sin x}$

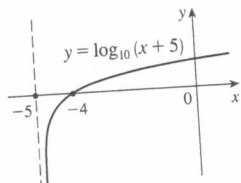
19. (a) 0.402430    (b) 1.454240    (c) 1.651496

21.

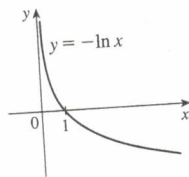


All graphs approach  $-\infty$  as  $x \rightarrow 0^+$ , all pass through  $(1, 0)$ , and all are increasing. The larger the base, the slower the rate of increase.

23. (a)



(b)



25. (a)  $\sqrt{e}$     (b)  $-\ln 5$

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

29. -3, 0    31.  $e^e$     33.  $\ln 3$

35. (a) 0.5210    (b) 3.0949

37. (a)  $x < \ln 10$     (b)  $x > 1/e$

39. About 1,084,588 mi    41. 8.3

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

45.  $-\infty$     47. 0    49.  $\infty$     51.  $(-\infty, -3) \cup (3, \infty)$

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

55.  $y = e^x - 3$     57.  $f^{-1}(x) = \sqrt[3]{\ln x}$     59.  $y = \frac{1}{10^x - 1}$

61.  $(-\frac{1}{2} \ln 3, \infty)$     63.  $(-\infty, 0), (4, \infty)$

65. (b)  $f^{-1}(x) = \frac{1}{2}(e^x - e^{-x})$     67.  $f$  is a constant function

71.  $-1 \leq x < 1 - \sqrt{3}$  or  $1 + \sqrt{3} < x \leq 3$

EXERCISES 7.4 ■ PAGE 419

1. The differentiation formula is simplest.

3.  $f'(x) = \frac{\cos(\ln x)}{x}$     5.  $f'(x) = \frac{3}{(3x-1)\ln 2}$

7.  $f'(x) = \frac{1}{5x^2 \sqrt{(\ln x)^4}}$     9.  $f'(x) = \frac{\sin x}{x} + \cos x \ln(5x)$

11.  $F'(t) = \frac{6}{2t+1} - \frac{12}{3t-1}$     13.  $g'(x) = \frac{2x^2-1}{x(x^2-1)}$

15.  $f'(u) = \frac{1 + \ln 2}{u[1 + \ln(2u)]^2}$     17.  $h'(t) = 3t^2 - 3^t \ln 3$

19.  $y' = \frac{10x+1}{5x^2+x-2}$     21.  $y' = \frac{-x}{1+x}$

23.  $y' = \frac{1}{\ln 10} + \log_{10} x$     25.  $y' = 5^{-1/x} (\ln 5)/x^2$

27.  $y' = x + 2x \ln(2x); y'' = 3 + 2 \ln(2x)$

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

31.  $f'(x) = \frac{2x-1 - (x-1)\ln(x-1)}{(x-1)[1 - \ln(x-1)]^2};$   
 $(1, 1+e) \cup (1+e, \infty)$

33.  $f'(x) = \frac{2(x-1)}{x(x-2)}; (-\infty, 0) \cup (2, \infty)$

35.  $\frac{1}{2}$     37.  $y = 3x - 2$     39.  $\cos x + 1/x$

41.  $y' = (2x+1)^5(x^4-3)^6 \left( \frac{10}{2x+1} + \frac{24x^3}{x^4-3} \right)$

43.  $y' = \frac{\sin^2 x \tan^4 x}{(x^2+1)^2} \left( 2 \cot x + \frac{4 \sec^2 x}{\tan x} - \frac{4x}{x^2+1} \right)$

45.  $y' = x^x(1 + \ln x)$

47.  $y' = x^{\sin x} \left( \frac{\sin x}{x} + \cos x \ln x \right)$

49.  $y' = (\cos x)^x (-x \tan x + \ln \cos x)$

51.  $y' = (\tan x)^{1/x} \left( \frac{\sec^2 x}{x \tan x} - \frac{\ln \tan x}{x^2} \right)$

53.  $y' = \frac{2x}{x^2 + y^2 - 2y}$     55.  $f^{(n)}(x) = \frac{(-1)^{n-1}(n-1)!}{(x-1)^n}$

57. 2.958516, 5.290718

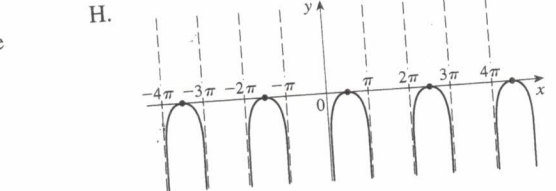
59. CU on  $(e^{8/3}, \infty)$ , CD on  $(0, e^{8/3})$ , IP  $(e^{8/3}, \frac{8}{3}e^{-4/3})$

61. A. All  $x$  in  $(2n\pi, (2n+1)\pi)$  ( $n$  an integer)

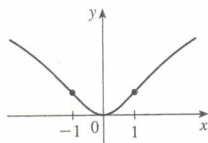
B.  $x$ -int.  $\pi/2 + 2n\pi$     C. Period  $2\pi$     D. VA  $x = n\pi$

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  $(2n\pi, (2n+1)\pi)$



63. 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  
 $(-\infty, -1), (1, \infty)$ ;

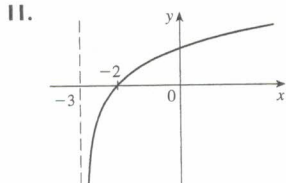
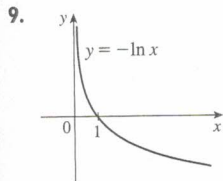


- IP  $(\pm 1, \ln 2)$  H. See graph at right.  
 65. Inc. on  $(0, 2.7), (4.5, 8.2), (10.9, 14.3)$ ;  
 IP  $(3.8, 1.7), (5.7, 2.1), (10.0, 2.7), (12.0, 2.9)$   
 67. (a)  $y = ab^t$  where  $a \approx 100.01244$  and  $b \approx 0.000045146$   
 (b)  $-670.63 \mu\text{A}$   
 69.  $3 \ln 2$  71.  $\frac{1}{3} \ln \frac{5}{2}$  73.  $\frac{1}{2}e^2 + e - \frac{1}{2}$   
 75.  $\frac{1}{3}(\ln x)^3 + C$  77.  $-\ln(1 + \cos^2 x) + C$  79.  $90/(\ln 10)$   
 83.  $\pi \ln 2$  85. 45,974 J 87.  $\frac{1}{3}$   
 89.  $0 < m < 1, m - 1 - \ln m$

EXERCISES 7.2\* = PAGE 428

1.  $2 \ln r - \ln 3 - \frac{1}{2} \ln s$  3.  $10 \ln u + 10 \ln v$

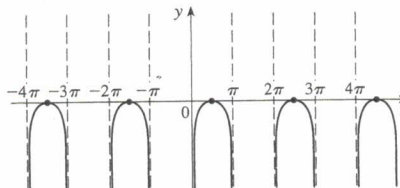
5.  $\ln 1215$  7.  $\ln \frac{(1+x^2)\sqrt{x}}{\sin x}$



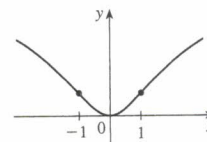
13.  $-\infty$  15.  $f'(x) = (2 + \ln x)/(2\sqrt{x})$   
 17.  $f'(x) = \frac{\cos(\ln x)}{x}$  19.  $f'(x) = \frac{1}{5x^5(\ln x)^4}$   
 21.  $f'(x) = \frac{\sin x}{x} + \cos x \ln(5x)$  23.  $g'(x) = -2a/(a^2 - x^2)$   
 25.  $F'(t) = \frac{6}{2t+1} - \frac{12}{3t-1}$  27.  $g'(x) = \frac{2x^2 - 1}{x(x^2 - 1)}$   
 29.  $f'(u) = \frac{1 + \ln 2}{u[1 + \ln(2u)]^2}$  31.  $y' = \frac{10x + 1}{5x^2 + x - 2}$   
 33.  $y' = \sec^2(\ln(ax + b)) \frac{a}{ax + b}$   
 35.  $y' = x + 2x \ln(2x)$ ;  $y'' = 3 + 2 \ln(2x)$   
 37.  $f'(x) = \frac{2x - 1 - (x-1)\ln(x-1)}{(x-1)[1 - \ln(x-1)]^2}$ ;  $(1, 1 + e) \cup (1 + e, \infty)$   
 39.  $f'(x) = -\frac{1}{2x\sqrt{1 - \ln x}}$ ;  $(0, e]$  41.  $\frac{1}{2}$  43.  $\cos x + 1/x$   
 45.  $y = 2x - 2$  47.  $y' = \frac{2x}{x^2 + y^2 - 2y}$   
 49.  $f^{(n)}(x) = \frac{(-1)^{n-1}(n-1)!}{(x-1)^n}$  51. 2.958516, 5.290718

53. A. All  $x$  in  $(2n\pi, (2n+1)\pi)$  ( $n$  an integer)  
 B. x-int.  $\pi/2 + 2n\pi$  C. Period  $2\pi$  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.



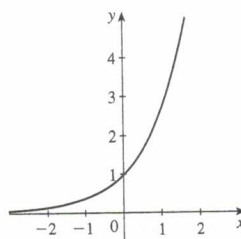
55. A.  $\mathbb{R}$  B. y-int 0; x-int. 0  
 C. About y-axis D. None  
 E. Inc. on  $(0, \infty)$ ;  
 dec. on  $(-\infty, 0)$   
 F. Loc. min.  $f(0) = 0$   
 G. CU on  $(-1, 1)$ ; CD on  
 $(-\infty, -1), (1, \infty)$ ;



- IP  $(\pm 1, \ln 2)$  H. See graph at right.  
 57. Inc. on  $(0, 2.7), (4.5, 8.2), (10.9, 14.3)$ ;  
 IP  $(3.8, 1.7), (5.7, 2.1), (10.0, 2.7), (12.0, 2.9)$   
 59.  $y' = (2x + 1)^5(x^4 - 3)^6 \left( \frac{10}{2x + 1} + \frac{24x^3}{x^4 - 3} \right)$   
 61.  $y' = \frac{\sin^2 x \tan^4 x}{(x^2 + 1)^2} \left( 2 \cot x + \frac{4 \sec^2 x}{\tan x} - \frac{4x}{x^2 + 1} \right)$   
 63.  $3 \ln 2$  65.  $\frac{1}{3} \ln \frac{5}{2}$  67.  $\frac{1}{2}e^2 + e - \frac{1}{2}$  69.  $\frac{1}{3}(\ln x)^3 + C$   
 71.  $-\ln(1 + \cos^2 x) + C$  75.  $\pi \ln 2$  77. 45,974 J  
 79.  $\frac{1}{3}$  81. (b) 0.405 85.  $0 < m < 1, m - 1 - \ln m$

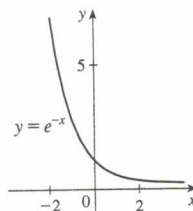
EXERCISES 7.3\* = PAGE 435

1.

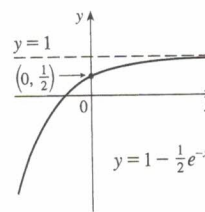


If  $f(x) = e^x$ , then  $f'(0) = 1$ .

3. (a)  $\frac{1}{25}$  (b) 10 5. (a)  $\sqrt{e}$  (b)  $-\ln 5$   
 7. (a)  $\frac{1}{3}(\ln k - 1)$  (b)  $\frac{1}{2}(1 + \sqrt{1 + 4e})$   
 9.  $-3, 0$  11.  $\ln 3$   
 13. (a) 0.5210 (b) 3.0949  
 15. (a)  $x < \ln 10$  (b)  $x > 1/e$   
 17.

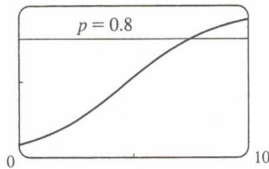


19.

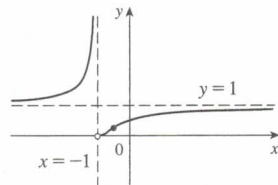


21. (a)  $(-\infty, \frac{1}{2} \ln 3]$  (b)  $f^{-1}(x) = \frac{1}{2} \ln(3 - x^2)$ ,  $[0, \sqrt{3})$   
 23.  $y = e^x - 3$  25.  $f^{-1}(x) = \sqrt[3]{\ln x}$  27. 1 29. 0  
 31. 0 33.  $f'(x) = e^x(x^3 + 3x^2 + 2x + 2)$   
 35.  $y' = 3ax^2 e^{ax^3}$  37.  $f'(u) = (-1/u^2)e^{1/u}$   
 39.  $F'(t) = e^{t \sin 2t}(2t \cos 2t + \sin 2t)$

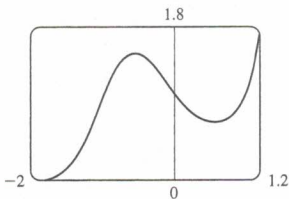
41.  $y' = 3e^{3x}/\sqrt{1+2e^{3x}}$     43.  $y' = e^{e^x}e^x$   
 45.  $y' = \frac{(ad-bc)e^x}{(ce^x+d)^2}$     47.  $y' = \frac{4e^{2x}}{(1+e^{2x})^2} \sin \frac{1-e^{2x}}{1+e^{2x}}$   
 49.  $y = 2x + 1$     51.  $y' = (1 - 2xye^{x^2y})/(x^2e^{x^2y} - 1)$   
 55.  $-4, -2$     57.  $f^{(n)}(x) = 2^n e^{2x}$     59. (b)  $-0.567143$   
 61. (a) 1    (b)  $kae^{-kt}/(1 + ae^{-kt})^2$   
 (c) 1     $t \approx 7.4$  h



63.  $-1$     65.  $f(2) = 2/\sqrt{e}, f(-1) = -1/\sqrt[3]{e}$   
 67. (a) Inc. on  $(2, \infty)$ ; dec. on  $(-\infty, 2)$   
 (b) CU on  $(-\infty, 3)$ ; CD on  $(3, \infty)$     (c)  $(3, -2e^{-3})$   
 69. 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



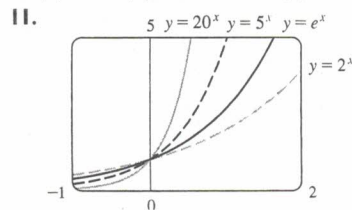
71. 28.57 min, when the rate of increase of drug level in the blood-stream is greatest; 85.71 min, when rate of decrease is greatest  
 73. Loc. max.  $f(-1/\sqrt{3}) = e^{2\sqrt{3}/9} \approx 1.5$ ;  
 loc. min.  $f(1/\sqrt{3}) = e^{-2\sqrt{3}/9} \approx 0.7$ ;  
 IP  $(-0.15, 1.15), (-1.09, 0.82)$



75.  $\frac{1}{3}(1 - e^{-15})$     77.  $\frac{2}{3}(1 + e^x)^{3/2} + C$   
 79.  $\frac{1}{2}e^{2x} + 2x - \frac{1}{2}e^{-2x} + C$     81.  $-e^{\cos x} + C$   
 83.  $2e^{\sqrt{x}} + C$     85. 4.644    87.  $\pi(e^2 - 1)/2$     91.  $\frac{1}{2}$

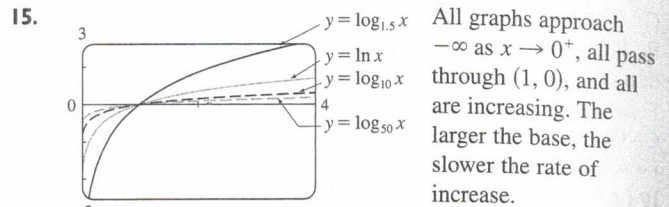
EXERCISES 7.4\* ■ PAGE 445

1. (a)  $a^x = e^{x \ln a}$     (b)  $(-\infty, \infty)$     (c)  $(0, \infty)$   
 (d) See Figures 1, 3, and 2.    3.  $e^{\sqrt{7} \ln 5}$     5.  $e^{x \ln \cos x}$   
 7. (a) 3    (b)  $-3$     9. (a) 3    (b)  $-2$



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) 0.402430    (b) 1.454240    (c) 1.651496



17.  $f(x) = 3 \cdot 2^x$     19. (b) About 1,084,588 mi  
 21.  $\infty$     23. 0  
 25.  $h'(t) = 3t^2 - 3^t \ln 3$     27.  $y' = 5^{-1/x}(\ln 5)/x^2$   
 29.  $f'(u) = 10 \ln 2 (2^u + 2^{-u})^9 (2^u - 2^{-u})$   
 31.  $f'(x) = \frac{3}{(3x-1) \ln 2}$     33.  $y' = \frac{1}{\ln 10} + \log_{10} x$   
 35.  $y' = x^x(1 + \ln x)$     37.  $y' = x^{\sin x} \left( \frac{\sin x}{x} + \cos x \ln x \right)$   
 39.  $y' = (\cos x)^x (-x \tan x + \ln \cos x)$   
 41.  $y' = (\tan x)^{1/x} \left( \frac{\sec^2 x}{x \tan x} - \frac{\ln \tan x}{x^2} \right)$   
 43.  $y = (10 \ln 10)x + 10(1 - \ln 10)$     45.  $90/(\ln 10)$   
 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.  $y = \frac{1}{10^x - 1}$     57. 8.3  
 59.  $10^8/\ln 10$  dB/(watt/m<sup>2</sup>)  
 61. (a)  $y = ab^t$  where  $a \approx 100.01244$  and  $b \approx 0.000045146$   
 (b)  $-670.63 \mu\text{A}$

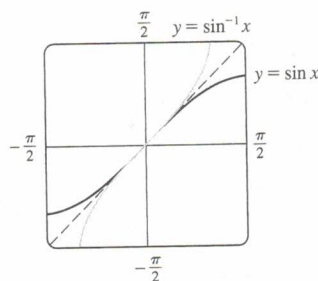
EXERCISES 7.5 ■ PAGE 453

1. About 235  
 3. (a)  $100(4.2)^t$     (b)  $\approx 7409$     (c)  $\approx 10,632$  bacteria/h  
 (d)  $(\ln 100)/(\ln 4.2) \approx 3.2$  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)  $\approx 9.92$  mg    (c)  $\approx 199.3$  years  
 11.  $\approx 2500$  years    13. (a)  $\approx 137^\circ\text{F}$     (b)  $\approx 116$  min  
 15. (a)  $13.3^\circ\text{C}$     (b)  $\approx 67.74$  min  
 17. (a)  $\approx 64.5$  kPa    (b)  $\approx 39.9$  kPa  
 19. (a) (i) \$3828.84    (ii) \$3840.25    (iii) \$3850.08  
 (iv) \$3851.61    (v) \$3852.01    (vi) \$3852.08  
 (b)  $dA/dt = 0.05A, A(0) = 3000$

EXERCISES 7.6 ■ PAGE 461

1. (a)  $\pi/3$     (b)  $\pi$     3. (a)  $\pi/4$     (b)  $\pi/4$   
 5. (a) 10    (b)  $\pi/3$     7.  $2/\sqrt{5}$     9.  $\frac{2}{3}\sqrt{2}$   
 13.  $x/\sqrt{1+x^2}$

15.

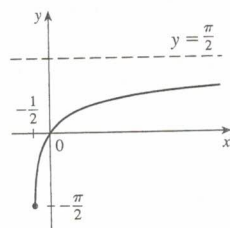


The second graph is the reflection of the first graph about the line  $y = x$ .

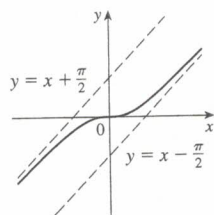
23.  $y' = \frac{1}{2\sqrt{x(1+x)}}$     25.  $y' = \frac{1}{\sqrt{-x^2-x}}$   
 27.  $G'(x) = -1 - \frac{x \arccos x}{\sqrt{1-x^2}}$     29.  $y' = -2e^{2x}/\sqrt{1-e^{4x}}$   
 31.  $y' = -(\sin \theta)/(1 + \cos^2 \theta)$     33.  $h'(t) = 0$   
 35.  $y' = \sqrt{a^2 - b^2}/(a + b \cos x)$   
 37.  $g'(x) = 2/\sqrt{1-(3-2x)^2}$ ; [1, 2], (1, 2)    39.  $\pi/6$

41.  $1 - \frac{x \arcsin x}{\sqrt{1-x^2}}$     43.  $-\pi/2$     45.  $\pi/2$   
 47. At a distance  $5 - 2\sqrt{5}$  from A    49.  $\frac{1}{4}$  rad/s

51. 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



53. 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.



55. Max. at  $x = 0$ , min. at  $x \approx \pm 0.87$ , IP at  $x \approx \pm 0.52$   
 57.  $\tan^{-1}x + x + C$   
 59.  $\pi$     61.  $\pi/12$     63.  $\tan^{-1}x + \frac{1}{2} \ln(1+x^2) + C$   
 65.  $\ln|\sin^{-1}x| + C$     67.  $\frac{1}{3} \sin^{-1}t^3 + C$   
 69.  $2 \tan^{-1}\sqrt{x} + C$     73.  $\pi/2 - 1$

EXERCISES 7.7 ■ PAGE 468

1. (a) 0    (b) 1    3. (a)  $\frac{3}{4}$     (b)  $\frac{1}{2}(e^2 - e^{-2}) \approx 3.62686$   
 5. (a) 1    (b) 0  
 21.  $\operatorname{sech} x = \frac{3}{5}$ ,  $\sinh x = \frac{4}{3}$ ,  $\operatorname{csch} x = \frac{3}{4}$ ,  $\tanh x = \frac{4}{5}$ ,  $\coth x = \frac{5}{4}$   
 23. (a) 1    (b) -1    (c)  $\infty$     (d)  $-\infty$     (e) 0    (f) 1  
 (g)  $\infty$     (h)  $-\infty$     (i) 0  
 31.  $f'(x) = x \cosh x$     33.  $h'(x) = \tanh x$   
 35.  $y' = 3e^{\cosh 3x} \sinh 3x$     37.  $f'(t) = -2e^t \operatorname{sech}^2(e^t) \tanh(e^t)$

39.  $y' = \frac{\operatorname{sech}^2 x}{1 + \tanh^2 x}$     41.  $G'(x) = \frac{-2 \sinh x}{(1 + \cosh x)^2}$

43.  $y' = \frac{1}{2\sqrt{x(1-x)}}$     45.  $y' = \sinh^{-1}(x/3)$

47.  $y' = \frac{-1}{x\sqrt{x^2+1}}$

51. (a) 0.3572    (b) 70.34°

53. (b)  $y = 2 \sinh 3x - 4 \cosh 3x$

55.  $(\ln(1 + \sqrt{2}), \sqrt{2})$

57.  $\frac{1}{3} \cosh^3 x + C$     59.  $2 \cosh \sqrt{x} + C$     61.  $-\operatorname{csch} x + C$

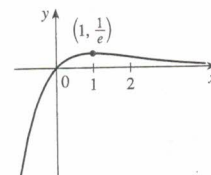
63.  $\ln\left(\frac{6 + 3\sqrt{3}}{4 + \sqrt{7}}\right)$     65.  $\tanh^{-1}e^x + C$

67. (a) 0, 0.48    (b) 0.04

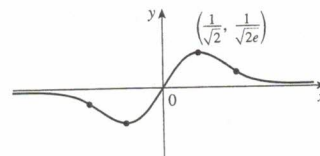
EXERCISES 7.8 ■ PAGE 478

1. (a) Indeterminate    (b) 0    (c) 0  
 (d)  $\infty, -\infty$ , or does not exist    (e) Indeterminate  
 3. (a)  $-\infty$     (b) Indeterminate    (c)  $\infty$   
 5. 2    7.  $\frac{9}{5}$     9.  $-\infty$     11.  $\infty$     13.  $p/q$   
 15. 0    17.  $-\infty$     19.  $\infty$     21.  $\frac{1}{2}$     23. 1  
 25.  $\ln \frac{5}{3}$     27. 1    29.  $\frac{1}{2}$     31. 0    33.  $-1/\pi^2$   
 35.  $\frac{1}{2}a(a-1)$     37.  $\frac{1}{24}$     39.  $\pi$     41. 3    43. 0  
 45.  $-2/\pi$     47.  $\frac{1}{2}$     49.  $\frac{1}{2}$     51.  $\infty$     53. 1  
 55.  $e^{-2}$     57.  $e^3$     59. 1    61.  $e^4$   
 63.  $1/\sqrt{e}$     65.  $e^2$     67.  $\frac{1}{4}$

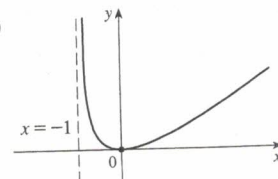
69. A.  $\mathbb{R}$     B. y-int. 0; x-int. 0  
 C. None    D. HA  $y = 0$   
 E. Inc. on  $(-\infty, 1)$ , dec. on  $(1, \infty)$   
 F. Loc. max.  $f(1) = 1/e$   
 G. CU on  $(2, \infty)$ ; CD on  $(-\infty, 2)$   
 IP  $(2, 2/e^2)$   
 H. See graph at right.

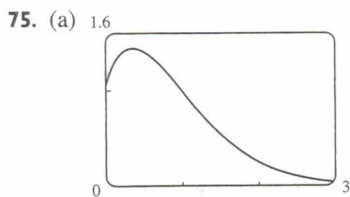


71. A.  $\mathbb{R}$     B. y-int. 0; x-int. 0    C. About (0, 0)    D. HA  $y = 0$   
 E. Inc. on  $(-1/\sqrt{2}, 1/\sqrt{2})$ ; dec. on  $(-\infty, -1/\sqrt{2})$ ,  $(1/\sqrt{2}, \infty)$   
 F. Loc. min.  $f(-1/\sqrt{2}) = -1/\sqrt{2}e$ ; loc. max.  $f(1/\sqrt{2}) = 1/\sqrt{2}e$   
 G. CU on  $(-\sqrt{3}/2, 0)$ ,  $(\sqrt{3}/2, \infty)$ ; CD on  $(-\infty, -\sqrt{3}/2)$ ,  $(0, \sqrt{3}/2)$ ;  
 IP  $(\pm\sqrt{3}/2, \pm\sqrt{3}/2e^{-3/2})$ , (0, 0)  
 H.

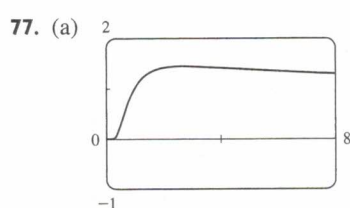


73. A.  $(-1, \infty)$     B. y-int. 0; x-int. 0  
 C. None    D. VA  $x = -1$   
 E. Inc. on  $(0, \infty)$ ; dec. on  $(-1, 0)$   
 F. Loc. min.  $f(0) = 0$   
 G. CU on  $(-1, \infty)$   
 H. See graph at right.

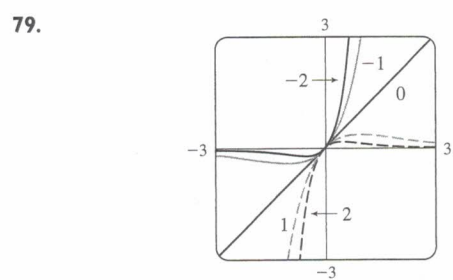




- (b)  $\lim_{x \rightarrow 0^+} x^{-x} = 1$   
 (c) Max. value  $f(1/e) = e^{1/e} \approx 1.44$  (d) 1.0



- (b)  $\lim_{x \rightarrow 0^+} x^{1/x} = 0, \lim_{x \rightarrow \infty} x^{1/x} = 1$   
 (c) Max. value  $f(e) = e^{1/e} \approx 1.44$  (d) IP at  $x \approx 0.58, 4.37$



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 maximum and minimum points and the IPs get closer to the origin.

81. 1 87.  $\pi/6$  89. 56 97.  $\frac{1}{3}$  99. (a) 0

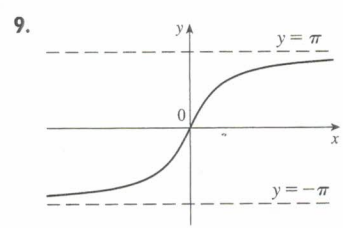
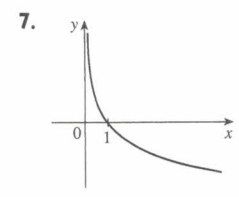
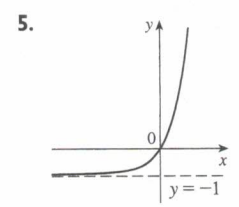
CHAPTER 7 REVIEW ■ PAGE 483

True-False Quiz

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

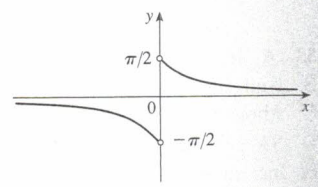
Exercises

1. No 3. (a) 7 (b)  $\frac{1}{8}$

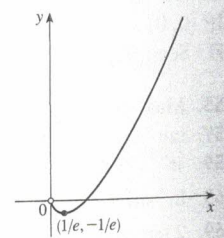


11. (a) 9 (b) 2 13.  $e^{1/3}$   
 15.  $\ln \ln 17$  17.  $\sqrt{1+e}$   
 19.  $\tan 1$  21.  $f'(t) = t + 2t \ln t$   
 23.  $h'(\theta) = 2 \sec^2(2\theta)e^{\tan 2\theta}$  25.  $y' = 5 \sec 5x$   
 27.  $y' = (1+c^2)e^{cx} \sin x$  29.  $y' = 2 \tan x$   
 31.  $y' = -\frac{e^{1/x}(1+2x)}{x^4}$  33.  $y' = 3^x \ln 3 (\ln 3)(1 + \ln x)$   
 35.  $H'(v) = (v/(1+v^2)) + \tan^{-1}v$   
 37.  $y' = 2x^2 \cosh(x^2) + \sinh(x^2)$   
 39.  $y' = \cot x - \sin x \cos x$  41.  $y' = -(1/x)[1 + 1/(\ln x)^2]$   
 43.  $y' = 3 \tanh 3x$  45.  $y' = (\cosh x)/\sqrt{\sinh^2 x - 1}$   
 47.  $y' = \frac{-3 \sin(e^{\sqrt{\tan 3x}})e^{\sqrt{\tan 3x}} \sec^2(3x)}{2\sqrt{\tan 3x}}$  49.  $f'(x) = g'(x)e^{g(x)}$   
 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.  $-\infty$  69.  $-1$  71.  $\pi$  73. 8  
 75. 0 77.  $\frac{1}{2}$

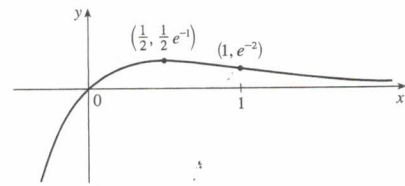
79. A.  $\{x | x \neq 0\}$  B. None  
 C. About  $(0, 0)$  D. HA  $y = 0$   
 E. Dec. on  $(-\infty, 0)$  and  $(0, \infty)$   
 F. None  
 G. CU on  $(0, \infty)$ ; CD on  $(-\infty, 0)$   
 H. See graph at right.



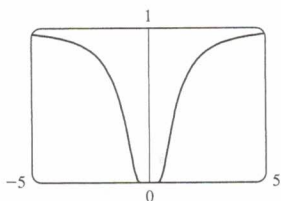
81. A.  $(0, \infty)$  B. x-int. 1  
 C. None D. None  
 E. Inc. on  $(1/e, \infty)$ ; dec. on  $(0, 1/e)$   
 F. Loc. min.  $f(1/e) = -1/e$   
 G. CU on  $(0, \infty)$   
 H. See graph at right.



83. A.  $\mathbb{R}$  B. y-int. 0, x-int. 0 C. None D. HA  $y = 0$   
 E. Inc. on  $(-\infty, \frac{1}{2})$ , dec. on  $(\frac{1}{2}, \infty)$  F. Loc. max.  $f(\frac{1}{2}) = 1/(2e)$   
 G. CU on  $(1, \infty)$ ; CD on  $(-\infty, 1)$ ; IP  $(1, e^{-2})$   
 H.



85.  $(\pm 0.82, 0.22); (\pm\sqrt{2/3}, e^{-3/2})$



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)  $200(3.24)^t$  (b)  $\approx 22,040$   
 (c)  $\approx 25,910$  bacteria/h (d)  $(\ln 50)/(\ln 3.24) \approx 3.33$  h  
 91. 4.32 days 93.  $\frac{1}{4}(1 - e^{-2})$  95.  $\arctan e - \pi/4$   
 97.  $2e^{\sqrt{x}} + C$  99.  $\frac{1}{2} \ln|x^2 + 2x| + C$   
 101.  $-\frac{1}{2}[\ln(\cos x)]^2 + C$  103.  $2^{\tan \theta}/\ln 2 + C$   
 105.  $-(1/x) - 2 \ln|x| + x + C$  109.  $e^{\sqrt{x}}/(2x)$   
 111.  $\frac{1}{3} \ln 4$  113.  $\pi^2/4$  115.  $\frac{2}{3}$  117.  $2/e$   
 121.  $f(x) = e^{2x}(1 + 2x)/(1 - e^{-x})$

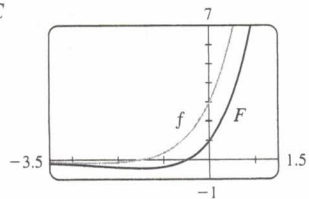
PROBLEMS PLUS ■ PAGE 487

7.  $1/\sqrt{2}$  9.  $\frac{1}{2}$  13.  $2\sqrt{e}$  15.  $a \leq e^{1/e}$

CHAPTER 8

EXERCISES 8.1 ■ PAGE 493

1.  $\frac{1}{3}x^3 \ln x - \frac{1}{9}x^3 + C$  3.  $\frac{1}{5}x \sin 5x + \frac{1}{25} \cos 5x + C$   
 5.  $2(r - 2)e^{r/2} + C$   
 7.  $-\frac{1}{\pi}x^2 \cos \pi x + \frac{2}{\pi^2}x \sin \pi x + \frac{2}{\pi^3} \cos \pi x + C$   
 9.  $\frac{1}{2}(2x + 1) \ln(2x + 1) - x + C$   
 11.  $t \arctan 4t - \frac{1}{8} \ln(1 + 16t^2) + C$   
 13.  $\frac{1}{2}t \tan 2t - \frac{1}{4} \ln|\sec 2t| + C$   
 15.  $x(\ln x)^2 - 2x \ln x + 2x + C$   
 17.  $\frac{1}{15}e^{2\theta}(2 \sin 3\theta - 3 \cos 3\theta) + C$   
 19.  $\pi/3$  21.  $1 - 1/e$  23.  $\frac{1}{2} - \frac{1}{2} \ln 2$  25.  $\frac{1}{4} - \frac{3}{4}e^{-2}$   
 27.  $\frac{1}{6}(\pi + 6 - 3\sqrt{3})$  29.  $\sin x (\ln \sin x - 1) + C$   
 31.  $\frac{32}{5}(\ln 2)^2 - \frac{64}{25} \ln 2 + \frac{62}{125}$   
 33.  $2\sqrt{x} \sin \sqrt{x} + 2 \cos \sqrt{x} + C$  35.  $-\frac{1}{2} - \pi/4$   
 37.  $\frac{1}{2}(x^2 - 1) \ln(1 + x) - \frac{1}{4}x^2 + \frac{1}{2}x + \frac{3}{4} + C$   
 39.  $(2x + 1)e^x + C$

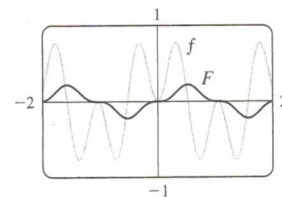
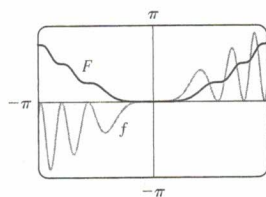


41.  $\frac{1}{3}x^2(1 + x^2)^{3/2} - \frac{2}{15}(1 + x^2)^{5/2} + C$   
 43. (b)  $-\frac{1}{4} \cos x \sin^3 x + \frac{3}{8}x - \frac{3}{16} \sin 2x + C$   
 45. (b)  $\frac{2}{3}, \frac{8}{15}$  51.  $x(\ln x)^3 - 3x(\ln x)^2 + 6x \ln x - 6x + C$   
 53.  $\frac{25}{4} - \frac{75}{4}e^{-2}$  55. 1.0475, 2.8731; 2.1828 57.  $4 - 8/\pi$

59.  $2\pi e$  61.  $\frac{9}{2} \ln 3 - \frac{13}{9}$  63.  $2 - e^{-t}(t^2 + 2t + 2)$  m  
 65. 2

EXERCISES 8.2 ■ PAGE 501

1.  $\frac{1}{5} \cos^5 x - \frac{1}{3} \cos^3 x + C$  3.  $-\frac{11}{384}$   
 5.  $\frac{1}{3\pi} \sin^3(\pi x) - \frac{2}{5\pi} \sin^5(\pi x) + \frac{1}{7\pi} \sin^7(\pi x) + C$   
 7.  $\pi/4$  9.  $3\pi/8$  11.  $\frac{3}{2}\theta + 2 \sin \theta + \frac{1}{4} \sin 2\theta + C$   
 13.  $\pi/16$  15.  $\frac{2}{45} \sqrt{\sin \alpha} (45 - 18 \sin^2 \alpha + 15 \sin^4 \alpha) + C$   
 17.  $\frac{1}{2} \cos^2 x - \ln |\cos x| + C$  19.  $\ln |\sin x| + 2 \sin x + C$   
 21.  $\frac{1}{2} \tan^2 x + C$  23.  $\tan x - x + C$   
 25.  $\frac{1}{5} \tan^5 t + \frac{2}{3} \tan^3 t + \tan t + C$  27.  $\frac{117}{8}$   
 29.  $\frac{1}{3} \sec^3 x - \sec x + C$   
 31.  $\frac{1}{4} \sec^4 x - \tan^2 x + \ln |\sec x| + C$   
 33.  $\frac{1}{6} \tan^6 \theta + \frac{1}{4} \tan^4 \theta + C$   
 35.  $x \sec x - \ln |\sec x + \tan x| + C$  37.  $\sqrt{3} - \frac{1}{3}\pi$   
 39.  $\frac{1}{3} \csc^3 \alpha - \frac{1}{5} \csc^5 \alpha + C$  41.  $\ln |\csc x - \cot x| + C$   
 43.  $-\frac{1}{6} \cos 3x - \frac{1}{26} \cos 13x + C$  45.  $\frac{1}{8} \sin 4\theta - \frac{1}{12} \sin 6\theta + C$   
 47.  $\frac{1}{2} \sin 2x + C$  49.  $\frac{1}{10} \tan^5(t^2) + C$   
 51.  $\frac{1}{4}x^2 - \frac{1}{4} \sin(x^2) \cos(x^2) + C$  53.  $\frac{1}{6} \sin 3x - \frac{1}{18} \sin 9x + C$



55. 0 57. 1 59. 0 61.  $\pi^2/4$  63.  $\pi(2\sqrt{2} - \frac{5}{2})$   
 65.  $s = (1 - \cos^3 \omega t)/(3\omega)$

EXERCISES 8.3 ■ PAGE 508

1.  $\sqrt{x^2 - 9}/(9x) + C$  3.  $\frac{1}{3}(x^2 - 18)\sqrt{x^2 + 9} + C$   
 5.  $\pi/24 + \sqrt{3}/8 - \frac{1}{4}$  7.  $-\sqrt{25 - x^2}/(25x) + C$   
 9.  $\ln(\sqrt{x^2 + 16} + x) + C$  11.  $\frac{1}{4} \sin^{-1}(2x) + \frac{1}{2}x\sqrt{1 - 4x^2} + C$   
 13.  $\frac{1}{6} \sec^{-1}(x/3) - \sqrt{x^2 - 9}/(2x^2) + C$   
 15.  $\frac{1}{16}\pi a^4$  17.  $\sqrt{x^2 - 7} + C$   
 19.  $\ln|(\sqrt{1 + x^2} - 1)/x| + \sqrt{1 + x^2} + C$  21.  $\frac{9}{500}\pi$   
 23.  $\frac{9}{2} \sin^{-1}((x - 2)/3) + \frac{1}{2}(x - 2)\sqrt{5 + 4x - x^2} + C$   
 25.  $\sqrt{x^2 + x + 1} - \frac{1}{2} \ln(\sqrt{x^2 + x + 1} + x + \frac{1}{2}) + C$   
 27.  $\frac{1}{2}(x + 1)\sqrt{x^2 + 2x} - \frac{1}{2} \ln|x + 1 + \sqrt{x^2 + 2x}| + C$   
 29.  $\frac{1}{4} \sin^{-1}(x^2) + \frac{1}{4}x^2\sqrt{1 - x^4} + C$   
 33.  $\frac{1}{6}(\sqrt{48} - \sec^{-1} 7)$  37. 0.81, 2; 2.10  
 41.  $r\sqrt{R^2 - r^2} + \pi r^2/2 - R^2 \arcsin(r/R)$  43.  $2\pi^2 R r^2$

EXERCISES 8.4 ■ PAGE 517

1. (a)  $\frac{A}{x + 3} + \frac{B}{3x + 1}$  (b)  $\frac{A}{x} + \frac{B}{x + 1} + \frac{C}{(x + 1)^2}$   
 3. (a)  $\frac{A}{x} + \frac{B}{x^2} + \frac{C}{x^3} + \frac{Dx + E}{x^2 + 4}$   
 (b)  $\frac{A}{x + 3} + \frac{B}{(x + 3)^2} + \frac{C}{x - 3} + \frac{D}{(x - 3)^2}$

5. (a)  $1 + \frac{A}{x-1} + \frac{B}{x+1} + \frac{Cx+D}{x^2+1}$   
 (b)  $\frac{At+B}{t^2+1} + \frac{Ct+D}{t^2+4} + \frac{Et+F}{(t^2+4)^2}$
7.  $x + 6 \ln|x-6| + C$
9.  $2 \ln|x+5| - \ln|x-2| + C$     11.  $\frac{1}{2} \ln \frac{3}{2}$
13.  $a \ln|x-b| + C$     15.  $\frac{7}{6} + \ln \frac{2}{3}$
17.  $\frac{27}{5} \ln 2 - \frac{9}{5} \ln 3$  (or  $\frac{9}{5} \ln \frac{8}{3}$ )
19.  $-\frac{1}{36} \ln|x+5| + \frac{1}{6} \frac{1}{x+5} + \frac{1}{36} \ln|x-1| + C$
21.  $\frac{1}{2}x^2 - 2 \ln(x^2+4) + 2 \tan^{-1}(x/2) + C$
23.  $2 \ln|x| + (1/x) + 3 \ln|x+2| + C$
25.  $\ln|x-1| - \frac{1}{2} \ln(x^2+9) - \frac{1}{3} \tan^{-1}(x/3) + C$
27.  $\frac{1}{2} \ln(x^2+1) + (1/\sqrt{2}) \tan^{-1}(x/\sqrt{2}) + C$
29.  $\frac{1}{2} \ln(x^2+2x+5) + \frac{3}{2} \tan^{-1}\left(\frac{x+1}{2}\right) + C$
31.  $\frac{1}{3} \ln|x-1| - \frac{1}{6} \ln(x^2+x+1) - \frac{1}{\sqrt{3}} \tan^{-1} \frac{2x+1}{\sqrt{3}} + C$
33.  $\frac{1}{4} \ln \frac{8}{3}$     35.  $\frac{1}{16} \ln|x| - \frac{1}{32} \ln(x^2+4) + \frac{1}{8(x^2+4)} + C$
37.  $\frac{7}{8} \sqrt{2} \tan^{-1}\left(\frac{x-2}{\sqrt{2}}\right) + \frac{3x-8}{4(x^2-4x+6)} + C$
39.  $\ln \left| \frac{\sqrt{x+1}-1}{\sqrt{x+1}+1} \right| + C$
41.  $2 + \ln \frac{25}{9}$     43.  $\frac{3}{10}(x^2+1)^{5/3} - \frac{3}{4}(x^2+1)^{2/3} + C$
45.  $2\sqrt{x} + 3\sqrt[3]{x} + 6\sqrt[6]{x} + 6 \ln|\sqrt[6]{x}-1| + C$
47.  $\ln \left[ \frac{(e^x+2)^2}{e^x+1} \right] + C$
49.  $\ln|\tan t + 1| - \ln|\tan t + 2| + C$
51.  $(x - \frac{1}{2}) \ln(x^2 - x + 2) - 2x + \sqrt{7} \tan^{-1}\left(\frac{2x-1}{\sqrt{7}}\right) + C$
53.  $-\frac{1}{2} \ln 3 \approx -0.55$
55.  $\frac{1}{2} \ln \left| \frac{x-2}{x} \right| + C$     59.  $\frac{1}{5} \ln \left| \frac{2 \tan(x/2) - 1}{\tan(x/2) + 2} \right| + C$
61.  $4 \ln \frac{2}{3} + 2$     63.  $-1 + \frac{11}{3} \ln 2$
65.  $t = -\ln P - \frac{1}{9} \ln(0.9P + 900) + C$ , where  $C \approx 10.23$
67. (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.

EXERCISES 8.5 ■ PAGE 524

1.  $\sin x + \frac{1}{3} \sin^3 x + C$
3.  $\sin x + \ln|\csc x - \cot x| + C$
5.  $4 - \ln 9$     7.  $e^{\pi/4} - e^{-\pi/4}$
9.  $\frac{243}{5} \ln 3 - \frac{242}{25}$     11.  $\frac{1}{2} \ln(x^2 - 4x + 5) + \tan^{-1}(x-2) + C$
13.  $\frac{1}{8} \cos^8 \theta - \frac{1}{6} \cos^6 \theta + C$  (or  $\frac{1}{4} \sin^4 \theta - \frac{1}{3} \sin^6 \theta + \frac{1}{8} \sin^8 \theta + C$ )
15.  $x/\sqrt{1-x^2} + C$
17.  $\frac{1}{4}x^2 - \frac{1}{2}x \sin x \cos x + \frac{1}{4} \sin^2 x + C$   
 (or  $\frac{1}{4}x^2 - \frac{1}{4}x \sin 2x - \frac{1}{8} \cos 2x + C$ )
19.  $e^{e^x} + C$     21.  $(x+1) \arctan \sqrt{x} - \sqrt{x} + C$
23.  $\frac{4097}{45}$     25.  $3x + \frac{23}{3} \ln|x-4| - \frac{5}{3} \ln|x+2| + C$
27.  $x - \ln(1+e^x) + C$     29.  $15 + 7 \ln \frac{2}{7}$
31.  $\sin^{-1}x - \sqrt{1-x^2} + C$
33.  $2 \sin^{-1}\left(\frac{x+1}{2}\right) + \frac{x+1}{2} \sqrt{3-2x-x^2} + C$
35. 0    37.  $\pi/8 - \frac{1}{4}$     39.  $\ln|\sec \theta - 1| - \ln|\sec \theta| + C$
41.  $\theta \tan \theta - \frac{1}{2} \theta^2 - \ln|\sec \theta| + C$     43.  $\frac{2}{3}(1+e^x)^{3/2} + C$
45.  $-\frac{1}{3}(x^3+1)e^{-x^3} + C$
47.  $\ln|x-1| - 3(x-1)^{-1} - \frac{3}{2}(x-1)^{-2} - \frac{1}{3}(x-1)^{-3} + C$
49.  $\ln \left| \frac{\sqrt{4x+1}-1}{\sqrt{4x+1}+1} \right| + C$     51.  $-\ln \left| \frac{\sqrt{4x^2+1}+1}{2x} \right| + C$
53.  $\frac{1}{m}x^2 \cosh(mx) - \frac{2}{m^2}x \sinh(mx) + \frac{2}{m^3} \cosh(mx) + C$
55.  $2 \ln \sqrt{x} - 2 \ln(1+\sqrt{x}) + C$
57.  $\frac{3}{7}(x+c)^{7/3} - \frac{3}{4}c(x+c)^{4/3} + C$
59.  $\sin(\sin x) - \frac{1}{3} \sin^3(\sin x) + C$     61.  $2(x-2\sqrt{x}+2)e^{\sqrt{x}} + C$
63.  $-\tan^{-1}(\cos^2 x) + C$     65.  $\frac{2}{3}[(x+1)^{3/2} - x^{3/2}] + C$
67.  $\sqrt{2} - 2/\sqrt{3} + \ln(2+\sqrt{3}) - \ln(1+\sqrt{2})$
69.  $e^x - \ln(1+e^x) + C$
71.  $-\sqrt{1-x^2} + \frac{1}{2}(\arcsin x)^2 + C$
73.  $\frac{1}{8} \ln|x-2| - \frac{1}{16} \ln(x^2+4) - \frac{1}{8} \tan^{-1}(x/2) + C$
75.  $2(x-2)\sqrt{1+e^x} + 2 \ln \frac{\sqrt{1+e^x}+1}{\sqrt{1+e^x}-1} + C$
77.  $\frac{2}{3} \tan^{-1}(x^{3/2}) + C$
79.  $\frac{1}{3}x \sin^3 x + \frac{1}{3} \cos x - \frac{1}{9} \cos^3 x + C$     81.  $xe^{x^2} + C$

EXERCISES 8.6 ■ PAGE 529

1.  $(-1/x)\sqrt{7-2x^2} - \sqrt{2} \sin^{-1}(\sqrt{2}x/\sqrt{7}) + C$
3.  $\frac{1}{2\pi} \sec(\pi x) \tan(\pi x) + \frac{1}{2\pi} \ln|\sec(\pi x) + \tan(\pi x)| + C$
5.  $\pi/4$     7.  $\frac{1}{2\pi} \tan^2(\pi x) + \frac{1}{\pi} \ln|\cos(\pi x)| + C$
9.  $-\sqrt{4x^2+9}/(9x) + C$     11.  $e - 2$
13.  $-\frac{1}{2} \tan^2(1/z) - \ln|\cos(1/z)| + C$
15.  $\frac{1}{2}(e^{2x}+1) \arctan(e^x) - \frac{1}{2}e^x + C$
17.  $\frac{2y-1}{8} \sqrt{6+4y-4y^2} + \frac{7}{8} \sin^{-1}\left(\frac{2y-1}{\sqrt{7}}\right) - \frac{1}{12}(6+4y-4y^2)^{3/2} + C$

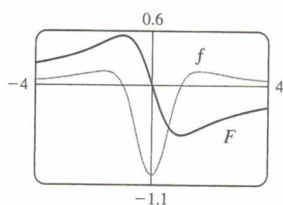


19.  $\frac{1}{9} \sin^3 x [3 \ln(\sin x) - 1] + C$
21.  $\frac{1}{2\sqrt{3}} \ln \left| \frac{e^x + \sqrt{3}}{e^x - \sqrt{3}} \right| + C$
23.  $\frac{1}{4} \tan x \sec^3 x + \frac{3}{8} \tan x \sec x + \frac{3}{8} \ln |\sec x + \tan x| + C$
25.  $\frac{1}{2} (\ln x) \sqrt{4 + (\ln x)^2} + 2 \ln |\ln x + \sqrt{4 + (\ln x)^2}| + C$
27.  $\sqrt{e^{2x} - 1} - \cos^{-1}(e^{-x}) + C$
29.  $\frac{1}{5} \ln |x^5 + \sqrt{x^{10} - 2}| + C$      31.  $2\pi^2$
35.  $\frac{1}{3} \tan x \sec^2 x + \frac{2}{3} \tan x + C$
37.  $\frac{1}{4} x(x^2 + 2) \sqrt{x^2 + 4} - 2 \ln(\sqrt{x^2 + 4} + x) + C$
39.  $\frac{1}{10} (1 + 2x)^{5/2} - \frac{1}{6} (1 + 2x)^{3/2} + C$
41.  $-\ln |\cos x| - \frac{1}{2} \tan^2 x + \frac{1}{4} \tan^4 x + C$
43. (a)  $-\ln \left| \frac{1 + \sqrt{1 - x^2}}{x} \right| + C;$

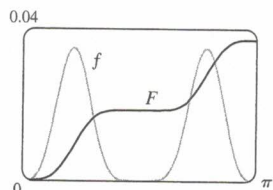
both have domain  $(-1, 0) \cup (0, 1)$

45.  $F(x) = \frac{1}{2} \ln(x^2 - x + 1) - \frac{1}{2} \ln(x^2 + x + 1);$

max. at  $-1$ , min. at  $1$ ; IP at  $-1.7, 0$ , and  $1.7$



47.  $F(x) = -\frac{1}{10} \sin^3 x \cos^7 x - \frac{3}{80} \sin x \cos^7 x + \frac{1}{160} \sin x \cos^5 x$   
 $+ \frac{1}{128} \sin x \cos^3 x + \frac{3}{256} \sin x \cos x + \frac{3}{256} x;$   
 max. at  $\pi$ , min. at  $0$ ; IP at  $0.7, \pi/2$ , and  $2.5$



### EXERCISES 8.7 ■ PAGE 541

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)  $5.932957, E_M \approx -0.063353$   
 (b)  $5.869247, E_S \approx 0.000357$
7. (a)  $2.413790$     (b)  $2.411453$     (c)  $2.412232$
9. (a)  $0.146879$     (b)  $0.147391$     (c)  $0.147219$
11. (a)  $0.451948$     (b)  $0.451991$     (c)  $0.451976$
13. (a)  $4.513618$     (b)  $4.748256$     (c)  $4.675111$

15. (a)  $-0.495333$     (b)  $-0.543321$     (c)  $-0.526123$

17. (a)  $1.064275$     (b)  $1.067416$     (c)  $1.074915$

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) The actual error is much smaller.

- (f)  $10.9$     (g)  $7.953789422$     (h)  $0.0593$

- (i) The actual error is smaller.    (j)  $n \geq 50$

25.

$n$	$L_n$	$R_n$	$T_n$	$M_n$
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 after Example 1.

27.

$n$	$T_n$	$M_n$	$S_n$
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

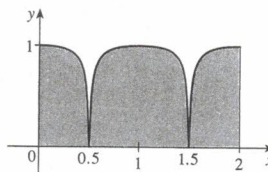
Observations are the same as after Example 1.

29. (a)  $19.8$     (b)  $20.6$     (c)  $20.5\bar{3}$

31. (a)  $23.44$     (b)  $0.341\bar{3}$     33.  $37.7\bar{3}$  ft/s

35.  $10,177$  megawatt-hours    37.  $828$     39.  $6.0$     41.  $59.4$

- 43.



### EXERCISES 8.8 ■ PAGE 551

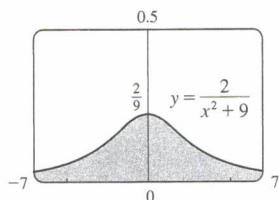
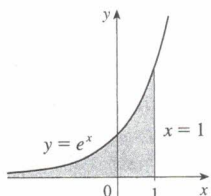
Abbreviations: C, convergent; D, divergent

1. (a) Infinite interval    (b) Infinite discontinuity

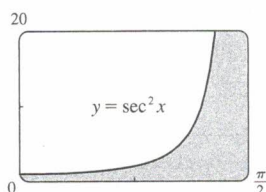
- (c) Infinite discontinuity    (d) Infinite interval

3.  $\frac{1}{2} - 1/(2t^2); 0.495, 0.49995, 0.4999995; 0.5$

5.  $\frac{1}{12}$  7. D 9.  $2e^{-2}$  11. D 13. 0 15. D  
 17. D 19.  $\frac{1}{25}$  21. D 23.  $\pi/9$   
 25.  $\frac{1}{2}$  27. D 29.  $\frac{32}{3}$  31. D 33.  $\frac{75}{4}$   
 35. D 37.  $-2/e$  39.  $\frac{8}{3} \ln 2 - \frac{8}{9}$   
 41.  $e$  43.  $2\pi/3$



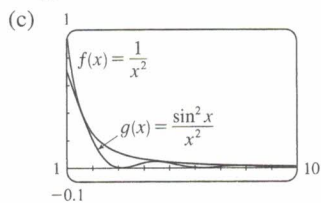
45. Infinite area



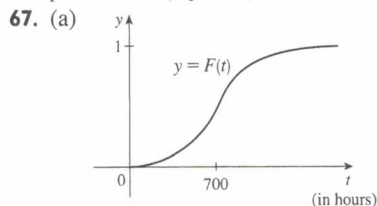
47. (a)

$t$	$\int_1^t [(\sin^2 x)/x^2] dx$
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.



49. C 51. D 53. D 55.  $\pi$  57.  $p < 1, 1/(1-p)$   
 59.  $p > -1, -1/(p+1)^2$  65.  $\sqrt{2GM/R}$



- (b) The rate at which the fraction  $F(t)$  increases as  $t$  increases  
 (c) 1; all bulbs burn out eventually  
 69. 1000  
 71. (a)  $F(s) = 1/s, s > 0$  (b)  $F(s) = 1/(s-1), s > 1$   
 (c)  $F(s) = 1/s^2, s > 0$   
 77.  $C = 1; \ln 2$  79. No

CHAPTER 8 REVIEW ■ PAGE 554

True-False Quiz

1. False 3. False 5. False 7. False  
 9. (a) True (b) False 11. False 13. False

Exercises

1.  $5 + 10 \ln \frac{2}{3}$  3.  $\ln 2$  5.  $\frac{2}{15}$   
 7.  $-\cos(\ln t) + C$  9.  $\frac{64}{5} \ln 4 - \frac{124}{25}$   
 11.  $\sqrt{3} - \frac{1}{3}\pi$  13.  $3e^{\sqrt[3]{x}}(\sqrt[3]{x^2} - 2\sqrt[3]{x} + 2) + C$   
 15.  $-\frac{1}{2} \ln|x| + \frac{3}{2} \ln|x+2| + C$   
 17.  $x \sec x - \ln|\sec x + \tan x| + C$   
 19.  $\frac{1}{18} \ln(9x^2 + 6x + 5) + \frac{1}{9} \tan^{-1}[\frac{1}{2}(3x+1)] + C$   
 21.  $\ln|x-2 + \sqrt{x^2-4x}| + C$   
 23.  $\ln \left| \frac{\sqrt{x^2+1}-1}{x} \right| + C$   
 25.  $\frac{3}{2} \ln(x^2+1) - 3 \tan^{-1}x + \sqrt{2} \tan^{-1}(x/\sqrt{2}) + C$   
 27.  $\frac{2}{5}$  29. 0 31.  $6 - \frac{3}{2}\pi$   
 33.  $\frac{x}{\sqrt{4-x^2}} - \sin^{-1}\left(\frac{x}{2}\right) + C$   
 35.  $4\sqrt{1+\sqrt{x}} + C$  37.  $\frac{1}{2} \sin 2x - \frac{1}{8} \cos 4x + C$   
 39.  $\frac{1}{8}e - \frac{1}{4}$  41.  $\frac{1}{36}$  43. D  
 45.  $4 \ln 4 - 8$  47.  $-\frac{4}{3}$  49.  $\pi/4$   
 51.  $(x+1) \ln(x^2+2x+2) + 2 \arctan(x+1) - 2x + C$   
 53. 0  
 55.  $\frac{1}{4}(2x-1)\sqrt{4x^2-4x-3} - \ln|2x-1 + \sqrt{4x^2-4x-3}| + C$   
 57.  $\frac{1}{2} \sin x \sqrt{4+\sin^2 x} + 2 \ln(\sin x + \sqrt{4+\sin^2 x}) + C$   
 61. No  
 63. (a) 1.925444 (b) 1.920915 (c) 1.922470  
 65. (a) 0.01348,  $n \geq 368$  (b) 0.00674,  $n \geq 260$   
 67. 8.6 mi  
 69. (a) 3.8 (b) 1.7867, 0.000646 (c)  $n \geq 30$   
 71. C 73. 2 75.  $\frac{3}{16}\pi^2$

PROBLEMS PLUS ■ PAGE 558

1. About 1.85 inches from the center 3. 0  
 7.  $f(\pi) = -\pi/2$  11.  $(b^b a^{-a})^{1/(b-a)} e^{-1}$   
 13.  $2 - \sin^{-1}(2/\sqrt{5})$

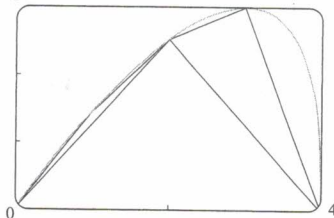
CHAPTER 9

EXERCISES 9.1 ■ PAGE 566

1.  $4\sqrt{5}$  3.  $\int_0^{2\pi} \sqrt{1+\sin^2 x} dx$  5.  $\int_1^4 \sqrt{9y^4+6y^2+2} dy$   
 7.  $\frac{2}{243}(82\sqrt{82}-1)$  9.  $\frac{1261}{240}$  11.  $\frac{32}{3}$   
 13.  $\ln(\sqrt{2}+1)$  15.  $\ln 3 - \frac{1}{2}$   
 17.  $\sqrt{1+e^2} - \sqrt{2} + \ln(\sqrt{1+e^2}-1) - 1 - \ln(\sqrt{2}-1)$   
 19.  $\sqrt{2} + \ln(1+\sqrt{2})$  21.  $\frac{46}{3}$  23. 5.115840

25. 1.569619

27. (a), (b) 3



$$L_1 = 4,$$

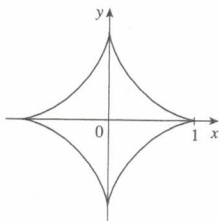
$$L_2 \approx 6.43,$$

$$L_4 \approx 7.50$$

(c)  $\int_0^4 \sqrt{1 + [4(3-x)/(3(4-x)^{2/3})]^2} dx$  (d) 7.7988

29.  $\sqrt{5} - \ln(\frac{1}{2}(1 + \sqrt{5})) - \sqrt{2} + \ln(1 + \sqrt{2})$

31. 6



33.  $s(x) = \frac{2}{27}[(1 + 9x)^{3/2} - 10\sqrt{10}]$  35.  $2\sqrt{2}(\sqrt{1+x} - 1)$

37. 209.1 m 39. 29.36 in. 41. 12.4

**EXERCISES 9.2 ■ PAGE 573**

1. (a)  $\int_0^1 2\pi x^4 \sqrt{1 + 16x^6} dx$  (b)  $\int_0^1 2\pi x \sqrt{1 + 16x^6} dx$

3. (a)  $\int_0^1 2\pi \tan^{-1} x \sqrt{1 + \frac{1}{(1+x^2)^2}} dx$

(b)  $\int_0^1 2\pi x \sqrt{1 + \frac{1}{(1+x^2)^2}} dx$

5.  $\frac{1}{27}\pi(145\sqrt{145} - 1)$  7.  $\frac{98}{3}\pi$

9.  $2\sqrt{1 + \pi^2} + (2/\pi) \ln(\pi + \sqrt{1 + \pi^2})$  11.  $\frac{21}{2}\pi$

13.  $\frac{1}{27}\pi(145\sqrt{145} - 10\sqrt{10})$  15.  $\pi a^2$

17. 9.023754 19. 13.527296

21.  $\frac{1}{4}\pi[4 \ln(\sqrt{17} + 4) - 4 \ln(\sqrt{2} + 1) - \sqrt{17} + 4\sqrt{2}]$

23.  $\frac{1}{6}\pi[\ln(\sqrt{10} + 3) + 3\sqrt{10}]$

27. (a)  $\frac{1}{3}\pi a^2$  (b)  $\frac{26}{45}\pi\sqrt{3}a^2$

29. (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)  $2\pi \left[ a^2 + \frac{ab^2 \sin^{-1}(\sqrt{b^2 - a^2/b})}{\sqrt{b^2 - a^2}} \right]$

31.  $\int_a^b 2\pi[c - f(x)]\sqrt{1 + [f'(x)]^2} dx$  33.  $4\pi^2 r^2$

**EXERCISES 9.3 ■ PAGE 583**

1. (a) 187.5 lb/ft<sup>2</sup> (b) 1875 lb (c) 562.5 lb

3. 6000 lb 5.  $6.7 \times 10^4$  N 7.  $9.8 \times 10^3$  N

9.  $1.2 \times 10^4$  lb 11.  $\frac{2}{3}\delta ah$  13.  $5.27 \times 10^5$  N

15. (a) 314 N (b) 353 N

17. (a)  $5.63 \times 10^3$  lb (b)  $5.06 \times 10^4$  lb

(c)  $4.88 \times 10^4$  lb (d)  $3.03 \times 10^5$  lb

19.  $2.5 \times 10^5$  N 21. 230;  $\frac{23}{7}$  23. 10; 1;  $(\frac{1}{21}, \frac{10}{21})$

25. (0, 1.6) 27.  $(\frac{1}{e-1}, \frac{e+1}{4})$  29.  $(\frac{9}{20}, \frac{9}{20})$

31.  $(\frac{\pi\sqrt{2}-4}{4(\sqrt{2}-1)}, \frac{1}{4(\sqrt{2}-1)})$  33. (2, 0)

35. 60; 160;  $(\frac{8}{3}, 1)$  37. (0.781, 1.330) 41.  $(0, \frac{1}{12})$

45.  $\frac{1}{3}\pi r^2 h$

**EXERCISES 9.4 ■ PAGE 589**

1. \$38,000 3. \$43,866,933.33 5. \$407.25

7. \$12,000 9. 3727; \$37,753

11.  $\frac{2}{3}(16\sqrt{2} - 8) \approx \$9.75$  million 13.  $\frac{(1-k)(b^{2-k} - a^{2-k})}{(2-k)(b^{1-k} - a^{1-k})}$

15.  $1.19 \times 10^{-4}$  cm<sup>3</sup>/s

17. 6.60 L/min 19. 5.77 L/min

**EXERCISES 9.5 ■ PAGE 596**

1. (a) The probability that a randomly chosen tire will have a lifetime between 30,000 and 40,000 miles

(b) The probability that a randomly chosen tire will have a lifetime of at least 25,000 miles

3. (a)  $f(x) \geq 0$  for all  $x$  and  $\int_{-\infty}^{\infty} f(x) dx = 1$

(b)  $1 - \frac{2}{3}\sqrt{3} \approx 0.35$

5. (a)  $1/\pi$  (b)  $\frac{1}{2}$

7. (a)  $f(x) \geq 0$  for all  $x$  and  $\int_{-\infty}^{\infty} f(x) dx = 1$  (b) 5

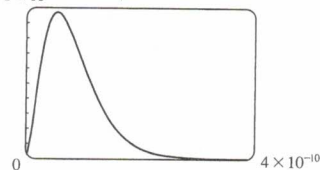
 11. (a)  $e^{-4/2.5} \approx 0.20$  (b)  $1 - e^{-2/2.5} \approx 0.55$  (c) If you aren't served within 10 minutes, you get a free hamburger.

13.  $\approx 44\%$

15. (a) 0.0668 (b)  $\approx 5.21\%$

17.  $\approx 0.9545$

19. (b) 0;  $a_0$  (c)  $1 \times 10^{10}$



(d)  $1 - 41e^{-8} \approx 0.986$  (e)  $\frac{3}{2}a_0$

**CHAPTER 9 REVIEW ■ PAGE 598**
**Exercises**

1.  $\frac{15}{2}$  3. (a)  $\frac{21}{16}$  (b)  $\frac{41}{10}\pi$  5. 3.292287 7.  $\frac{124}{5}$

9.  $\approx 458$  lb 11.  $(\frac{8}{5}, 1)$  13.  $(2, \frac{2}{3})$  15.  $2\pi^2$

17. \$7166.67

 19. (a)  $f(x) \geq 0$  for all  $x$  and  $\int_{-\infty}^{\infty} f(x) dx = 1$   
 (b)  $\approx 0.3455$  (c) 5, yes

21. (a)  $1 - e^{-3/8} \approx 0.31$  (b)  $e^{-5/4} \approx 0.29$

(c)  $8 \ln 2 \approx 5.55$  min

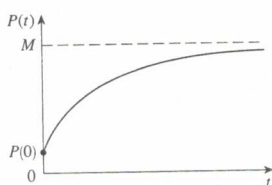
PROBLEMS PLUS ■ PAGE 600

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.  $2/\pi, 1/\pi$

CHAPTER 10

EXERCISES 10.1 ■ PAGE 607

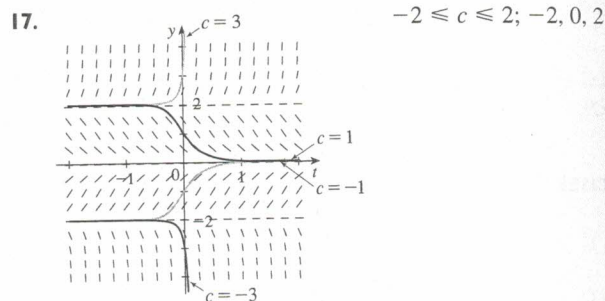
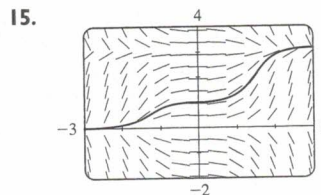
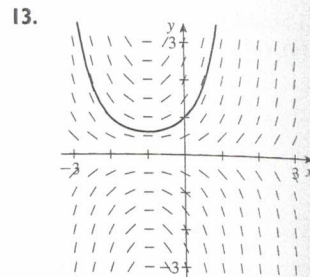
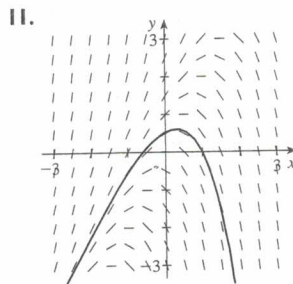
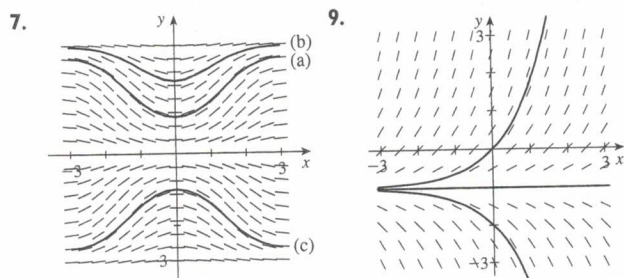
3. (a)  $\frac{1}{2}, -1$  5. (d)  
 7. (a) It must be either 0 or decreasing  
 (c)  $y = 0$  (d)  $y = 1/(x + 2)$   
 9. (a)  $0 < P < 4200$  (b)  $P > 4200$   
 (c)  $P = 0, P = 4200$   
 13. (a) At the beginning; stays positive, but decreases



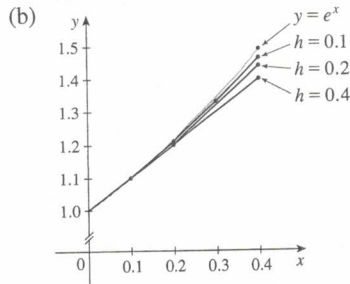
EXERCISES 10.2 ■ PAGE 614

1. (a) (b)  $y = 0,$   
 $y = 2,$   
 $y = -2$

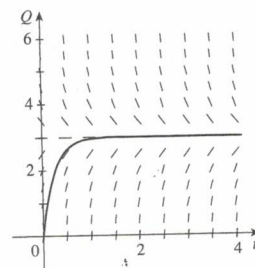
3. III 5. IV



19. (a) (i) 1.4 (ii) 1.44 (iii) 1.4641 Underestimates

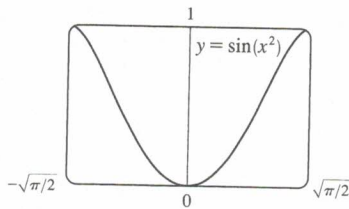


- (c) (i) 0.0918 (ii) 0.0518 (iii) 0.0277  
 It appears that the error is also halved (approximately).  
 21.  $-1, -3, -6.5, -12.25$  23. 1.7616  
 25. (a) (i) 3 (ii) 2.3928 (iii) 2.3701 (iv) 2.3681  
 (c) (i)  $-0.6321$  (ii)  $-0.0249$  (iii)  $-0.0022$  (iv)  $-0.0002$   
 It appears that the error is also divided by 10 (approximately).  
 27. (a), (d) (b) 3  
 (c) Yes;  $Q = 3$   
 (e) 2.77 C

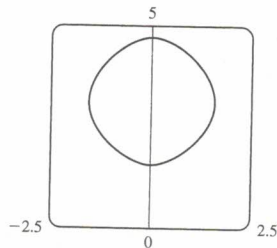


EXERCISES 10.3 ■ PAGE 622

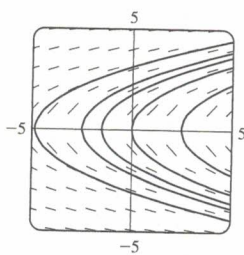
1.  $y = Kx$     3.  $y = K\sqrt{x^2 + 1}$   
 5.  $y + \ln |\sec y| = \frac{1}{3}x^3 + x + C$   
 7.  $y = \pm\sqrt{3(te^t - e^t + C)^{2/3} - 1}$     9.  $u = Ae^{2t+t^2/2} - 1$   
 11.  $y = -\sqrt{x^2 + 9}$     13.  $\cos x + x \sin x = y^2 + \frac{1}{3}e^{3y} + \frac{2}{3}$   
 15.  $u = -\sqrt{t^2 + \tan t + 25}$     17.  $y = \frac{4a}{\sqrt{3}} \sin x - a$   
 19.  $y = e^{x^2/2}$     21.  $y = Ke^x - x - 1$   
 23. (a)  $\sin^{-1}y = x^2 + C$   
 (b)  $y = \sin(x^2)$ ,  $-\sqrt{\pi/2} \leq x \leq \sqrt{\pi/2}$     (c) No



25.  $\cos y = \cos x - 1$

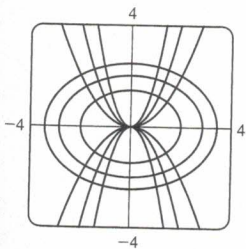


27. (a), (c)

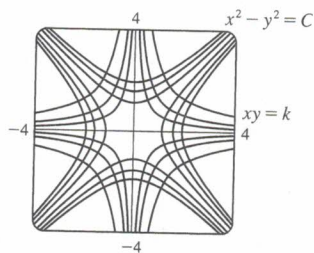


(b)  $y = \pm\sqrt{2(x + C)}$

29.  $y = Cx^2$



31.  $x^2 - y^2 = C$



33.  $Q(t) = 3 - 3e^{-4t}$ ; 3    35.  $P(t) = M - Me^{-kt}$ ,  $M$

37. (a)  $x = a - \frac{4}{(kt + 2/\sqrt{a})^2}$

(b)  $t = \frac{2}{k\sqrt{a-b}} \left( \tan^{-1} \sqrt{\frac{b}{a-b}} - \tan^{-1} \sqrt{\frac{b-x}{a-b}} \right)$

39. (a)  $C(t) = (C_0 - r/k)e^{-kt} + r/k$   
 (b)  $r/k$ ; the concentration approaches  $r/k$  regardless of the value of  $C_0$

41. (a)  $15e^{-t/100}$  kg    (b)  $15e^{-0.2} \approx 12.3$  kg

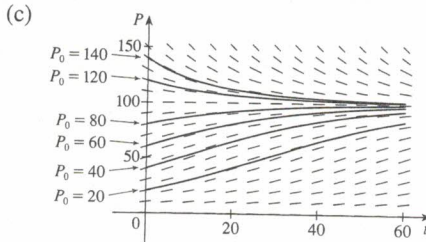
43. About 4.9%    45.  $g/k$

47. (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  $A_0 = A(0)$

EXERCISES 10.4 ■ PAGE 634

1. (a) 100; 0.05    (b) Where  $P$  is close to 0 or 100; on the line  $P = 50$ ;  $0 < P_0 < 100$ ;  $P_0 > 100$



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  $P = 100$

3. (a)  $3.23 \times 10^7$  kg    (b)  $\approx 1.55$  years

5. (a)  $dP/dt = \frac{1}{265}P(1 - P/100)$ ,  $P$  in billions

(b) 5.49 billion    (c) In billions: 7.81, 27.72

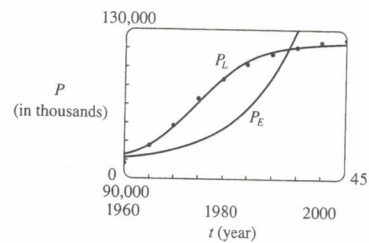
(d) In billions: 5.48, 7.61, 22.41

7. (a)  $dy/dt = ky(1 - y)$     (b)  $y = \frac{y_0}{y_0 + (1 - y_0)e^{-kt}}$

(c) 3:36 PM

11.  $P_E(t) = 1578.3(1.0933)^t + 94,000$ ;

$P_L(t) = \frac{32,658.5}{1 + 12.75e^{-0.1706t}} + 94,000$



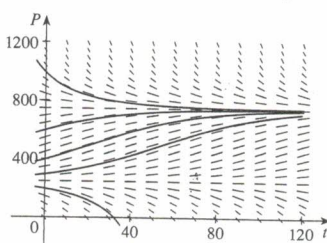
13. (a)  $P(t) = \frac{m}{k} + \left( P_0 - \frac{m}{k} \right) e^{kt}$     (b)  $m < kP_0$

(c)  $m = kP_0$ ,  $m > kP_0$     (d) Declining

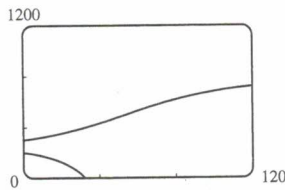
15. (a) Fish are caught at a rate of 15 per week.

(b) See part (d)    (c)  $P = 250$ ,  $P = 750$

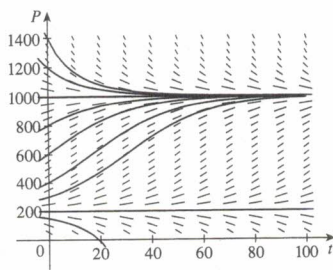
(d)  $0 < P_0 < 250$ :  $P \rightarrow 0$ ;  
 $P_0 = 250$ :  $P \rightarrow 250$ ;  
 $P_0 > 250$ :  $P \rightarrow 750$



(e)  $P(t) = \frac{250 - 750ke^{t/25}}{1 - ke^{t/25}}$   
 where  $k = \frac{1}{11}, -\frac{1}{9}$



17. (b)  $0 < P_0 < 200: P \rightarrow 0;$   
 $P_0 = 200: P \rightarrow 200;$   
 $P_0 > 200: P \rightarrow 1000$



(c)  $P(t) = \frac{m(K - P_0) + K(P_0 - m)e^{(K-m)(k/K)t}}{K - P_0 + (P_0 - m)e^{(K-m)(k/K)t}}$

19. (a)  $P(t) = P_0 e^{(k/r)[\sin(rt - \phi) + \sin \phi]}$  (b) Does not exist

EXERCISES 10.5 ■ PAGE 642

1. Yes 3. No 5.  $y = \frac{2}{3}e^x + Ce^{-2x}$

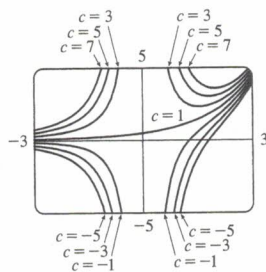
7.  $y = x^2 \ln|x| + Cx^2$  9.  $y = \frac{2}{3}\sqrt{x} + C/x$

11.  $y = \frac{\int \sin(x^2) dx + C}{\sin x}$  13.  $u = \frac{t^2 + 2t + 2C}{2(t + 1)}$

15.  $y = -x - 1 + 3e^x$  17.  $v = t^3 e^{t^2} + 5e^{t^2}$

19.  $y = -x \cos x - x$

21.  $y = \frac{(x - 1)e^x + C}{x^2}$

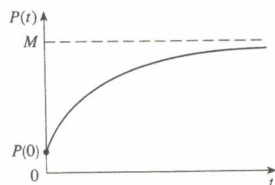


25.  $y = \pm \left(Cx^4 + \frac{2}{5x}\right)^{-1/2}$

27. (a)  $I(t) = 4 - 4e^{-5t}$  (b)  $4 - 4e^{-1/2} \approx 1.57$  A

29.  $Q(t) = 3(1 - e^{-4t}), I(t) = 12e^{-4t}$

31.  $P(t) = M + Ce^{-kt}$



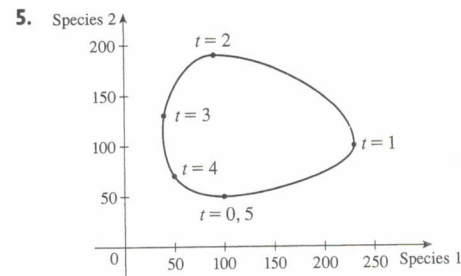
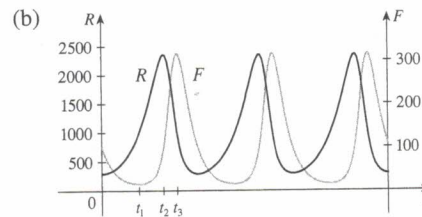
33.  $y = \frac{2}{5}(100 + 2t) - 40,000(100 + 2t)^{-3/2}; 0.2275$  kg/L

35. (b)  $mg/c$  (c)  $(mg/c)[t + (m/c)e^{-ct/m}] - m^2g/c^2$

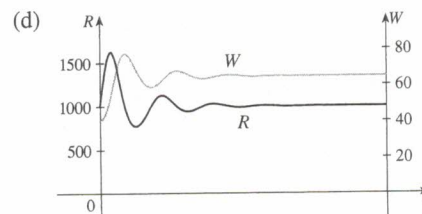
EXERCISES 10.6 ■ PAGE 648

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) 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. (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.

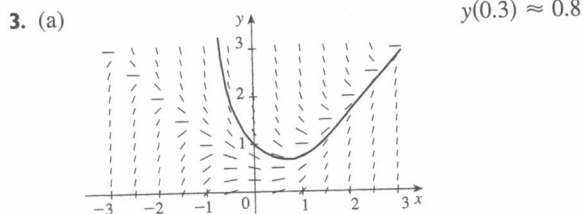
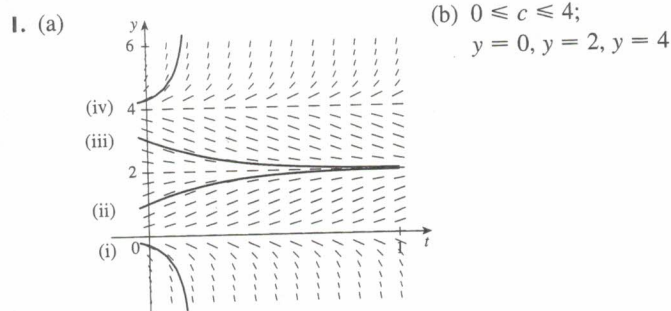


CHAPTER 10 REVIEW ■ PAGE 651

True-False Quiz

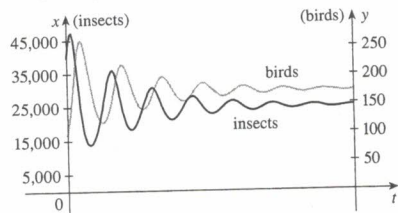
1. True 3. False 5. True 7. True

Exercises



- (b) 0.75676  
 (c)  $y = x$  and  $y = -x$ ; there is a local maximum or minimum  
 5.  $y = (\frac{1}{2}x^2 + C)e^{-\sin x}$     7.  $y = \pm \sqrt{\ln(x^2 + 2x^{3/2} + C)}$   
 9.  $r(t) = 5e^{t-t^2}$     11.  $y = \frac{1}{2}x(\ln x)^2 + 2x$     13.  $x = C - \frac{1}{2}y^2$   
 15. (a)  $P(t) = \frac{2000}{1 + 19e^{-0.1t}}$ ;  $\approx 560$     (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.



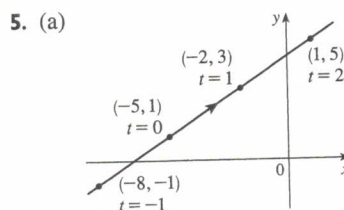
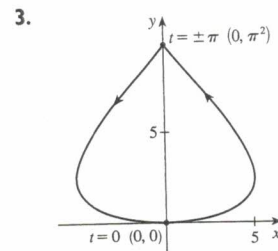
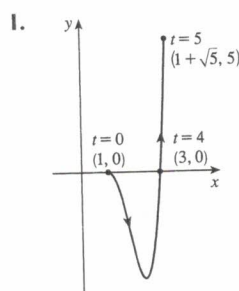
25. (a)  $y = (1/k) \cosh kx + a - 1/k$  or  
 $y = (1/k) \cosh kx - (1/k) \cosh kb + h$     (b)  $(2/k) \sinh kb$

PROBLEMS PLUS = PAGE 654

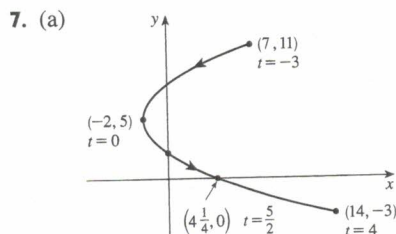
1.  $f(x) = \pm 10e^x$     5.  $y = x^{1/n}$     7.  $20^\circ\text{C}$   
 9. (b)  $f(x) = \frac{x^2 - L^2}{4L} - \frac{1}{2}L \ln\left(\frac{x}{L}\right)$     (c) No  
 11. (a) 9.8 h    (b)  $31,900\pi \approx 100,000 \text{ ft}^2$ ;  $6283 \text{ ft}^2/\text{h}$   
 (c) 5.1 h  
 13.  $x^2 + (y - 6)^2 = 25$

CHAPTER 11

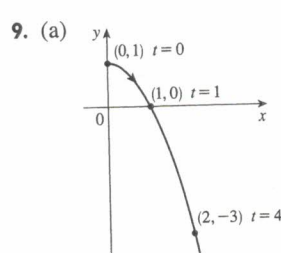
EXERCISES 11.1 = PAGE 662



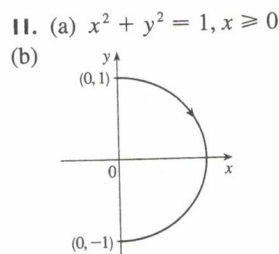
(b)  $y = \frac{2}{3}x + \frac{13}{3}$



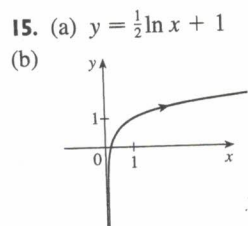
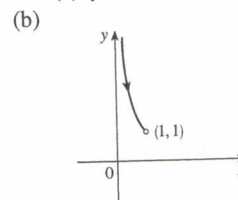
(b)  $x = \frac{1}{4}(y - 5)^2 - 2$ ,  
 $-3 \leq y \leq 11$



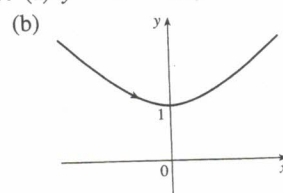
(b)  $y = 1 - x^2, x \geq 0$



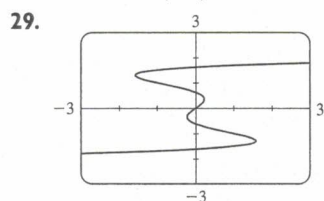
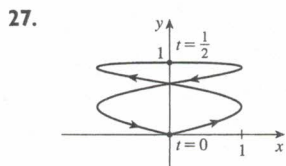
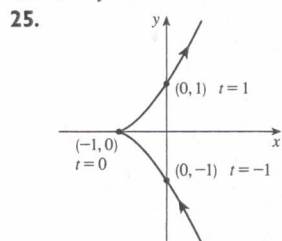
13. (a)  $y = 1/x, y > 1$



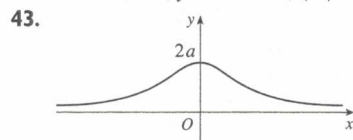
17. (a)  $y^2 - x^2 = 1, y \geq 1$



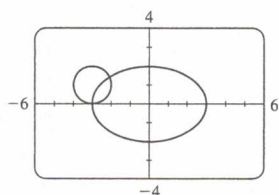
19. Moves counterclockwise along the circle  $(x - 3)^2 + (y - 1)^2 = 4$  from  $(3, 3)$  to  $(3, -1)$   
 21. Moves 3 times clockwise around the ellipse  $(x^2/25) + (y^2/4) = 1$ , starting and ending at  $(0, -2)$   
 23. It is contained in the rectangle described by  $1 \leq x \leq 4$  and  $2 \leq y \leq 3$ .



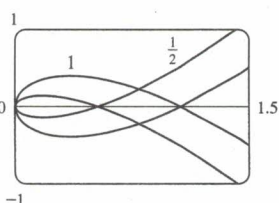
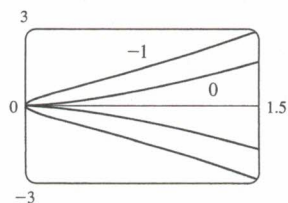
31. (b)  $x = -2 + 5t, y = 7 - 8t, 0 \leq t \leq 1$   
 33. (a)  $x = 2 \cos t, y = 1 - 2 \sin t, 0 \leq t \leq 2\pi$   
 (b)  $x = 2 \cos t, y = 1 + 2 \sin t, 0 \leq t \leq 6\pi$   
 (c)  $x = 2 \cos t, y = 1 + 2 \sin t, \pi/2 \leq t \leq 3\pi/2$   
 37. The curve  $y = x^{2/3}$  is generated in (a). In (b), only the portion with  $x \geq 0$  is generated, and in (c) we get only the portion with  $x > 0$ .  
 41.  $x = a \cos \theta, y = b \sin \theta; (x^2/a^2) + (y^2/b^2) = 1$ , ellipse



45. (a) Two points of intersection



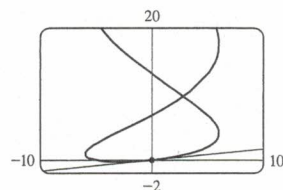
- (b) One collision point at  $(-3, 0)$  when  $t = 3\pi/2$   
 (c) There are still two intersection points, but no collision point.  
 47. For  $c = 0$ , there is a cusp; for  $c > 0$ , there is a loop whose size increases as  $c$  increases.



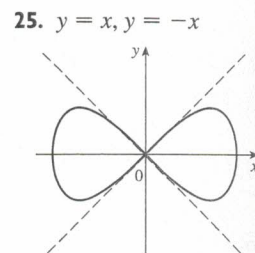
49. As  $n$  increases, the number of oscillations increases;  $a$  and  $b$  determine the width and height.

EXERCISES 11.2 PAGE 672

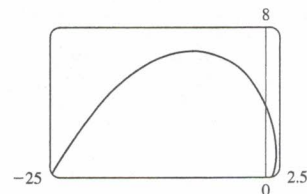
1.  $\frac{2t + 1}{t \cos t + \sin t}$  3.  $y = -x$   
 5.  $y = -(2/e)x + 3$  7.  $y = 2x + 1$   
 9.  $y = \frac{1}{6}x$



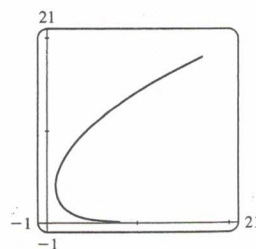
11.  $1 + \frac{3}{2}t, 3/(4t), t > 0$   
 13.  $-e^{-t}, e^{-t}/(1 - e^t), t < 0$   
 15.  $-\frac{3}{2} \tan t, -\frac{3}{4} \sec^3 t, \pi/2 < t < 3\pi/2$   
 17. Horizontal at  $(6, \pm 16)$ , vertical at  $(10, 0)$   
 19. Horizontal at  $(\pm\sqrt{2}, \pm 1)$  (four points), vertical at  $(\pm 2, 0)$   
 21.  $(0.6, 2); (5 \cdot 6^{-6/5}, e^{6^{-1/5}})$   
 23.



27. (a)  $d \sin \theta / (r - d \cos \theta)$  29.  $(\frac{16}{27}, \frac{29}{9}), (-2, -4)$   
 31.  $\pi ab$  33.  $3 - e$  35.  $2\pi r^2 + \pi d^2$   
 37.  $\int_1^2 \sqrt{1 + 4t^2} dt \approx 3.1678$   
 39.  $\int_0^{2\pi} \sqrt{3 - 2 \sin t - 2 \cos t} dt \approx 10.0367$  41.  $4\sqrt{2} - 2$   
 43.  $-\sqrt{10}/3 + \ln(3 + \sqrt{10}) + \sqrt{2} - \ln(1 + \sqrt{2})$   
 45.  $\sqrt{2}(e^\pi - 1)$



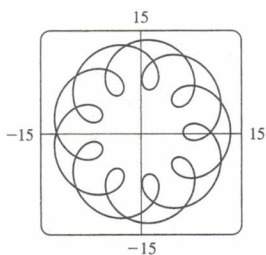
47.  $e^3 + 11 - e^{-8}$



49. 612.3053 51.  $6\sqrt{2}, \sqrt{2}$



55. (a)  $t \in [0, 4\pi]$



(b)  $\approx 294$

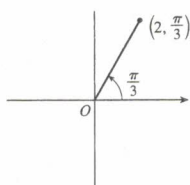
57.  $\int_0^1 2\pi(t^2 + 1)e^t \sqrt{e^{2t}(t+1)^2(t^2 + 2t + 2)} dt \approx 103.5999$

59.  $\frac{2}{1215}\pi(247\sqrt{13} + 64)$     61.  $\frac{6}{5}\pi a^2$     63. 59.101

65.  $\frac{24}{5}\pi(949\sqrt{26} + 1)$     71.  $\frac{1}{4}$

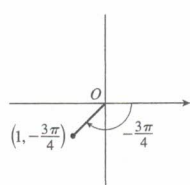
EXERCISES 11.3 = PAGE 683

1. (a)



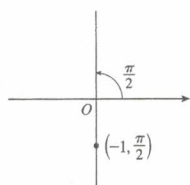
$(2, 7\pi/3), (-2, 4\pi/3)$

(b)



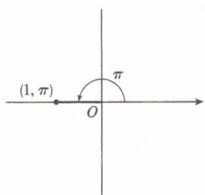
$(1, 5\pi/4), (-1, \pi/4)$

(c)



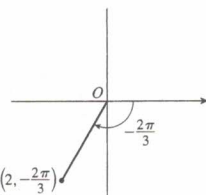
$(1, 3\pi/2), (-1, 5\pi/2)$

3. (a)



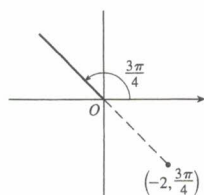
$(-1, 0)$

(b)



$(-1, -\sqrt{3})$

(c)

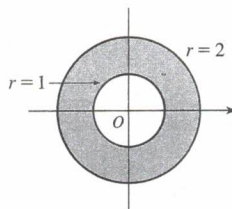


$(\sqrt{2}, -\sqrt{2})$

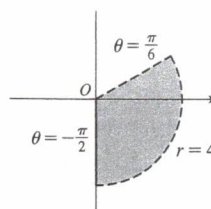
5. (a) (i)  $(2\sqrt{2}, 7\pi/4)$     (ii)  $(-2\sqrt{2}, 3\pi/4)$

(b) (i)  $(2, 2\pi/3)$     (ii)  $(-2, 5\pi/3)$

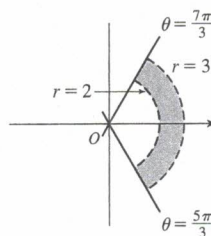
7.



9.



11.



13.  $2\sqrt{3}$     15. Circle, center  $O$ , radius 2

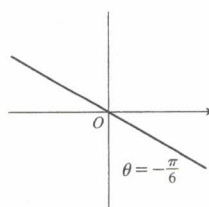
17. Circle, center  $(0, \frac{3}{2})$ , radius  $\frac{3}{2}$

19. Horizontal line, 1 unit above the  $x$ -axis

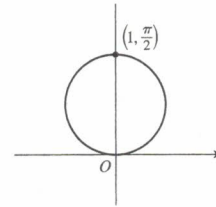
21.  $r = 3 \sec \theta$     23.  $r = -\cot \theta \csc \theta$     25.  $r = 2c \cos \theta$

27. (a)  $\theta = \pi/6$     (b)  $x = 3$

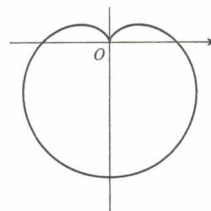
29.



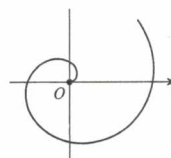
31.



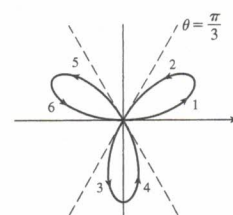
33.



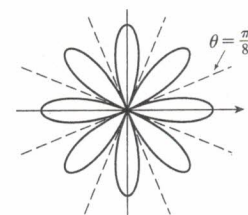
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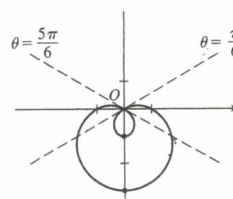
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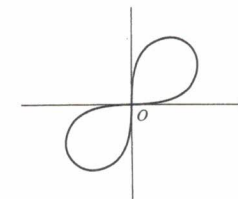
39.

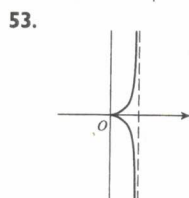
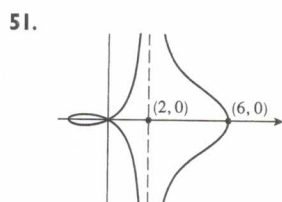
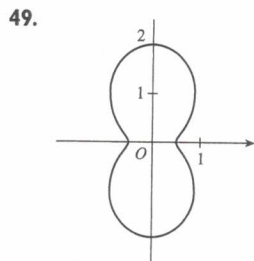
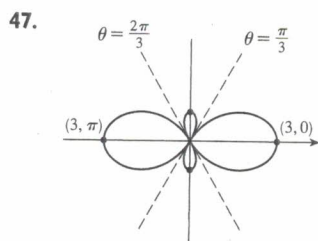
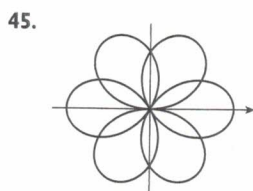


41.



43.





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  $\theta = 2\pi - \sin^{-1}(1/c)$ .

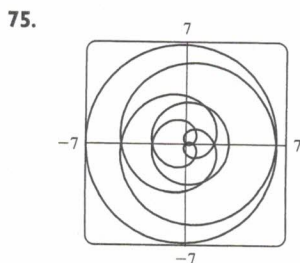
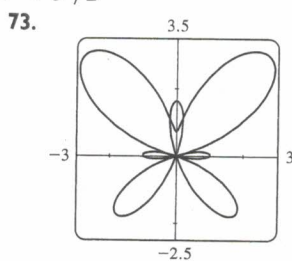
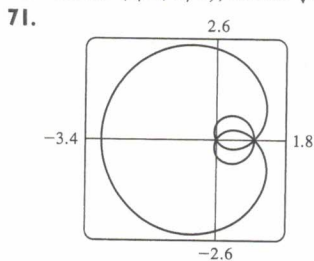
57.  $\sqrt{3}$     59.  $-\pi$     61. 1

63. Horizontal at  $(3/\sqrt{2}, \pi/4)$ ,  $(-3/\sqrt{2}, 3\pi/4)$ ; vertical at  $(3, 0)$ ,  $(0, \pi/2)$

65. Horizontal at  $(\frac{3}{2}, \pi/3)$ ,  $(0, \pi)$  [the pole], and  $(\frac{3}{2}, 5\pi/3)$ ; vertical at  $(2, 0)$ ,  $(\frac{1}{2}, 2\pi/3)$ ,  $(\frac{1}{2}, 4\pi/3)$

67. Horizontal at  $(3, \pi/2)$ ,  $(1, 3\pi/2)$ ; vertical at  $(\frac{3}{2} + \frac{1}{2}\sqrt{3}, \alpha)$ ,  $(\frac{3}{2} + \frac{1}{2}\sqrt{3}, \pi - \alpha)$  where  $\alpha = \sin^{-1}(-\frac{1}{2} + \frac{1}{2}\sqrt{3})$

69. Center  $(b/2, a/2)$ , radius  $\sqrt{a^2 + b^2}/2$



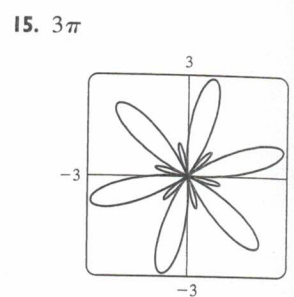
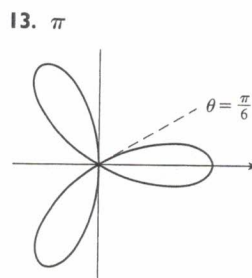
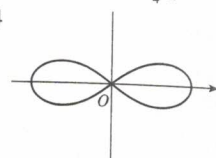
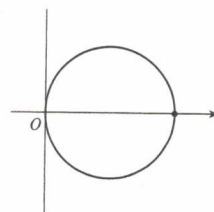
77. By counterclockwise rotation through angle  $\pi/6$ ,  $\pi/3$ , or  $\alpha$  about the origin

79. (a) A rose with  $n$  loops if  $n$  is odd and  $2n$  loops if  $n$  is even  
(b) Number of loops is always  $2n$

81. For  $0 < a < 1$ , the curve is an oval, which develops a dimple as  $a \rightarrow 1^-$ . When  $a > 1$ , the curve splits into two parts, one of which has a loop.

EXERCISES 11.4 ■ PAGE 689

1.  $\pi^5/10,240$     3.  $\pi/12 + \frac{1}{8}\sqrt{3}$     5.  $\pi^2$     7.  $\frac{41}{4}\pi$   
9.  $\frac{9}{4}\pi$     11. 4



17.  $\frac{1}{8}\pi$     19.  $\frac{9}{20}\pi$     21.  $\pi - \frac{3}{2}\sqrt{3}$     23.  $\frac{1}{3}\pi + \frac{1}{2}\sqrt{3}$   
25.  $4\sqrt{3} - \frac{4}{3}\pi$     27.  $\pi$     29.  $\frac{5}{24}\pi - \frac{1}{4}\sqrt{3}$     31.  $\frac{1}{2}\pi - 1$   
33.  $1 - \frac{1}{2}\sqrt{2}$     35.  $\frac{1}{4}(\pi + 3\sqrt{3})$

37.  $(\frac{3}{2}, \pi/6)$ ,  $(\frac{3}{2}, 5\pi/6)$ , and the pole

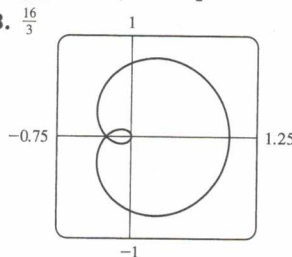
39.  $(1, \theta)$  where  $\theta = \pi/12, 5\pi/12, 13\pi/12, 17\pi/12$  and  $(-1, \theta)$  where  $\theta = 7\pi/12, 11\pi/12, 19\pi/12, 23\pi/12$

41.  $(\frac{1}{2}\sqrt{3}, \pi/3)$ ,  $(\frac{1}{2}\sqrt{3}, 2\pi/3)$ , and the pole

43. Intersection at  $\theta \approx 0.89, 2.25$ ; area  $\approx 3.46$     45.  $\pi$

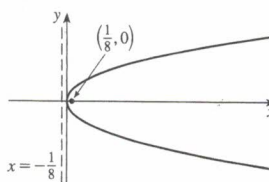
47.  $\frac{8}{3}[(\pi^2 + 1)^{3/2} - 1]$     49. 29.0653    51. 9.6884

53.  $\frac{16}{3}$     55. (b)  $2\pi(2 - \sqrt{2})$

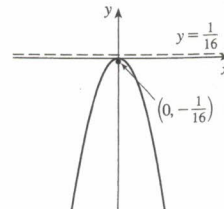


EXERCISES 11.5 ■ PAGE 696

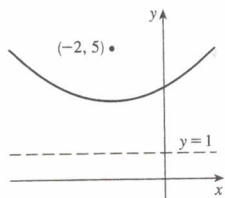
1.  $(0, 0)$ ,  $(\frac{1}{8}, 0)$ ,  $x = -\frac{1}{8}$



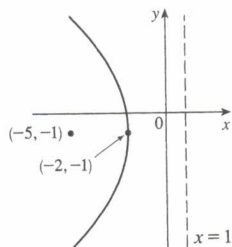
3.  $(0, 0)$ ,  $(0, -\frac{1}{16})$ ,  $y = \frac{1}{16}$



5.  $(-2, 3), (-2, 5), y = 1$

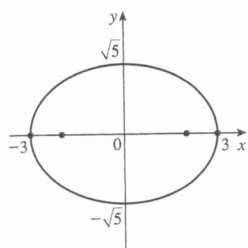


7.  $(-2, -1), (-5, -1), x = 1$

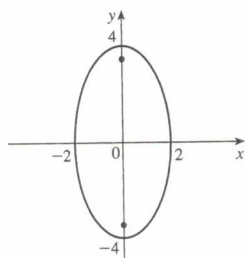


9.  $x = -y^2$ , focus  $(-\frac{1}{4}, 0)$ , directrix  $x = \frac{1}{4}$

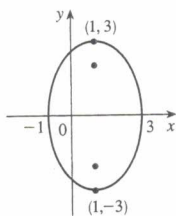
11.  $(\pm 3, 0), (\pm 2, 0)$



13.  $(0, \pm 4), (0, \pm 2\sqrt{3})$

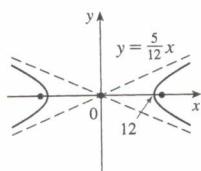


15.  $(1, \pm 3), (1, \pm\sqrt{5})$

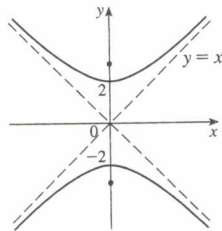


17.  $\frac{x^2}{4} + \frac{y^2}{9} = 1$ , foci  $(0, \pm\sqrt{5})$

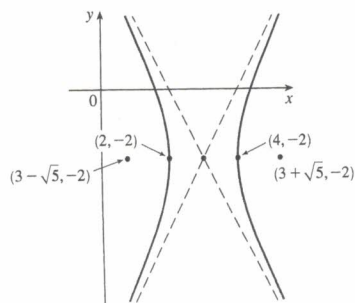
19.  $(\pm 12, 0), (\pm 13, 0)$   
 $y = \pm \frac{5}{12}x$



21.  $(0, \pm 2), (0, \pm 2\sqrt{2})$   
 $y = \pm x$



23.  $(4, -2), (2, -2);$   
 $(3 \pm \sqrt{5}, -2);$   
 $y + 2 = \pm 2(x - 3)$



25. Parabola,  $(0, -1), (0, -\frac{3}{4})$

27. Ellipse,  $(\pm\sqrt{2}, 1), (\pm 1, 1)$

29. Hyperbola,  $(0, 1), (0, -3); (0, -1 \pm \sqrt{5})$  31.  $x^2 = -8y$

33.  $y^2 = -12(x + 1)$  35.  $y - 3 = 2(x - 2)^2$

37.  $\frac{x^2}{25} + \frac{y^2}{21} = 1$  39.  $\frac{x^2}{12} + \frac{(y - 4)^2}{16} = 1$

41.  $\frac{(x + 1)^2}{12} + \frac{(y - 4)^2}{16} = 1$  43.  $\frac{x^2}{9} - \frac{y^2}{16} = 1$

45.  $\frac{(y - 1)^2}{25} - \frac{(x + 3)^2}{39} = 1$  47.  $\frac{x^2}{9} - \frac{y^2}{36} = 1$

49.  $\frac{x^2}{3,763,600} + \frac{y^2}{3,753,196} = 1$

51. (a)  $\frac{121x^2}{1,500,625} - \frac{121y^2}{3,339,375} = 1$  (b)  $\approx 248$  mi

55. (a) Ellipse (b) Hyperbola (c) No curve

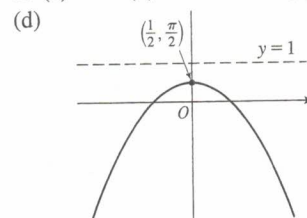
59. 9.69 61.  $\frac{b^2c}{a} + ab \ln\left(\frac{a}{b+c}\right)$  where  $c^2 = a^2 + b^2$

EXERCISES 11.6 ■ PAGE 704

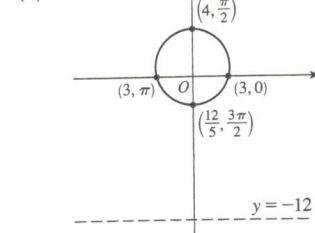
1.  $r = \frac{42}{4 + 7 \sin \theta}$  3.  $r = \frac{15}{4 - 3 \cos \theta}$

5.  $r = \frac{8}{1 - \sin \theta}$  7.  $r = \frac{4}{2 + \cos \theta}$

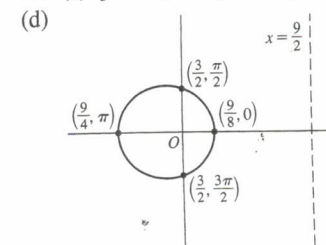
9. (a) 1 (b) Parabola (c)  $y = 1$



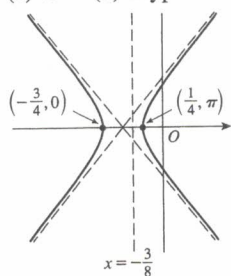
11. (a)  $\frac{1}{4}$  (b) Ellipse (c)  $y = -12$



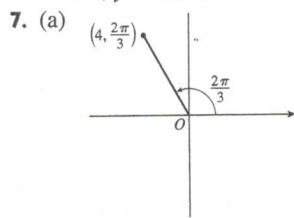
13. (a)  $\frac{1}{3}$  (b) Ellipse (c)  $x = \frac{9}{2}$



15. (a) 2 (b) Hyperbola (c)  $x = -\frac{3}{8}$   
 (d)

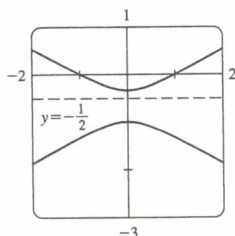


5.  $x = t, y = \sqrt{t}; x = t^4, y = t^2;$   
 $x = \tan^2 t, y = \tan t, 0 \leq t < \pi/2$

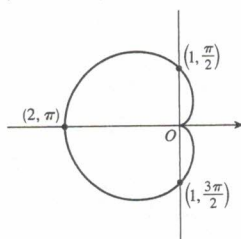


- (b)  $(3\sqrt{2}, 3\pi/4),$   
 $(-3\sqrt{2}, 7\pi/4)$

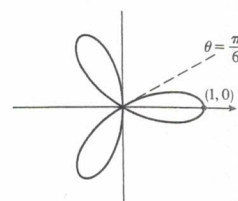
17. (a)  $2, y = -\frac{1}{2}$



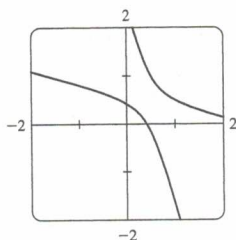
9.  $(-2, 2\sqrt{3})$



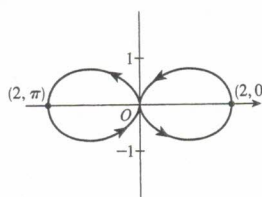
11.



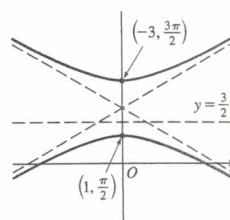
- (b)  $r = \frac{1}{1 - 2 \sin(\theta - 3\pi/4)}$



13.

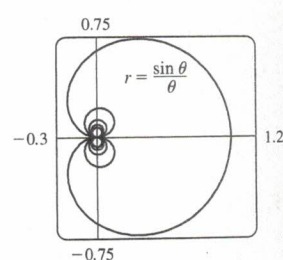


15.

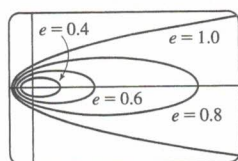


17.  $r = \frac{2}{\cos \theta + \sin \theta}$

19.



19. 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.



25.  $r = \frac{2.26 \times 10^8}{1 + 0.093 \cos \theta}$

27. 35.64 AU    29.  $7.0 \times 10^7$  km    31.  $3.6 \times 10^8$  km

21. 2    23. -1

25.  $\frac{1 + \sin t}{1 + \cos t}, \frac{1 + \cos t + \sin t}{(1 + \cos t)^3}$     27.  $(\frac{11}{8}, \frac{3}{4})$

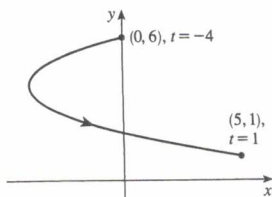
CHAPTER 11 REVIEW = PAGE 705

True-False Quiz

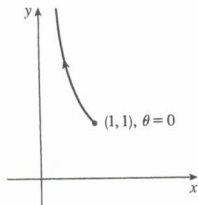
1. False    3. False    5. True    7. False    9. True

Exercises

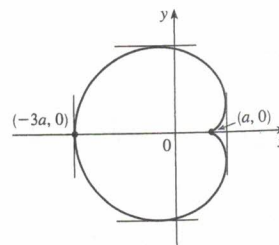
1.  $x = y^2 - 8y + 12$



3.  $y = 1/x$



29. Vertical tangent at  $(\frac{3}{2}a, \pm\frac{1}{2}\sqrt{3}a), (-3a, 0);$   
 horizontal tangent at  $(a, 0), (-\frac{1}{2}a, \pm\frac{3}{2}\sqrt{3}a)$



31. 18    33.  $(2, \pm\pi/3)$     35.  $\frac{1}{2}(\pi - 1)$

37.  $2(5\sqrt{5} - 1)$

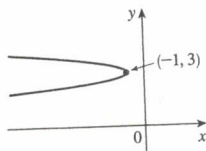
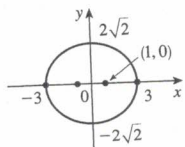
39.  $\frac{2\sqrt{\pi^2 + 1} - \sqrt{4\pi^2 + 1}}{2\pi} + \ln\left(\frac{2\pi + \sqrt{4\pi^2 + 1}}{\pi + \sqrt{\pi^2 + 1}}\right)$

41.  $471,295\pi/1024$

43. 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  $x = 1$ . For  $-1 < c < 0$ , it bulges to the left. At  $c = 0$  there is a cusp at  $(0, 0)$ . For  $c > 0$ , there is a loop.

45.  $(\pm 1, 0), (\pm 3, 0)$

47.  $(-\frac{25}{24}, 3), (-1, 3)$



49.  $\frac{x^2}{25} + \frac{y^2}{9} = 1$     51.  $\frac{y^2}{72/5} - \frac{x^2}{8/5} = 1$

53.  $\frac{x^2}{25} + \frac{(8y - 399)^2}{160,801} = 1$     55.  $r = \frac{4}{3 + \cos \theta}$

57.  $x = a(\cot \theta + \sin \theta \cos \theta), y = a(1 + \sin^2 \theta)$

PROBLEMS PLUS ■ PAGE 708

1.  $\ln(\pi/2)$

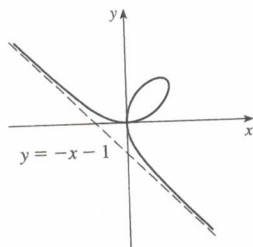
3.  $[-\frac{3}{4}\sqrt{3}, \frac{3}{4}\sqrt{3}] \times [-1, 2]$

5. (a) At  $(0, 0)$  and  $(\frac{3}{2}, \frac{3}{2})$

(b) Horizontal tangents at  $(0, 0)$  and  $(\sqrt[3]{2}, \sqrt[3]{4})$ ;

vertical tangents at  $(0, 0)$  and  $(\sqrt[3]{4}, \sqrt[3]{2})$

(d) (g)  $\frac{3}{2}$



CHAPTER 12

EXERCISES 12.1 ■ PAGE 720

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. 0.8, 0.96, 0.992, 0.9984, 0.99968    5.  $-3, \frac{3}{2}, -\frac{1}{2}, \frac{1}{8}, -\frac{1}{40}$

7. 3, 5, 9, 17, 33    9.  $a_n = 1/(2n - 1)$     11.  $a_n = 5n - 3$

13.  $a_n = (-\frac{2}{3})^{n-1}$     15.  $\frac{1}{3}, \frac{2}{5}, \frac{3}{7}, \frac{4}{9}, \frac{5}{11}, \frac{6}{13}$ ; yes;  $\frac{1}{2}$

17. 1    19. 5    21. 1    23. 1    25. 0    27. D

29. 0    31. 0    33. 0    35. 0    37. 1    39.  $e^2$

41.  $\ln 2$     43. D    45. D    47. 1    49.  $\frac{1}{2}$

51. D    53. 0

55. (a) 1060, 1123.60, 1191.02, 1262.48, 1338.23    (b) D

57.  $-1 < r < 1$

59. Convergent by the Monotonic Sequence Theorem;  $5 \leq L < 8$

61. Decreasing; yes    63. Not monotonic; no

65. Decreasing; yes    67. 2    69.  $\frac{1}{2}(3 + \sqrt{5})$

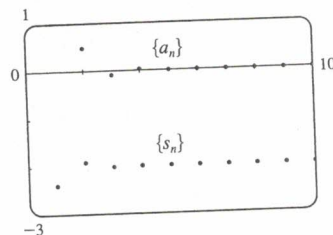
71. (b)  $\frac{1}{2}(1 + \sqrt{5})$     73. (a) 0    (b) 9, 11

EXERCISES 12.2 ■ PAGE 730

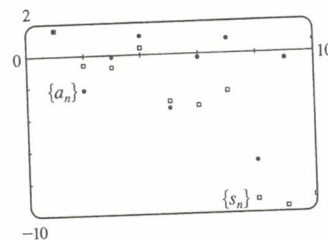
1. (a) A sequence is an ordered list of numbers whereas a series is the sum of a list of numbers.

(b) A series is convergent if the sequence of partial sums is a convergent sequence. A series is divergent if it is not convergent.

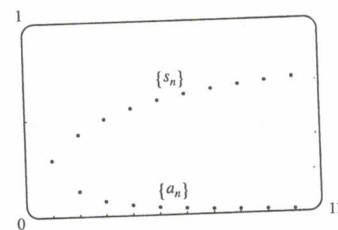
3. -2.40000, -1.92000,  
-2.01600, -1.99680,  
-2.00064, -1.99987,  
-2.00003, -1.99999,  
-2.00000, -2.00000;  
convergent, sum = -2



5. 1.55741, -0.62763,  
-0.77018, 0.38764,  
-2.99287, -3.28388,  
-2.41243, -9.21214,  
-9.66446, -9.01610;  
divergent



7. 0.29289, 0.42265,  
0.50000, 0.55279,  
0.59175, 0.62204,  
0.64645, 0.66667,  
0.68377, 0.69849;  
convergent, sum = 1



9. (a) C    (b) D    11. 9    13. D    15. 60    17.  $\frac{1}{7}$

19. D    21. D    23. D    25.  $\frac{5}{2}$     27. D    29. D

31. D    33.  $e/(e - 1)$     35.  $\frac{3}{2}$     37.  $\frac{11}{6}$     39.  $e - 1$

41.  $\frac{2}{9}$     43. 1138/333    45. 5063/3300

47.  $-3 < x < 3; \frac{x}{3 - x}$     49.  $-\frac{1}{4} < x < \frac{1}{4}; \frac{1}{1 - 4x}$

51. All  $x; \frac{2}{2 - \cos x}$     53. 1

55.  $a_1 = 0, a_n = \frac{2}{n(n+1)}$  for  $n > 1$ , sum = 1

57. (a)  $S_n = \frac{D(1 - c^n)}{1 - c}$     (b) 5    59.  $\frac{1}{2}(\sqrt{3} - 1)$

63.  $\frac{1}{n(n+1)}$     65. The series is divergent.

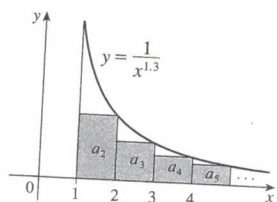
71.  $\{s_n\}$  is bounded and increasing.

73. (a)  $0, \frac{1}{9}, \frac{2}{9}, \frac{1}{3}, \frac{2}{3}, \frac{7}{9}, \frac{8}{9}, 1$

75. (a)  $\frac{1}{2}, \frac{5}{6}, \frac{23}{24}, \frac{119}{120}, \frac{(n+1)! - 1}{(n+1)!}$  (c) 1

EXERCISES 12.3 = PAGE 739

1. C



3. D 5. C 7. C 9. D 11. C 13. D 15. C  
 17. C 19. C 21. D 23. C 25. C 27.  $p > 1$   
 29.  $p < -1$  31.  $(1, \infty)$   
 33. (a) 1.54977, error  $\leq 0.1$  (b) 1.64522, error  $\leq 0.005$   
 (c)  $n > 1000$   
 35. 0.00145 41.  $b < 1/e$

EXERCISES 12.4 = PAGE 745

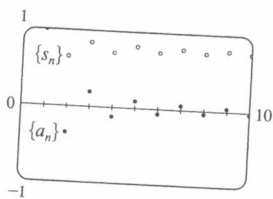
1. (a) Nothing (b) C 3. C 5. D 7. C 9. C  
 11. C 13. C 15. C 17. D 19. D 21. C  
 23. C 25. D 27. C 29. C 31. D  
 33. 1.249, error  $< 0.1$  35. 0.76352, error  $< 0.001$   
 45. Yes

EXERCISES 12.5 = PAGE 749

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. C 5. C 7. D 9. C 11. C 13. D  
 15. C 17. C 19. D

21. 1.0000, 0.6464,  
 0.8389, 0.7139, 0.8033,  
 0.7353, 0.7893, 0.7451, 0.7821,  
 0.7505; error  $< 0.0275$



23. 5 25. 4 27. 0.9721 29. 0.0676  
 31. An underestimate 33.  $p$  is not a negative integer  
 35.  $\{b_n\}$  is not decreasing

EXERCISES 12.6 = PAGE 755

Abbreviations: AC, absolutely convergent;  
 CC, conditionally convergent

1. (a) D (b) C (c) May converge or diverge  
 3. AC 5. CC 7. AC 9. D 11. AC 13. AC

15. AC 17. CC 19. AC 21. AC 23. D

25. AC 27. D 29. D 31. (a) and (d)

35. (a)  $\frac{661}{960} \approx 0.68854$ , error  $< 0.00521$   
 (b)  $n \geq 11$ , 0.693109

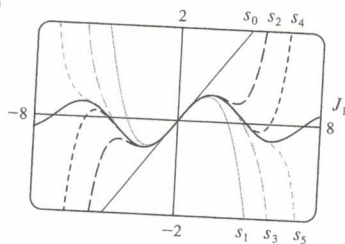
EXERCISES 12.7 = PAGE 758

1. C 3. D 5. C 7. D 9. C 11. C 13. C  
 15. C 17. D 19. C 21. C 23. D 25. C  
 27. C 29. C 31. D 33. C 35. C 37. C

EXERCISES 12.8 = PAGE 763

1. 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 constants

3. 1,  $[-1, 1)$  5. 1,  $[-1, 1]$  7.  $\infty, (-\infty, \infty)$   
 9. 2,  $(-2, 2)$  11.  $\frac{1}{2}, (-\frac{1}{2}, \frac{1}{2}]$  13. 4,  $(-4, 4]$   
 15. 1,  $[1, 3]$  17.  $\frac{1}{3}, [-\frac{13}{3}, -\frac{11}{3})$  19.  $\infty, (-\infty, \infty)$   
 21.  $b, (a-b, a+b)$  23. 0,  $\{\frac{1}{2}\}$  25.  $\frac{1}{4}, [-\frac{1}{2}, 0]$   
 27.  $\infty, (-\infty, \infty)$  29. (a) Yes (b) No 31.  $k^k$  33. No  
 35. (a)  $(-\infty, \infty)$   
 (b), (c)

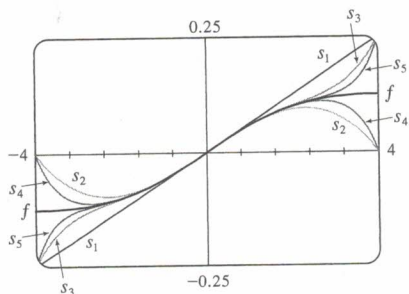


37.  $(-1, 1)$ ,  $f(x) = (1+2x)/(1-x^2)$  41. 2

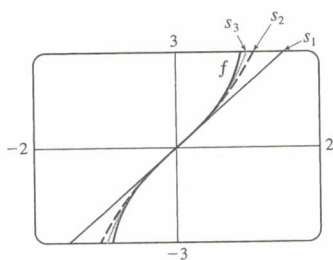
EXERCISES 12.9 = PAGE 769

1. 10 3.  $\sum_{n=0}^{\infty} (-1)^n x^n, (-1, 1)$  5.  $2 \sum_{n=0}^{\infty} \frac{1}{3^{n+1}} x^n, (-3, 3)$   
 7.  $\sum_{n=0}^{\infty} (-1)^n \frac{1}{9^{n+1}} x^{2n+1}, (-3, 3)$  9.  $1 + 2 \sum_{n=1}^{\infty} x^n, (-1, 1)$   
 11.  $\sum_{n=0}^{\infty} \left[ (-1)^{n+1} - \frac{1}{2^{n+1}} \right] x^n, (-1, 1)$   
 13. (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)  $\frac{1}{2} \sum_{n=2}^{\infty} (-1)^n n(n-1) x^n, R = 1$   
 15.  $\ln 5 - \sum_{n=1}^{\infty} \frac{x^n}{n5^n}, R = 5$  17.  $\sum_{n=3}^{\infty} \frac{n-2}{2^{n-1}} x^n, R = 2$

19.  $\sum_{n=0}^{\infty} (-1)^n \frac{1}{16^{n+1}} x^{2n+1}, R = 4$



21.  $\sum_{n=0}^{\infty} \frac{2x^{2n+1}}{2n+1}, R = 1$



23.  $C + \sum_{n=0}^{\infty} \frac{t^{8n+2}}{8n+2}, R = 1$

25.  $C + \sum_{n=1}^{\infty} (-1)^{n+1} \frac{x^{2n-1}}{4n^2-1}, R = 1$

27. 0.199989    29. 0.000983    31. 0.09531

33. (b) 0.920    37.  $[-1, 1], [-1, 1), (-1, 1)$

## EXERCISES 12.10 ■ PAGE 782

1.  $b_8 = f^{(8)}(5)/8!$     3.  $\sum_{n=0}^{\infty} (n+1)x^n, R = 1$

5.  $\sum_{n=0}^{\infty} (n+1)x^n, R = 1$

7.  $\sum_{n=0}^{\infty} (-1)^n \frac{\pi^{2n+1}}{(2n+1)!} x^{2n+1}, R = \infty$

9.  $\sum_{n=0}^{\infty} \frac{5^n}{n!} x^n, R = \infty$     11.  $\sum_{n=0}^{\infty} \frac{x^{2n+1}}{(2n+1)!}, R = \infty$

13.  $-1 - 2(x-1) + 3(x-1)^2 + 4(x-1)^3 + (x-1)^4,$   
 $R = \infty$

15.  $\sum_{n=0}^{\infty} \frac{e^3}{n!} (x-3)^n, R = \infty$

17.  $\sum_{n=0}^{\infty} (-1)^{n+1} \frac{1}{(2n)!} (x-\pi)^{2n}, R = \infty$

19.  $\frac{1}{3} + \sum_{n=1}^{\infty} (-1)^n \frac{1 \cdot 3 \cdot 5 \cdots (2n-1)}{2^n \cdot 3^{2n+1} \cdot n!} (x-9)^n, R = 9$

25.  $1 + \frac{x}{2} + \sum_{n=2}^{\infty} (-1)^{n-1} \frac{1 \cdot 3 \cdot 5 \cdots (2n-3)}{2^n n!} x^n, R = 1$

27.  $\sum_{n=0}^{\infty} (-1)^n \frac{(n+1)(n+2)}{2^{n+4}} x^n, R = 2$

29.  $\sum_{n=0}^{\infty} (-1)^n \frac{\pi^{2n+1}}{(2n+1)!} x^{2n+1}, R = \infty$

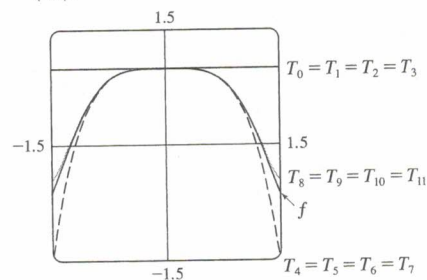
31.  $\sum_{n=0}^{\infty} \frac{2^n + 1}{n!} x^n, R = \infty$

33.  $\sum_{n=0}^{\infty} (-1)^n \frac{1}{2^{2n}(2n)!} x^{4n+1}, R = \infty$

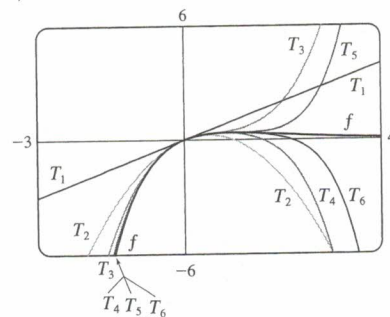
35.  $\frac{1}{2}x + \sum_{n=1}^{\infty} (-1)^n \frac{1 \cdot 3 \cdot 5 \cdots (2n-1)}{n! 2^{3n+1}} x^{2n+1}, R = 2$

37.  $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{2^{2n-1}}{(2n)!} x^{2n}, R = \infty$

39.  $\sum_{n=0}^{\infty} (-1)^n \frac{1}{(2n)!} x^{4n}, R = \infty$



41.  $\sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{(n-1)!} x^n, R = \infty$



43. 0.81873

45. (a)  $1 + \sum_{n=1}^{\infty} \frac{1 \cdot 3 \cdot 5 \cdots (2n-1)}{2^n n!} x^{2n}$

(b)  $x + \sum_{n=1}^{\infty} \frac{1 \cdot 3 \cdot 5 \cdots (2n-1)}{(2n+1)2^n n!} x^{2n+1}$

47.  $C + \sum_{n=0}^{\infty} (-1)^n \frac{x^{6n+2}}{(6n+2)(2n)!}, R = \infty$

49.  $C + \sum_{n=1}^{\infty} (-1)^n \frac{1}{2n(2n)!} x^{2n}, R = \infty$     51. 0.440

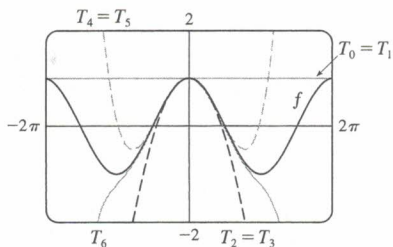
53. 0.40102    55.  $\frac{1}{3}$     57.  $\frac{1}{120}$     59.  $1 - \frac{3}{2}x^2 + \frac{25}{24}x^4$

61.  $1 + \frac{1}{6}x^2 + \frac{7}{360}x^4$     63.  $e^{-x^4}$

65.  $1/\sqrt{2}^x$     67.  $e^3 - 1$

EXERCISES 12.11 ■ PAGE 791

1. (a)  $T_0(x) = 1 = T_1(x)$ ,  $T_2(x) = 1 - \frac{1}{2}x^2 = T_3(x)$ ,  
 $T_4(x) = 1 - \frac{1}{2}x^2 + \frac{1}{24}x^4 = T_5(x)$ ,  
 $T_6(x) = 1 - \frac{1}{2}x^2 + \frac{1}{24}x^4 - \frac{1}{720}x^6$

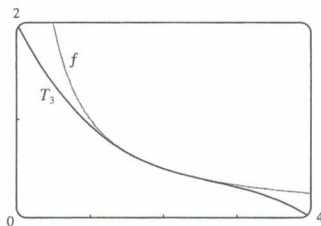


(b)

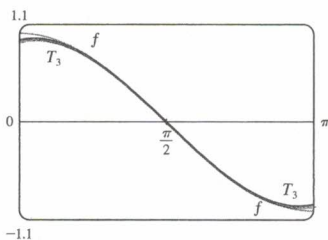
$x$	$f$	$T_0 = T_1$	$T_2 = T_3$	$T_4 = T_5$	$T_6$
$\frac{\pi}{4}$	0.7071	1	0.6916	0.7074	0.7071
$\frac{\pi}{2}$	0	1	-0.2337	0.0200	-0.0009
$\pi$	-1	1	-3.9348	0.1239	-1.2114

(c) As  $n$  increases,  $T_n(x)$  is a good approximation to  $f(x)$  on a larger and larger interval.

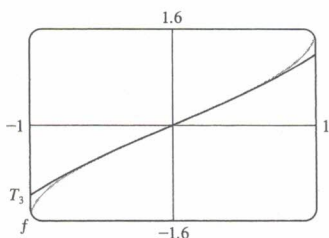
3.  $\frac{1}{2} - \frac{1}{4}(x-2) + \frac{1}{8}(x-2)^2 - \frac{1}{16}(x-2)^3$



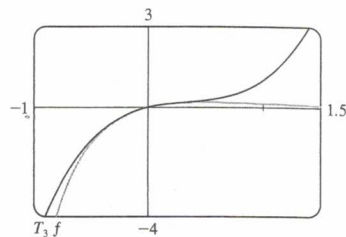
5.  $-\left(x - \frac{\pi}{2}\right) + \frac{1}{6}\left(x - \frac{\pi}{2}\right)^3$



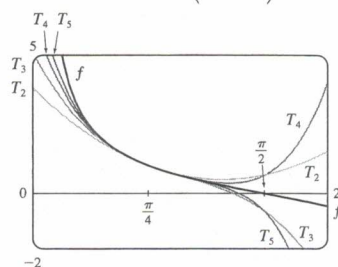
7.  $x + \frac{1}{6}x^3$



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)  $2 + \frac{1}{4}(x-4) - \frac{1}{64}(x-4)^2$  (b)  $1.5625 \times 10^{-5}$   
 15. (a)  $1 + \frac{2}{3}(x-1) - \frac{1}{9}(x-1)^2 + \frac{4}{81}(x-1)^3$  (b) 0.000097  
 17. (a)  $1 + \frac{1}{2}x^2$  (b) 0.0015    19. (a)  $1 + x^2$  (b) 0.00006  
 21. (a)  $x^2 - \frac{1}{6}x^4$  (b) 0.042    23. 0.17365    25. Four  
 27.  $-1.037 < x < 1.037$     29.  $-0.86 < x < 0.86$   
 31. 21 m, no    37. (c) They differ by about  $8 \times 10^{-9}$  km.

CHAPTER 12 REVIEW ■ PAGE 795

True-False Quiz

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

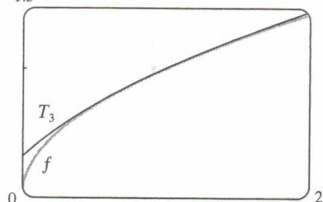
Exercises

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. 0.18976224, 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.  $-\sum_{n=1}^{\infty} \frac{x^n}{n}$ ,  $R = 1$   
 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) 0.000006



59.  $-\frac{1}{6}$

PROBLEMS PLUS ■ PAGE 797

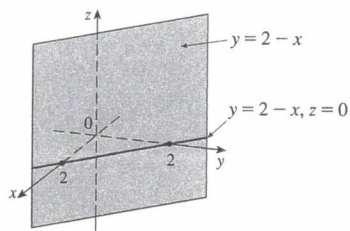
1.  $15!/5! = 10,897,286,400$   
 3. (b) 0 if  $x = 0$ ,  $(1/x) - \cot x$  if  $x \neq k\pi$ ,  $k$  an integer  
 5. (a)  $s_n = 3 \cdot 4^n$ ,  $l_n = 1/3^n$ ,  $p_n = 4^n/3^{n-1}$  (c)  $\frac{2}{5}\sqrt{3}$   
 9.  $(-1, 1)$ ,  $\frac{x^3 + 4x^2 + x}{(1-x)^4}$  II.  $\ln \frac{1}{2}$   
 13. (a)  $\frac{250}{101}\pi(e^{-(n-1)\pi/5} - e^{-n\pi/5})$  (b)  $\frac{250}{101}\pi$

CHAPTER 13

EXERCISES 13.1 ■ PAGE 805

1.  $(4, 0, -3)$  3.  $Q; R$

5. A vertical plane that intersects the  $xy$ -plane in the line  $y = 2 - x$ ,  $z = 0$  (see graph at right)



7.  $|PQ| = 6$ ,  $|QR| = 2\sqrt{10}$ ,  $|RP| = 6$ ; isosceles triangle

9. (a) No (b) Yes

11.  $(x-1)^2 + (y+4)^4 + (z-3)^2 = 25$ ;

$(x-1)^2 + (z-3)^2 = 9$ ,  $y = 0$  (a circle)

13.  $(x-3)^2 + (y-8)^2 + (z-1)^2 = 30$

15.  $(3, -2, 1)$ , 5

17.  $(2, 0, -6)$ ,  $9/\sqrt{2}$  19. (b)  $\frac{5}{2}, \frac{1}{2}\sqrt{94}, \frac{1}{2}\sqrt{85}$

21. (a)  $(x-2)^2 + (y+3)^2 + (z-6)^2 = 36$

(b)  $(x-2)^2 + (y+3)^2 + (z-6)^2 = 4$

(c)  $(x-2)^2 + (y+3)^2 + (z-6)^2 = 9$

23. A plane parallel to the  $xz$ -plane and 4 units to the left of it

25. A half-space consisting of all points in front of the plane  $x = 3$

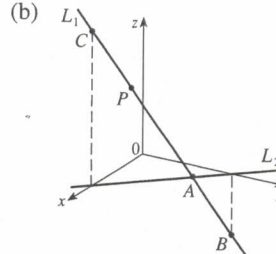
27. All points on or between the horizontal planes  $z = 0$  and  $z = 6$

29. All points on or inside a sphere with radius  $\sqrt{3}$  and center  $O$

31. All points on or inside a circular cylinder of radius 3 with axis the  $y$ -axis

33.  $0 < x < 5$  35.  $r^2 < x^2 + y^2 + z^2 < R^2$

37. (a)  $(2, 1, 4)$



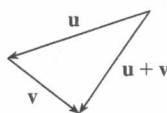
39.  $14x - 6y - 10z = 9$ , a plane perpendicular to  $AB$

EXERCISES 13.2 ■ PAGE 813

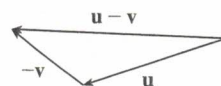
1. (a) Scalar (b) Vector (c) Vector (d) Scalar

3.  $\vec{AB} = \vec{DC}$ ,  $\vec{DA} = \vec{CB}$ ,  $\vec{DE} = \vec{EB}$ ,  $\vec{EA} = \vec{CE}$

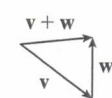
5. (a)



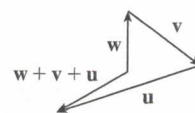
(b)



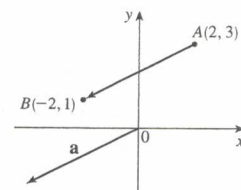
(c)



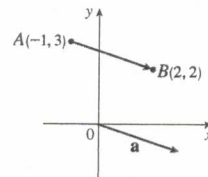
(d)



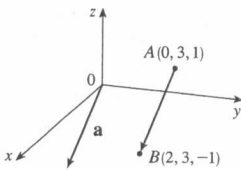
7.  $\mathbf{a} = \langle -4, -2 \rangle$



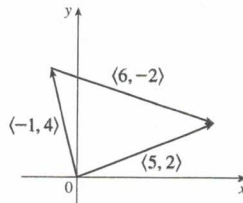
9.  $\mathbf{a} = \langle 3, -1 \rangle$



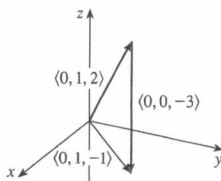
11.  $\mathbf{a} = \langle 2, 0, -2 \rangle$



13.  $\langle 5, 2 \rangle$



15.  $\langle 0, 1, -1 \rangle$



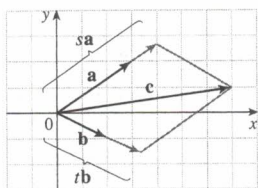
17.  $\langle 2, -18 \rangle$ ,  $\langle 1, -42 \rangle$ , 13, 10

19.  $-\mathbf{i} + \mathbf{j} + 2\mathbf{k}$ ,  $-4\mathbf{i} + \mathbf{j} + 9\mathbf{k}$ ,  $\sqrt{14}$ ,  $\sqrt{82}$

21.  $-\frac{3}{\sqrt{58}}\mathbf{i} + \frac{7}{\sqrt{58}}\mathbf{j}$  23.  $\frac{8}{9}\mathbf{i} - \frac{1}{9}\mathbf{j} + \frac{4}{9}\mathbf{k}$

25.  $\langle 2, 2\sqrt{3} \rangle$  27.  $\approx 45.96$  ft/s,  $\approx 38.57$  ft/s  
 29.  $100\sqrt{7} \approx 264.6$  N,  $\approx 139.1^\circ$   
 31.  $\sqrt{493} \approx 22.2$  mi/h, N8°W  
 33.  $\mathbf{T}_1 \approx -196\mathbf{i} + 3.92\mathbf{j}$ ,  $\mathbf{T}_2 \approx 196\mathbf{i} + 3.92\mathbf{j}$   
 35.  $\pm(\mathbf{i} + 4\mathbf{j})/\sqrt{17}$  37.  $\mathbf{0}$

39. (a), (b) (d)  $s = \frac{9}{7}$ ,  $t = \frac{11}{7}$



41. A sphere with radius 1, centered at  $(x_0, y_0, z_0)$

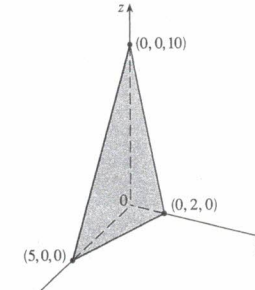
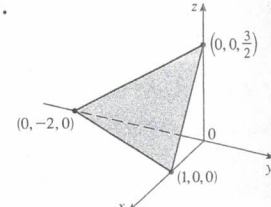
EXERCISES 13.3 ■ PAGE 820

1. (b), (c), (d) are meaningful  
 3. 14 5. 19 7. 32 9. -15  
 11.  $\mathbf{u} \cdot \mathbf{v} = \frac{1}{2}$ ,  $\mathbf{u} \cdot \mathbf{w} = -\frac{1}{2}$   
 15.  $\cos^{-1}\left(\frac{9 - 4\sqrt{7}}{20}\right) \approx 95^\circ$  17.  $\cos^{-1}\left(\frac{5}{\sqrt{1015}}\right) \approx 81^\circ$   
 19.  $\cos^{-1}\left(\frac{-1}{2\sqrt{7}}\right) \approx 101^\circ$  21.  $45^\circ, 45^\circ, 90^\circ$   
 23. (a) Neither (b) Orthogonal  
 (c) Orthogonal (d) Parallel  
 25. Yes 27.  $(\mathbf{i} - \mathbf{j} - \mathbf{k})/\sqrt{3}$  [or  $(-\mathbf{i} + \mathbf{j} + \mathbf{k})/\sqrt{3}$ ]  
 29.  $\frac{3}{5\sqrt{2}}$ ,  $\frac{4}{5\sqrt{2}}$ ,  $\frac{1}{\sqrt{2}}$ ;  $65^\circ, 56^\circ, 45^\circ$   
 31.  $\frac{2}{7}, \frac{3}{7}, -\frac{6}{7}$ ;  $73^\circ, 65^\circ, 149^\circ$   
 33.  $1/\sqrt{3}, 1/\sqrt{3}, 1/\sqrt{3}$ ;  $55^\circ, 55^\circ, 55^\circ$   
 35.  $3, \langle \frac{9}{5}, -\frac{12}{5} \rangle$  37.  $\frac{9}{7}, \langle \frac{27}{49}, \frac{54}{49}, -\frac{18}{49} \rangle$   
 39.  $1/\sqrt{21}, \frac{2}{21}\mathbf{i} - \frac{1}{21}\mathbf{j} + \frac{4}{21}\mathbf{k}$   
 43.  $\langle 0, 0, -2\sqrt{10} \rangle$  or any vector of the form  $\langle s, t, 3s - 2\sqrt{10} \rangle$ ,  $s, t \in \mathbb{R}$   
 45. 144 J 47.  $2400 \cos(40^\circ) \approx 1839$  ft-lb 49.  $\frac{13}{5}$   
 51.  $\cos^{-1}(1/\sqrt{3}) \approx 55^\circ$

EXERCISES 13.4 ■ PAGE 828

1.  $16\mathbf{i} + 48\mathbf{k}$  3.  $15\mathbf{i} - 3\mathbf{j} + 3\mathbf{k}$  5.  $\frac{1}{2}\mathbf{i} - \mathbf{j} + \frac{3}{2}\mathbf{k}$   
 7.  $t^4\mathbf{i} - 2t^3\mathbf{j} + t^2\mathbf{k}$  9.  $\mathbf{0}$  11.  $\mathbf{i} + \mathbf{j} + \mathbf{k}$   
 13. (a) Scalar (b) Meaningless (c) Vector  
 (d) Meaningless (e) Meaningless (f) Scalar  
 15. 24; into the page 17.  $\langle 5, -3, 1 \rangle, \langle -5, 3, -1 \rangle$   
 19.  $\langle -2/\sqrt{6}, -1/\sqrt{6}, 1/\sqrt{6} \rangle, \langle 2/\sqrt{6}, 1/\sqrt{6}, -1/\sqrt{6} \rangle$   
 27. 16 29. (a)  $\langle 6, 3, 2 \rangle$  (b)  $\frac{7}{2}$   
 31. (a)  $\langle 13, -14, 5 \rangle$  (b)  $\frac{1}{2}\sqrt{390}$   
 33. 82 35. 3 39.  $10.8 \sin 80^\circ \approx 10.6$  N·m  
 41.  $\approx 417$  N 43. (b)  $\sqrt{97/3}$   
 49. (a) No (b) No (c) Yes

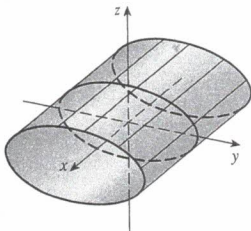
EXERCISES 13.5 ■ PAGE 838

1. (a) True (b) False (c) True (d) False (e) False  
 (f) True (g) False (h) True (i) True (j) False  
 (k) True  
 3.  $\mathbf{r} = (2\mathbf{i} + 2.4\mathbf{j} + 3.5\mathbf{k}) + t(3\mathbf{i} + 2\mathbf{j} - \mathbf{k})$ ;  
 $x = 2 + 3t, y = 2.4 + 2t, z = 3.5 - t$   
 5.  $\mathbf{r} = (\mathbf{i} + 6\mathbf{k}) + t(\mathbf{i} + 3\mathbf{j} + \mathbf{k})$ ;  
 $x = 1 + t, y = 3t, z = 6 + t$   
 7.  $x = 1 - 5t, y = 3, z = 2 - 2t$ ;  $\frac{x-1}{-5} = \frac{z-2}{-2}, y = 3$   
 9.  $x = 2 + 2t, y = 1 + \frac{1}{2}t$ ,  
 $z = -3 - 4t$ ;  
 $(x-2)/2 = 2y-2 = (z+3)/(-4)$   
 11.  $x = 1 + t, y = -1 + 2t, z = 1 + t$ ;  
 $x - 1 = (y + 1)/2 = z - 1$   
 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.  $\mathbf{r}(t) = (2\mathbf{i} - \mathbf{j} + 4\mathbf{k}) + t(2\mathbf{i} + 7\mathbf{j} - 3\mathbf{k})$ ,  $0 \leq t \leq 1$   
 19. Parallel 21. Skew  
 23.  $-2x + y + 5z = 1$  25.  $x + y - z = -1$   
 27.  $2x - y + 3z = 0$  29.  $3x - 7z = -9$   
 31.  $x + y + z = 2$  33.  $-13x + 17y + 7z = -42$   
 35.  $33x + 10y + 4z = 190$  37.  $x - 2y + 4z = -1$   
 39.   
 41.   
 43.  $(2, 3, 5)$  45.  $(2, 3, 1)$  47.  $1, 0, -1$   
 49. Perpendicular 51. Neither,  $\approx 70.5^\circ$  53. Parallel  
 55. (a)  $x = 1, y = -t, z = t$  (b)  $\cos^{-1}\left(\frac{5}{3\sqrt{3}}\right) \approx 15.8^\circ$   
 57.  $x = 1, y - 2 = -z$   
 59.  $x + 2y + z = 5$  61.  $(x/a) + (y/b) + (z/c) = 1$   
 63.  $x = 3t, y = 1 - t, z = 2 - 2t$   
 65.  $P_1$  and  $P_3$  are parallel,  $P_2$  and  $P_4$  are identical  
 67.  $\sqrt{61/14}$  69.  $\frac{18}{7}$  71.  $5/(2\sqrt{14})$  75.  $1/\sqrt{6}$

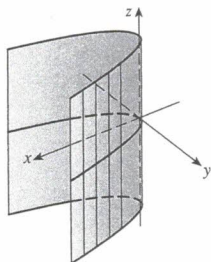
EXERCISES 13.6 ■ PAGE 846

1. (a) Parabola  
 (b) Parabolic cylinder with rulings parallel to the  $z$ -axis  
 (c) Parabolic cylinder with rulings parallel to the  $x$ -axis

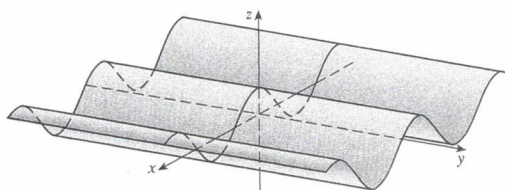
3. Elliptic cylinder



5. Parabolic cylinder

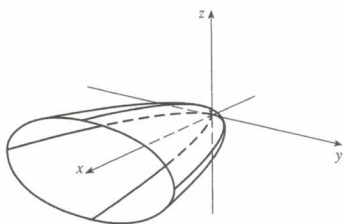


7. Cylindrical surface

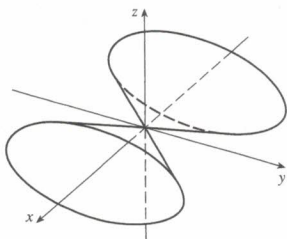


9. (a)  $x = k, y^2 - z^2 = 1 - k^2$ , hyperbola ( $k \neq \pm 1$ );  
 $y = k, x^2 - z^2 = 1 - k^2$ , hyperbola ( $k \neq \pm 1$ );  
 $z = k, x^2 + y^2 = 1 + k^2$ , circle  
 (b) The hyperboloid is rotated so that it has axis the y-axis  
 (c) The hyperboloid is shifted one unit in the negative y-direction

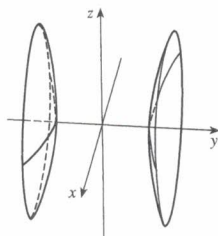
11. Elliptic paraboloid with axis the x-axis



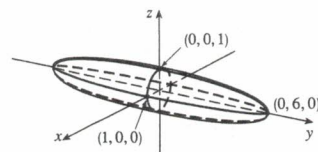
13. Elliptic cone with axis the x-axis



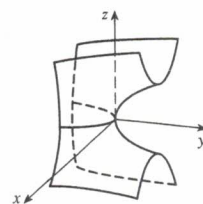
15. Hyperboloid of two sheets



17. Ellipsoid

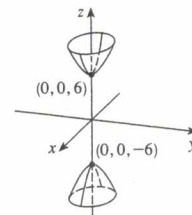


19. Hyperbolic paraboloid



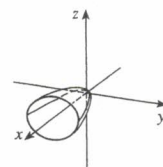
21. VII    23. II    25. VI    27. VIII

29.  $-\frac{x^2}{9} - \frac{y^2}{4} + \frac{z^2}{36} = 1$   
 Hyperboloid of two sheets  
 with axis the z-axis



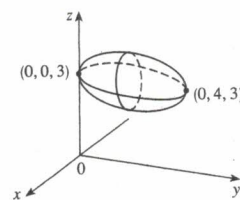
31.  $\frac{x}{6} = \frac{y^2}{3} + \frac{z^2}{2}$

Elliptic paraboloid with vertex  
 (0, 0, 0) and axis the x-axis

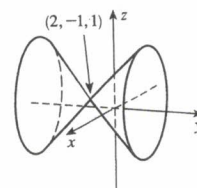


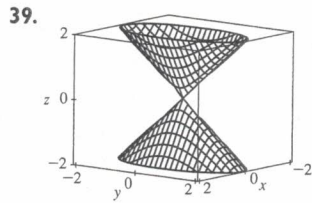
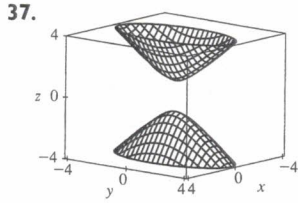
33.  $x^2 + \frac{(y-2)^2}{4} + (z-3)^2 = 1$

Ellipsoid with center (0, 2, 3)



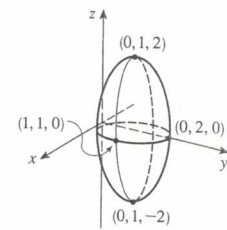
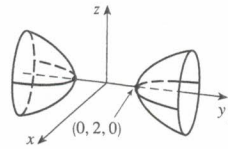
35.  $(y+1)^2 = (x-2)^2 + (z-1)^2$   
 Circular cone with vertex (2, -1, 1)  
 and axis parallel to the y-axis





33. Hyperboloid of two sheets

35. Ellipsoid



37.  $4x^2 + y^2 + z^2 = 16$

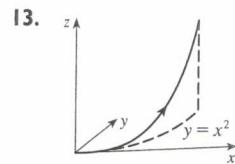
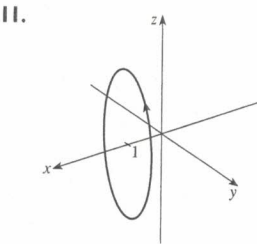
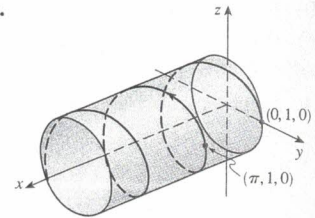
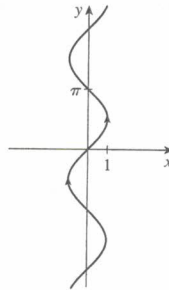
PROBLEMS PLUS = PAGE 851

1.  $(\sqrt{3} - 1.5) \text{ m}$   
 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)  $4\pi/3$

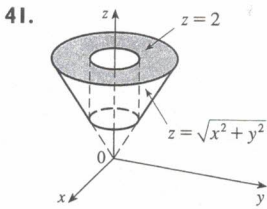
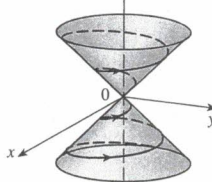
CHAPTER 14

EXERCISES 14.1 = PAGE 858

1.  $(-1, 2]$     3.  $\langle 1, 0, 0 \rangle$     5.  $\mathbf{i} + \mathbf{j} + \mathbf{k}$   
 7.    9.

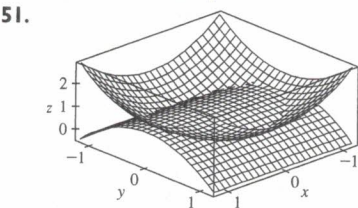


15.  $\mathbf{r}(t) = \langle t, 2t, 3t \rangle, 0 \leq t \leq 1;$   
 $x = t, y = 2t, z = 3t, 0 \leq t \leq 1$   
 17.  $\mathbf{r}(t) = \langle 3t + 1, 2t - 1, 5t + 2 \rangle, 0 \leq t \leq 1;$   
 $x = 3t + 1, y = 2t - 1, z = 5t + 2, 0 \leq t \leq 1$   
 19. VI    21. IV    23. V  
 25.    27.  $(0, 0, 0), (1, 0, 1)$



43.  $y = x^2 + z^2$     45.  $-4x = y^2 + z^2$ , paraboloid

47. (a)  $\frac{x^2}{(6378.137)^2} + \frac{y^2}{(6378.137)^2} + \frac{z^2}{(6356.523)^2} = 1$   
 (b) Circle    (c) Ellipse



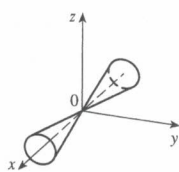
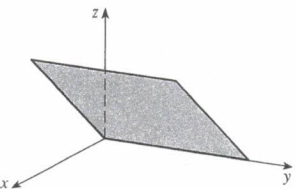
CHAPTER 13 REVIEW = PAGE 848

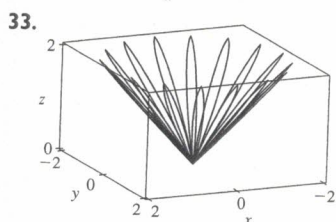
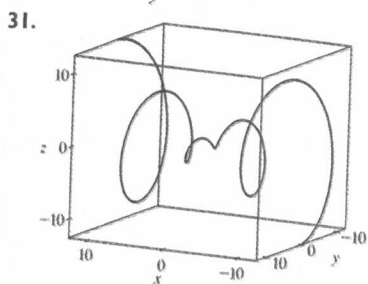
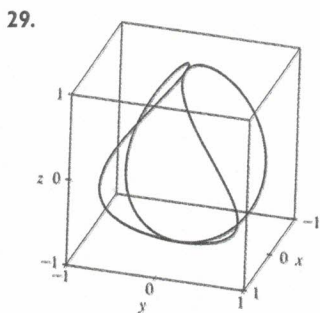
True-False Quiz

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

Exercises

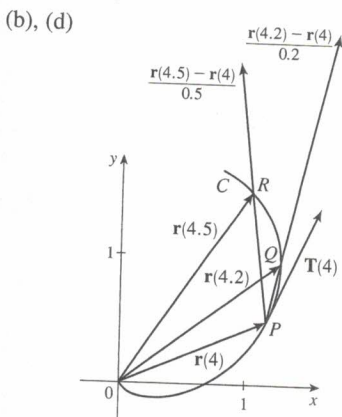
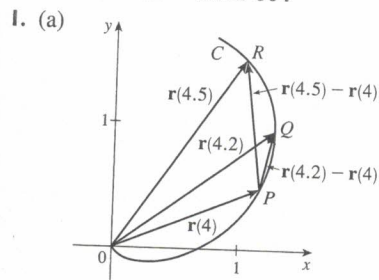
1. (a)  $(x + 1)^2 + (y - 2)^2 + (z - 1)^2 = 69$   
 (b)  $(y - 2)^2 + (z - 1)^2 = 68, x = 0$   
 (c) Center  $(4, -1, -3)$ , radius 5  
 3.  $\mathbf{u} \cdot \mathbf{v} = 3\sqrt{2}; |\mathbf{u} \times \mathbf{v}| = 3\sqrt{2}$ ; out of the page  
 5.  $-2, -4$     7. (a) 2    (b)  $-2$     (c)  $-2$     (d) 0  
 9.  $\cos^{-1}(\frac{1}{3}) \approx 71^\circ$     11. (a)  $\langle 4, -3, 4 \rangle$     (b)  $\sqrt{41}/2$   
 13. 166 N, 114 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





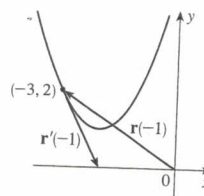
37.  $\mathbf{r}(t) = t\mathbf{i} + \frac{1}{2}(t^2 - 1)\mathbf{j} + \frac{1}{2}(t^2 + 1)\mathbf{k}$   
 39.  $x = 2 \cos t, y = 2 \sin t, z = 4 \cos^2 t$     41. Yes

EXERCISES 14.2 = PAGE 864

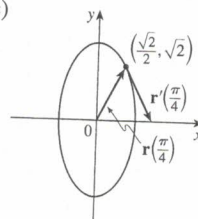


(c)  $\mathbf{r}'(4) = \lim_{h \rightarrow 0} \frac{\mathbf{r}(4+h) - \mathbf{r}(4)}{h}$ ;  $\mathbf{T}(4) = \frac{\mathbf{r}'(4)}{|\mathbf{r}'(4)|}$

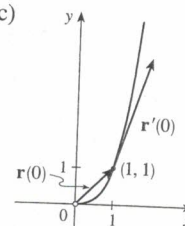
3. (a), (c)      (b)  $\mathbf{r}'(t) = \langle 1, 2t \rangle$



5. (a), (c)



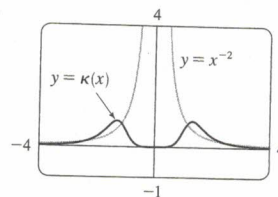
7. (a), (c)



- (b)  $\mathbf{r}'(t) = \cos t \mathbf{i} - 2 \sin t \mathbf{j}$       (b)  $\mathbf{r}'(t) = e^t \mathbf{i} + 3e^{3t} \mathbf{j}$   
 9.  $\mathbf{r}'(t) = \langle t \cos t + \sin t, 2t, \cos 2t - 2t \sin 2t \rangle$   
 11.  $\mathbf{r}'(t) = 4e^{4t} \mathbf{k}$     13.  $\mathbf{r}'(t) = 2te^{t^2} \mathbf{i} + [3/(1+3t)] \mathbf{k}$   
 15.  $\mathbf{r}'(t) = \mathbf{b} + 2t\mathbf{c}$     17.  $\langle \frac{1}{3}, \frac{2}{3}, \frac{2}{3} \rangle$     19.  $\frac{3}{5} \mathbf{j} + \frac{4}{5} \mathbf{k}$   
 21.  $\langle 1, 2t, 3t^2 \rangle, \langle 1/\sqrt{14}, 2/\sqrt{14}, 3/\sqrt{14} \rangle, \langle 0, 2, 6t \rangle, \langle 6t^2, -6t, 2 \rangle$   
 23.  $x = 3 + t, y = 2t, z = 2 + 4t$   
 25.  $x = 1 - t, y = t, z = 1 - t$   
 27.  $x = t, y = 1 - t, z = 2t$   
 29.  $x = -\pi - t, y = \pi + t, z = -\pi t$   
 31.  $66^\circ$     33.  $4\mathbf{i} - 3\mathbf{j} + 5\mathbf{k}$     35.  $\mathbf{i} + \mathbf{j} + \mathbf{k}$   
 37.  $e^t \mathbf{i} + t^2 \mathbf{j} + (t \ln t - t) \mathbf{k} + \mathbf{C}$   
 39.  $t^2 \mathbf{i} + t^3 \mathbf{j} + (\frac{2}{3}t^{3/2} - \frac{2}{3}) \mathbf{k}$   
 45.  $2t \cos t + 2 \sin t - 2 \cos t \sin t$

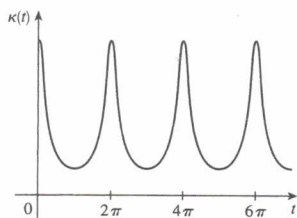
EXERCISES 14.3 = PAGE 872

1.  $20\sqrt{29}$     3.  $e - e^{-1}$     5.  $\frac{1}{27}(13^{3/2} - 8)$     7. 15.3841  
 9. 1.2780    11. 42  
 13.  $\mathbf{r}(t(s)) = \frac{2}{\sqrt{29}}s \mathbf{i} + \left(1 - \frac{3}{\sqrt{29}}s\right) \mathbf{j} + \left(5 + \frac{4}{\sqrt{29}}s\right) \mathbf{k}$   
 15.  $(3 \sin 1, 4, 3 \cos 1)$   
 17. (a)  $\langle (2/\sqrt{29}) \cos t, 5/\sqrt{29}, (-2/\sqrt{29}) \sin t \rangle, \langle -\sin t, 0, -\cos t \rangle$     (b)  $\frac{2}{29}$   
 19. (a)  $\frac{1}{e^{2t} + 1} \langle \sqrt{2}e^t, e^{2t}, -1 \rangle, \frac{1}{e^{2t} + 1} \langle 1 - e^{2t}, \sqrt{2}e^t, \sqrt{2}e^t \rangle$   
 (b)  $\sqrt{2}e^{2t}/(e^{2t} + 1)^2$   
 21.  $2/(4t^2 + 1)^{3/2}$     23.  $\frac{4}{25}$     25.  $\frac{1}{7}\sqrt{\frac{19}{14}}$   
 27.  $2/(4x^2 - 8x + 5)^{3/2}$     29.  $15\sqrt{x}/(1 + 100x^3)^{3/2}$   
 31.  $(-\frac{1}{2} \ln 2, 1/\sqrt{2})$ ; approaches 0  
 33. (a) P    (b) 1.3, 0.7    35.



37. a is  $y = f(x)$ , b is  $y = \kappa(x)$

39.  $\kappa(t) = \frac{6\sqrt{4\cos^2 t - 12\cos t + 13}}{(17 - 12\cos t)^{3/2}}$

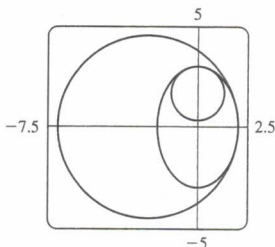


integer multiples of  $2\pi$

41.  $1/(\sqrt{2}e^t)$     43.  $\langle \frac{2}{3}, \frac{2}{3}, \frac{1}{3} \rangle, \langle -\frac{1}{3}, \frac{2}{3}, -\frac{2}{3} \rangle, \langle -\frac{2}{3}, \frac{1}{3}, \frac{2}{3} \rangle$

45.  $y = 6x + \pi, x + 6y = 6\pi$

47.  $(x + \frac{5}{2})^2 + y^2 = \frac{81}{4}, x^2 + (y - \frac{5}{3})^2 = \frac{16}{9}$



49.  $(-1, -3, 1)$     57.  $2/(t^4 + 4t^2 + 1)$

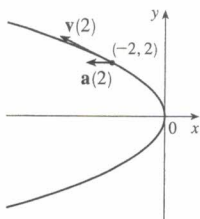
59.  $2.07 \times 10^{10} \text{ \AA} \approx 2 \text{ m}$

EXERCISES 14.4 ■ PAGE 882

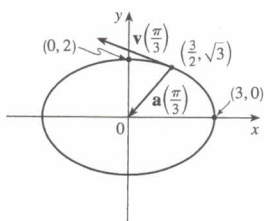
1. (a)  $1.8\mathbf{i} - 3.8\mathbf{j} - 0.7\mathbf{k}, 2.0\mathbf{i} - 2.4\mathbf{j} - 0.6\mathbf{k}, 2.8\mathbf{i} + 1.8\mathbf{j} - 0.3\mathbf{k}, 2.8\mathbf{i} + 0.8\mathbf{j} - 0.4\mathbf{k}$

(b)  $2.4\mathbf{i} - 0.8\mathbf{j} - 0.5\mathbf{k}, 2.58$

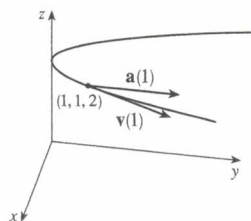
3.  $\mathbf{v}(t) = \langle -t, 1 \rangle$   
 $\mathbf{a}(t) = \langle -1, 0 \rangle$   
 $|\mathbf{v}(t)| = \sqrt{t^2 + 1}$



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.  $\mathbf{v}(t) = \mathbf{i} + 2t\mathbf{j}$   
 $\mathbf{a}(t) = 2\mathbf{j}$   
 $|\mathbf{v}(t)| = \sqrt{1 + 4t^2}$



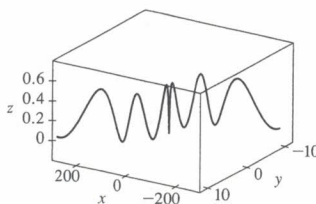
9.  $\langle 2t, 3t^2, 2t \rangle, \langle 2, 6t, 2 \rangle, |t|\sqrt{9t^2 + 8}$

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.  $\mathbf{v}(t) = t\mathbf{i} + 2t\mathbf{j} + \mathbf{k}, \mathbf{r}(t) = (\frac{1}{2}t^2 + 1)\mathbf{i} + t^2\mathbf{j} + t\mathbf{k}$

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)



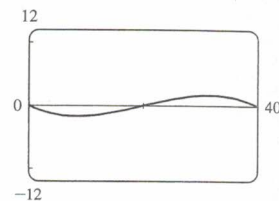
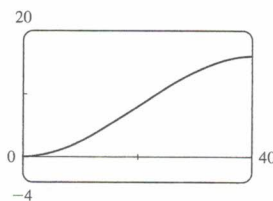
19.  $t = 4$     21.  $\mathbf{r}(t) = t\mathbf{i} - t\mathbf{j} + \frac{5}{2}t^2\mathbf{k}, |\mathbf{v}(t)| = \sqrt{25t^2 + 2}$

23. (a)  $\approx 22 \text{ km}$  (b)  $\approx 3.2 \text{ km}$  (c)  $500 \text{ m/s}$

25.  $30 \text{ m/s}$     27.  $\approx 10.2^\circ, \approx 79.8^\circ$

29.  $13.0^\circ < \theta < 36.0^\circ, 55.4^\circ < \theta < 85.5^\circ$

31. (a)  $16 \text{ m}$  (b)  $\approx 23.6^\circ$  upstream



33.  $6t, 6$     35.  $0, 1$     37.  $e^t - e^{-t}, \sqrt{2}$

39.  $4.5 \text{ cm/s}^2, 9.0 \text{ cm/s}^2$     41.  $t = 1$

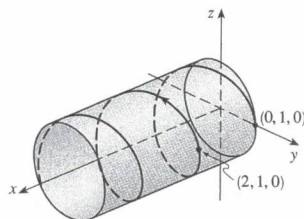
CHAPTER 14 REVIEW ■ PAGE 886

True-False Quiz

1. True    3. False    5. False    7. True  
 9. False    11. 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.  $\pi/2$

11. (a)  $\langle t^2, t, 1 \rangle / \sqrt{t^4 + t^2 + 1}$

(b)  $\langle 2t, 1 - t^4, -2t^3 - t \rangle / \sqrt{t^8 + 4t^6 + 2t^4 + 5t^2}$

(c)  $\sqrt{t^8 + 4t^6 + 2t^4 + 5t^2} / (t^4 + t^2 + 1)^2$

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. (a) About 3.8 ft above the ground, 60.8 ft from the athlete  
 (b)  $\approx 21.4$  ft (c)  $\approx 64.2$  ft from the athlete  
 21. (c)  $-2e^{-t} \mathbf{v}_d + e^{-t} \mathbf{R}$

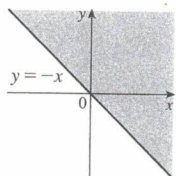
**PROBLEMS PLUS ■ PAGE 888**

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)  $\approx 0.94$  ft to the right of the table's edge,  $\approx 15$  ft/s  
 (b)  $\approx 7.6^\circ$  (c)  $\approx 2.13$  ft to the right of the table's edge  
 7.  $56^\circ$

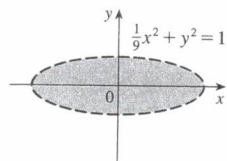
**CHAPTER 15**

**EXERCISES 15.1 ■ PAGE 901**

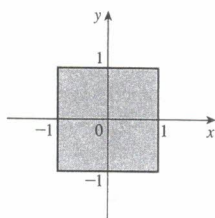
1. (a)  $-27$ ; a temperature of  $-15^\circ\text{C}$  with wind blowing at 40 km/h feels equivalent to about  $-27^\circ\text{C}$  without wind.  
 (b) When the temperature is  $-20^\circ\text{C}$ , what wind speed gives a wind chill of  $-30^\circ\text{C}$ ? 20 km/h  
 (c) With a wind speed of 20 km/h, what temperature gives a wind chill of  $-49^\circ\text{C}$ ?  $-35^\circ\text{C}$   
 (d) A function of wind speed that gives wind-chill values when the temperature is  $-5^\circ\text{C}$   
 (e) A function of temperature that gives wind-chill values when the wind speed is 50 km/h  
 3. Yes  
 5. (a) 25; a 40-knot wind blowing in the open sea for 15 h will create waves about 25 ft high.  
 (b)  $f(30, t)$  is a function of  $t$  giving the wave heights produced by 30-knot 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.  
 7. (a) 4 (b)  $\mathbb{R}^2$  (c)  $[0, \infty)$   
 9. (a)  $e$  (b)  $\{(x, y, z) \mid z \geq x^2 + y^2\}$  (c)  $[1, \infty)$   
 11.  $\{(x, y) \mid y \geq -x\}$



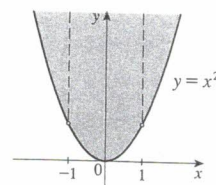
13.  $\{(x, y) \mid \frac{1}{9}x^2 + y^2 < 1\}$



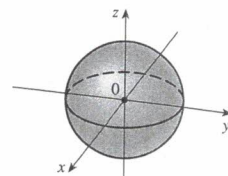
15.  $\{(x, y) \mid -1 \leq x \leq 1, -1 \leq y \leq 1\}$



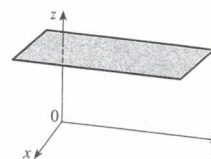
17.  $\{(x, y) \mid y \geq x^2, x \neq \pm 1\}$



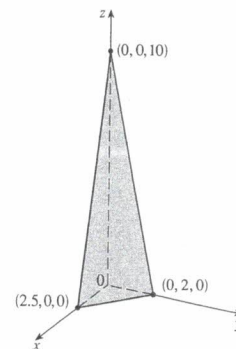
19.  $\{(x, y, z) \mid x^2 + y^2 + z^2 \leq 1\}$



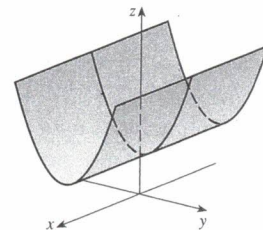
21.  $z = 3$ , horizontal plane



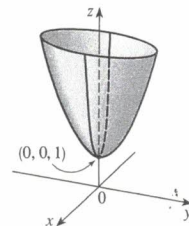
23.  $4x + 5y + z = 10$ , plane



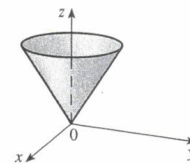
25.  $z = y^2 + 1$ , parabolic cylinder



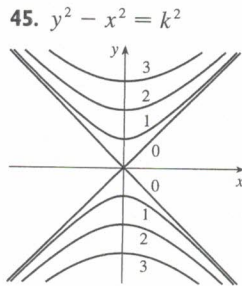
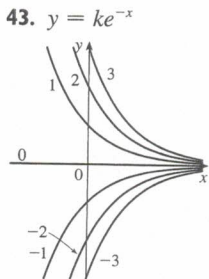
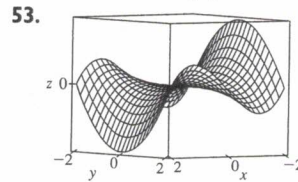
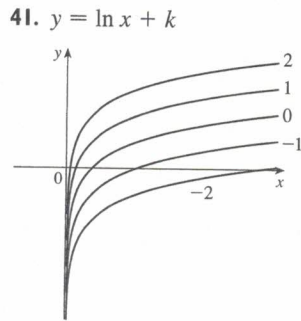
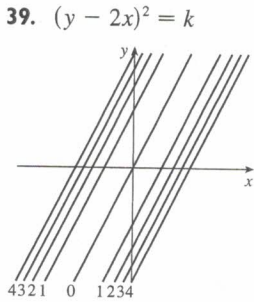
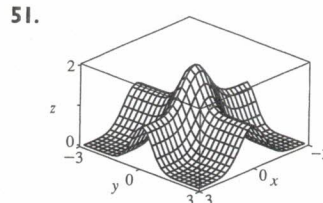
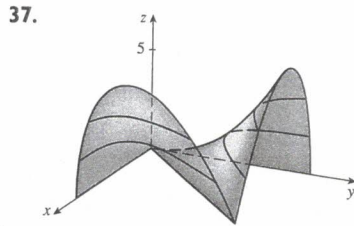
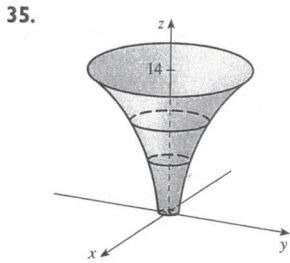
27.  $z = 4x^2 + y^2 + 1$   
elliptic paraboloid



29.  $z = \sqrt{x^2 + y^2}$ ,  
top half of cone



31.  $\approx 56$ ,  $\approx 35$     33. Steep; nearly flat



55. (a) C (b) II 57. (a) F (b) I

59. (a) B (b) VI

61. Family of parallel planes

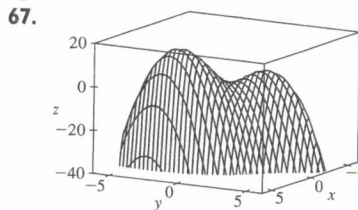
63. Family of hyperboloids of one or two sheets with axis the y-axis

65. (a) Shift the graph of  $f$  upward 2 units

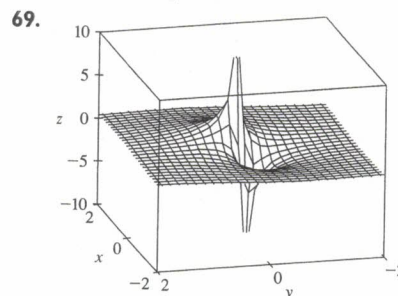
(b) Stretch the graph of  $f$  vertically by a factor of 2

(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



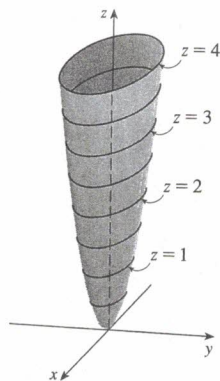
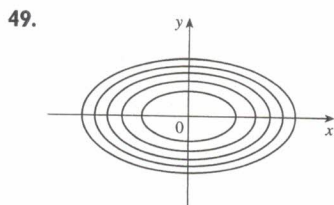
$f$  appears to have a maximum value of about 15. There are two local maximum points but no local minimum point.



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.

71. 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  $(0, 0, 1)$ .

73.  $c = -2, 0, 2$  75. (b)  $y = 0.75x + 0.01$

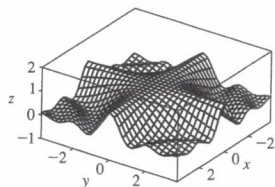




EXERCISES 15.2 ■ PAGE 913

1. Nothing; if  $f$  is continuous,  $f(3, 1) = 6$     3.  $-\frac{5}{2}$   
 5. 1    7.  $\frac{2}{7}$     9. Does not exist    11. Does not exist  
 13. 0    15. Does not exist    17. 2    19. 1  
 21. Does not exist  
 23. The graph shows that the function approaches different numbers along different lines.  
 25.  $h(x, y) = (2x + 3y - 6)^2 + \sqrt{2x + 3y - 6}$ ;  
 $\{(x, y) \mid 2x + 3y \geq 6\}$   
 27. Along the line  $y = x$     29.  $\{(x, y) \mid y \neq \pm e^{x/2}\}$   
 31.  $\{(x, y) \mid y \geq 0\}$     33.  $\{(x, y) \mid x^2 + y^2 > 4\}$   
 35.  $\{(x, y, z) \mid y \geq 0, y \neq \sqrt{x^2 + z^2}\}$   
 37.  $\{(x, y) \mid (x, y) \neq (0, 0)\}$     39. 0    41. -1

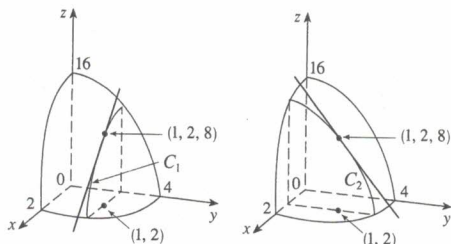
43.



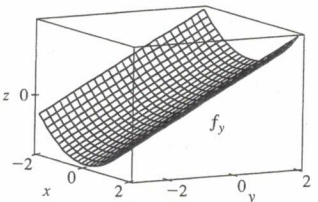
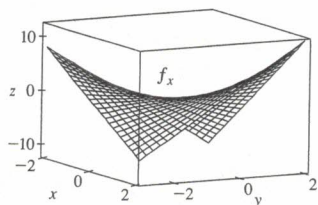
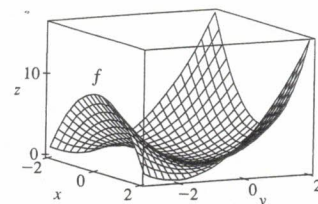
$f$  is continuous on  $\mathbb{R}^2$

EXERCISES 15.3 ■ PAGE 924

1. (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  
 3. (a)  $f_T(-15, 30) \approx 1.3$ ; for a temperature of  $-15^\circ\text{C}$  and wind speed of 30 km/h, the wind-chill index rises by  $1.3^\circ\text{C}$  for each degree the temperature increases.  $f_v(-15, 30) \approx -0.15$ ; for a temperature of  $-15^\circ\text{C}$  and wind speed of 30 km/h, the wind-chill index decreases by  $0.15^\circ\text{C}$  for each km/h the wind speed increases.  
 (b) Positive, negative    (c) 0  
 5. (a) Positive    (b) Negative  
 7. (a) Positive    (b) Negative  
 9.  $c = f, b = f_x, a = f_y$   
 11.  $f_x(1, 2) = -8 = \text{slope of } C_1, f_y(1, 2) = -4 = \text{slope of } C_2$



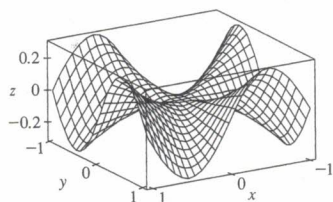
13.  $f_x = 2x + 2xy, f_y = 2y + x^2$



15.  $f_x(x, y) = -3y, f_y(x, y) = 5y^4 - 3x$   
 17.  $f_x(x, t) = -\pi e^{-t} \sin \pi x, f_t(x, t) = -e^{-t} \cos \pi x$   
 19.  $\partial z/\partial x = 20(2x + 3y)^9, \partial z/\partial y = 30(2x + 3y)^9$   
 21.  $f_x(x, y) = 2y/(x + y)^2, f_y(x, y) = -2x/(x + y)^2$   
 23.  $\partial w/\partial \alpha = \cos \alpha \cos \beta, \partial w/\partial \beta = -\sin \alpha \sin \beta$   
 25.  $f_x(r, s) = \frac{2r^2}{r^2 + s^2} + \ln(r^2 + s^2), f_s(r, s) = \frac{2rs}{r^2 + s^2}$   
 27.  $\partial u/\partial t = e^{w/t}(1 - w/t), \partial u/\partial w = e^{w/t}$   
 29.  $f_x = z - 10xy^3z^4, f_y = -15x^2y^2z^4, f_z = x - 20x^2y^3z^3$   
 31.  $\partial w/\partial x = 1/(x + 2y + 3z), \partial w/\partial y = 2/(x + 2y + 3z), \partial w/\partial z = 3/(x + 2y + 3z)$   
 33.  $\partial u/\partial x = y \sin^{-1}(yz), \partial u/\partial y = x \sin^{-1}(yz) + xyz/\sqrt{1 - y^2z^2}, \partial u/\partial z = xyz^2/\sqrt{1 - y^2z^2}$   
 35.  $f_x = yz^2 \tan(yt), f_y = xyz^2 t \sec^2(yt) + xz^2 \tan(yt), f_z = 2xyz \tan(yt), f_t = xy^2z^2 \sec^2(yt)$   
 37.  $\partial u/\partial x_i = x_i/\sqrt{x_1^2 + x_2^2 + \dots + x_n^2}$   
 39.  $\frac{1}{5}$     41.  $\frac{1}{4}$   
 43.  $f_x(x, y) = y^2 - 3x^2y, f_y(x, y) = 2xy - x^3$   
 45.  $\frac{\partial z}{\partial x} = \frac{3yz - 2x}{2z - 3xy}, \frac{\partial z}{\partial y} = \frac{3xz - 2y}{2z - 3xy}$   
 47.  $\frac{\partial z}{\partial x} = \frac{1 + y^2z^2}{1 + y + y^2z^2}, \frac{\partial z}{\partial y} = \frac{-z}{1 + y + y^2z^2}$   
 49. (a)  $f'(x), g'(y)$     (b)  $f'(x + y), f'(x + y)$   
 51.  $f_{xx} = 6xy^5 + 24x^2y, f_{xy} = 15x^2y^4 + 8x^3 = f_{yx}, f_{yy} = 20x^3y^3$   
 53.  $w_{uu} = v^2/(u^2 + v^2)^{3/2}, w_{uv} = -uv/(u^2 + v^2)^{3/2} = w_{vu}, w_{vv} = u^2/(u^2 + v^2)^{3/2}$   
 55.  $z_{xx} = -2x/(1 + x^2)^2, z_{xy} = 0 = z_{yx}, z_{yy} = -2y/(1 + y^2)^2$

61.  $12xy, 72xy$   
 63.  $24 \sin(4x + 3y + 2z), 12 \sin(4x + 3y + 2z)$   
 65.  $\theta e^{r\theta}(2 \sin \theta + \theta \cos \theta + r\theta \sin \theta)$  67.  $4/(y + 2z)^3, 0$   
 69.  $\approx 12.2, \approx 16.8, \approx 23.25$  81.  $R^2/R_1^2$   
 87. No 89.  $x = 1 + t, y = 2, z = 2 - 2t$   
 93.  $-2$

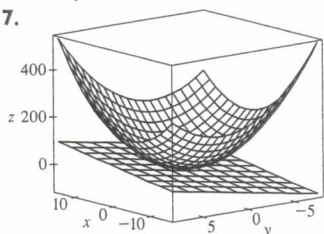
95. (a)



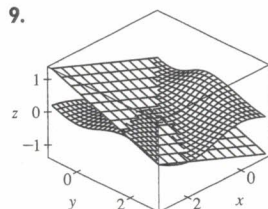
- (b)  $f_x(x, y) = \frac{x^4y + 4x^2y^3 - y^5}{(x^2 + y^2)^2}, f_y(x, y) = \frac{x^5 - 4x^3y^2 - xy^4}{(x^2 + y^2)^2}$   
 (c) 0, 0 (e) No, since  $f_{xy}$  and  $f_{yx}$  are not continuous.

EXERCISES 15.4 ■ PAGE 935

1.  $z = -8x - 2y$   
 3.  $x + y - 2z = 0$   
 5.  $z = y$   
 7.



9.



11.  $2x + \frac{1}{4}y - 1$  13.  $\frac{1}{9}x - \frac{2}{9}y + \frac{2}{3}$  15.  $1 - \pi y$   
 19.  $-\frac{2}{3}x - \frac{7}{3}y + \frac{20}{3}; 2.84\bar{6}$  21.  $\frac{3}{7}x + \frac{2}{7}y + \frac{6}{7}z; 6.9914$   
 23.  $4T + H - 329; 129^\circ\text{F}$   
 25.  $dz = 3x^2 \ln(y^2) dx + (2x^3/y) dy$   
 27.  $dm = 5p^4q^3 dp + 3p^5q^2 dq$   
 29.  $dR = \beta^2 \cos \gamma d\alpha + 2\alpha\beta \cos \gamma d\beta - \alpha\beta^2 \sin \gamma d\gamma$   
 31.  $\Delta z = 0.9225, dz = 0.9$  33.  $5.4 \text{ cm}^2$  35.  $16 \text{ cm}^3$   
 37. 150 39.  $\frac{1}{17} \approx 0.059 \Omega$  41. 2.3%  
 43.  $\varepsilon_1 = \Delta x, \varepsilon_2 = \Delta y$

EXERCISES 15.5 ■ PAGE 943

1.  $(2x + y) \cos t + (2y + x)e^t$   
 3.  $[(x/t) - y \sin t]/\sqrt{1 + x^2 + y^2}$   
 5.  $e^{y/z}[2t - (x/z) - (2xy/z^2)]$   
 7.  $\partial z/\partial s = 2xy^3 \cos t + 3x^2y^2 \sin t,$   
 $\partial z/\partial t = -2sxy^3 \sin t + 3sx^2y^2 \cos t$   
 9.  $\partial z/\partial s = t^2 \cos \theta \cos \phi - 2st \sin \theta \sin \phi,$   
 $\partial z/\partial t = 2st \cos \theta \cos \phi - s^2 \sin \theta \sin \phi$   
 11.  $\frac{\partial z}{\partial s} = e^r \left( t \cos \theta - \frac{s}{\sqrt{s^2 + t^2}} \sin \theta \right),$   
 $\frac{\partial z}{\partial t} = e^r \left( s \cos \theta - \frac{t}{\sqrt{s^2 + t^2}} \sin \theta \right)$

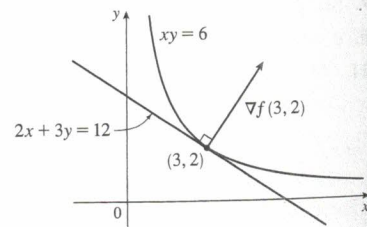
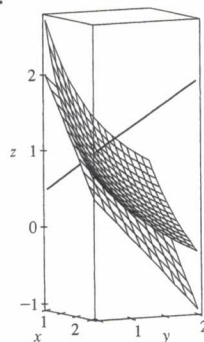
13. 62 15. 7, 2

17.  $\frac{\partial u}{\partial r} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial r} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial r}, \frac{\partial u}{\partial s} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial s} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial s},$   
 $\frac{\partial u}{\partial t} = \frac{\partial u}{\partial x} \frac{\partial x}{\partial t} + \frac{\partial u}{\partial y} \frac{\partial y}{\partial t}$   
 19.  $\frac{\partial w}{\partial x} = \frac{\partial w}{\partial r} \frac{\partial r}{\partial x} + \frac{\partial w}{\partial s} \frac{\partial s}{\partial x} + \frac{\partial w}{\partial t} \frac{\partial t}{\partial x},$   
 $\frac{\partial w}{\partial y} = \frac{\partial w}{\partial r} \frac{\partial r}{\partial y} + \frac{\partial w}{\partial s} \frac{\partial s}{\partial y} + \frac{\partial w}{\partial t} \frac{\partial t}{\partial y}$   
 21. 85, 178, 54 23.  $\frac{9}{7}, \frac{9}{7}$  25. 36, 24, 30  
 27.  $\frac{4(xy)^{3/2} - y}{x - 2x^2\sqrt{xy}}$  29.  $\frac{\sin(x - y) + e^y}{\sin(x - y) - xe^y}$   
 31.  $\frac{3yz - 2x}{2z - 3xy}, \frac{3xz - 2y}{2z - 3xy}$   
 33.  $\frac{1 + y^2z^2}{1 + y + y^2z^2}, -\frac{z}{1 + y + y^2z^2}$

35.  $2^\circ\text{C/s}$  37.  $\approx -0.33 \text{ m/s per minute}$   
 39. (a)  $6 \text{ m}^3/\text{s}$  (b)  $10 \text{ m}^2/\text{s}$  (c)  $0 \text{ m/s}$   
 41.  $\approx -0.27 \text{ L/s}$  43.  $-1/(12\sqrt{3}) \text{ rad/s}$   
 45. (a)  $\partial z/\partial r = (\partial z/\partial x) \cos \theta + (\partial z/\partial y) \sin \theta,$   
 $\partial z/\partial \theta = -(\partial z/\partial x)r \sin \theta + (\partial z/\partial y)r \cos \theta$   
 51.  $4rs \partial^2 z/\partial x^2 + (4r^2 + 4s^2) \partial^2 z/\partial x \partial y + 4rs \partial^2 z/\partial y^2 + 2 \partial z/\partial y$

EXERCISES 15.6 ■ PAGE 956

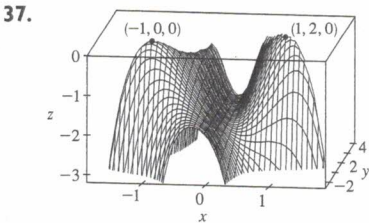
1.  $\approx -0.08 \text{ mb/km}$  3.  $\approx 0.778$  5.  $2 + \sqrt{3}/2$   
 7. (a)  $\nabla f(x, y) = \langle 2 \cos(2x + 3y), 3 \cos(2x + 3y) \rangle$   
 (b)  $\langle 2, 3 \rangle$  (c)  $\sqrt{3} - \frac{3}{2}$   
 9. (a)  $\langle e^{2yz}, 2xze^{2yz}, 2xye^{2yz} \rangle$  (b)  $\langle 1, 12, 0 \rangle$  (c)  $-\frac{22}{3}$   
 11.  $23/10$  13.  $-8/\sqrt{10}$  15.  $4/\sqrt{30}$  17.  $9/(2\sqrt{5})$   
 19.  $2/5$  21.  $4\sqrt{2}, \langle -1, 1 \rangle$  23.  $1, \langle 0, 1 \rangle$   
 25.  $1, \langle 3, 6, -2 \rangle$  27. (b)  $\langle -12, 92 \rangle$   
 29. All points on the line  $y = x + 1$   
 31. (a)  $-40/(3\sqrt{3})$   
 33. (a)  $32/\sqrt{3}$  (b)  $\langle 38, 6, 12 \rangle$  (c)  $2\sqrt{406}$  35.  $\frac{327}{13}$   
 39. (a)  $x + y + z = 11$  (b)  $x - 3 = y - 3 = z - 5$   
 41. (a)  $4x - 5y - z = 4$  (b)  $\frac{x-2}{4} = \frac{y-1}{-5} = \frac{z+1}{-1}$   
 43. (a)  $x + y - z = 1$  (b)  $x - 1 = y = -z$   
 45. 47.  $\langle 2, 3 \rangle, 2x + 3y = 12$



53. No 59.  $x = -1 - 10t, y = 1 - 16t, z = 2 - 12t$   
 63. 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 15.7 ■ PAGE 966

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. Maximum  $f(-1, \frac{1}{2}) = 11$
7. Minima  $f(1, 1) = 0, f(-1, -1) = 0$ , saddle point at  $(0, 0)$
9. Saddle points at  $(1, -1), (-1, 1)$
11. Minimum  $f(2, 1) = -8$ , saddle point at  $(0, 0)$
13. None    15. Minimum  $f(0, 0) = 0$ , saddle points at  $(\pm 1, 0)$
17. Minima  $f(0, 1) = f(\pi, -1) = f(2\pi, 1) = -1$ ,  
saddle points at  $(\pi/2, 0), (3\pi/2, 0)$
21. Minima  $f(1, \pm 1) = 3, f(-1, \pm 1) = 3$
23. 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  $(\pi, \pi)$
25. Minima  $f(-1.714, 0) \approx -9.200, f(1.402, 0) \approx 0.242$ ,  
saddle point  $(0.312, 0)$ , lowest point  $(-1.714, 0, -9.200)$
27. Maxima  $f(-1.267, 0) \approx 1.310, f(1.629, \pm 1.063) \approx 8.105$ ,  
saddle points  $(-0.259, 0), (1.526, 0)$ ,  
highest points  $(1.629, \pm 1.063, 8.105)$
29. Maximum  $f(2, 0) = 9$ , minimum  $f(0, 3) = -14$
31. Maximum  $f(\pm 1, 1) = 7$ , minimum  $f(0, 0) = 4$
33. Maximum  $f(3, 0) = 83$ , minimum  $f(1, 1) = 0$
35. Maximum  $f(1, 0) = 2$ , minimum  $f(-1, 0) = -2$



39.  $\sqrt{3}$     41.  $(2, 1, \sqrt{5}), (2, 1, -\sqrt{5})$     43.  $\frac{100}{3}, \frac{100}{3}, \frac{100}{3}$
45.  $8r^3/(3\sqrt{3})$
47.  $\frac{4}{3}$     49. Cube, edge length  $c/12$
51. Square base of side 40 cm, height 20 cm    53.  $L^3/(3\sqrt{3})$

EXERCISES 15.8 ■ PAGE 976

1.  $\approx 59, 30$
3. No maximum, minima  $f(1, 1) = f(-1, -1) = 2$
5. Maxima  $f(\pm 2, 1) = 4$ , minima  $f(\pm 2, -1) = -4$
7. Maximum  $f(1, 3, 5) = 70$ , minimum  $f(-1, -3, -5) = -70$
9. Maximum  $2/\sqrt{3}$ , minimum  $-2/\sqrt{3}$
11. Maximum  $\sqrt{3}$ , minimum 1
13. Maximum  $f(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) = 2$ ,  
minimum  $f(-\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}) = -2$
15. Maximum  $f(1, \sqrt{2}, -\sqrt{2}) = 1 + 2\sqrt{2}$ ,  
minimum  $f(1, -\sqrt{2}, \sqrt{2}) = 1 - 2\sqrt{2}$
17. Maximum  $\frac{3}{2}$ , minimum  $\frac{1}{2}$
19. Maxima  $f(\pm 1/\sqrt{2}, \mp 1/(2\sqrt{2})) = e^{1/4}$ ,  
minima  $f(\pm 1/\sqrt{2}, \pm 1/(2\sqrt{2})) = e^{-1/4}$
- 27–37. See Exercises 39–49 in Section 15.7.
39.  $L^3/(3\sqrt{3})$

41. Nearest  $(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$ , farthest  $(-1, -1, 2)$
43. Maximum  $\approx 9.7938$ , minimum  $\approx -5.3506$
45. (a)  $c/n$     (b) When  $x_1 = x_2 = \dots = x_n$

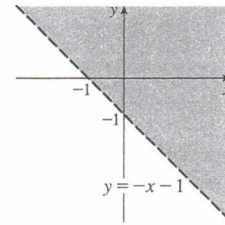
CHAPTER 15 REVIEW ■ PAGE 980

True-False Quiz

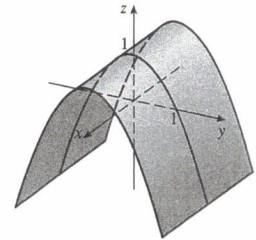
1. True    3. False    5. False    7. True    9. False
11. True

Exercises

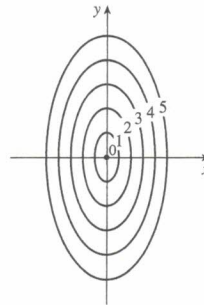
1.  $\{(x, y) \mid y > -x - 1\}$



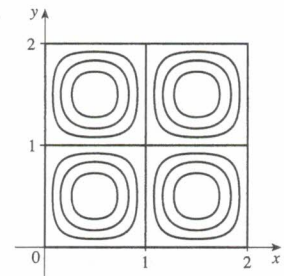
- 3.



- 5.



- 7.



9.  $\frac{2}{3}$

11. (a)  $\approx 3.5^\circ\text{C/m}, -3.0^\circ\text{C/m}$     (b)  $\approx 0.35^\circ\text{C/m}$  by Equation 15.6.9 (Definition 15.6.2 gives  $\approx 1.1^\circ\text{C/m}$ .)  
(c)  $-0.25$
13.  $f_x = 1/\sqrt{2x + y^2}, f_y = y/\sqrt{2x + y^2}$
15.  $g_u = \tan^{-1}v, g_v = u/(1 + v^2)$
17.  $T_p = \ln(q + e^r), T_q = p/(q + e^r), T_r = pe^r/(q + e^r)$
19.  $f_{xx} = 24x, f_{xy} = -2y = f_{yx}, f_{yy} = -2x$
21.  $f_{xx} = k(k - 1)x^{k-2}y^l z^m, f_{xy} = klx^{k-1}y^{l-1}z^m = f_{yx},$   
 $f_{xz} = kmx^{k-1}y^l z^{m-1} = f_{zx}, f_{yz} = l(l - 1)x^k y^{l-2} z^m,$   
 $f_{yz} = lmx^k y^{l-1} z^{m-1} = f_{zy}, f_{zz} = m(m - 1)x^k y^l z^{m-2}$
25. (a)  $z = 8x + 4y + 1$     (b)  $\frac{x-1}{8} = \frac{y+2}{4} = 1-z$
27. (a)  $2x - 2y - 3z = 3$     (b)  $\frac{x-2}{4} = \frac{y+1}{-4} = \frac{z-1}{-6}$
29. (a)  $4x - y - 2z = 6$   
(b)  $x = 3 + 8t, y = 4 - 2t, z = 1 - 4t$
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.  $ze^{x\sqrt{y}}(z\sqrt{y}, xz/(2\sqrt{y}), 2)$     45.  $\frac{43}{5}$
47.  $\sqrt{145}/2, \sqrt{4, \frac{9}{2}}$     49.  $\approx \frac{5}{8}$  knot/mi

51. Minimum  $f(-4, 1) = -11$   
 53. Maximum  $f(1, 1) = 1$ ; saddle points  $(0, 0), (0, 3), (3, 0)$   
 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  $(-1, \pm 1), (1, 0)$   
 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 984

1.  $L^2W^2, \frac{1}{4}L^2W^2$     3. (a)  $x = w/3$ , base =  $w/3$     (b) Yes  
 7.  $\sqrt{6}/2, 3\sqrt{2}/2$

CHAPTER 16

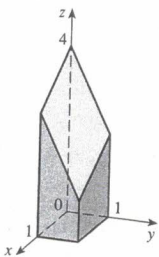
EXERCISES 16.1 ■ PAGE 994

1. (a) 288    (b) 144  
 3. (a)  $\pi^2/2 \approx 4.935$     (b) 0  
 5. (a) -6    (b) -3.5  
 7.  $U < V < L$   
 9. (a)  $\approx 248$     (b) 15.5  
 11. 60    13. 3  
 15. 1.141606, 1.143191, 1.143535, 1.143617, 1.143637, 1.143642

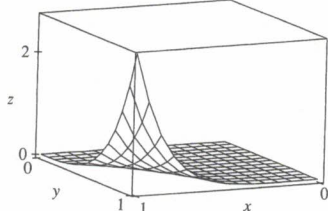
EXERCISES 16.2 ■ PAGE 1000

1.  $500y^3, 3x^2$     3. 10    5. 2    7.  $261,632/45$     9.  $\frac{21}{2} \ln 2$   
 11. 0    13.  $\pi$     15.  $\frac{21}{2}$     17.  $9 \ln 2$   
 19.  $\frac{1}{2}(\sqrt{3} - 1) - \frac{1}{12}\pi$     21.  $\frac{1}{2}(e^2 - 3)$

23.



25. 47.5    27.  $\frac{166}{27}$     29. 2    31.  $\frac{64}{3}$   
 33.  $21e - 57$

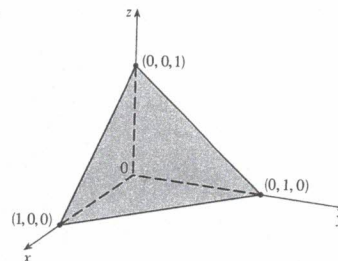


35.  $\frac{5}{6}$   
 37. Fubini's Theorem does not apply. The integrand has an infinite discontinuity at the origin.

EXERCISES 16.3 ■ PAGE 1008

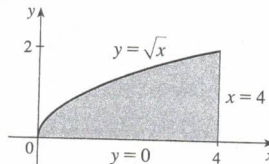
1. 32    3.  $\frac{3}{10}$     5.  $e - 1$     7.  $\frac{4}{3}$     9.  $\pi$     11.  $\frac{1}{2}e^{16} - \frac{17}{2}$   
 13.  $\frac{1}{2}(1 - \cos 1)$     15.  $\frac{147}{20}$     17. 0    19.  $\frac{7}{18}$     21.  $\frac{31}{8}$   
 23. 6    25.  $\frac{128}{15}$     27.  $\frac{1}{3}$     29. 0, 1.213, 0.713    31.  $\frac{64}{3}$

33.

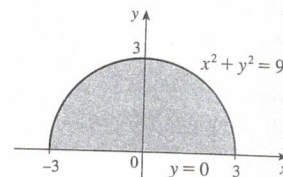


35. 13,984,735,616/14,549,535    37.  $\pi/2$

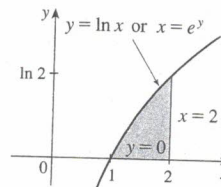
39.  $\int_0^2 \int_{y^2}^4 f(x, y) dx dy$



41.  $\int_{-3}^3 \int_0^{\sqrt{9-x^2}} f(x, y) dy dx$



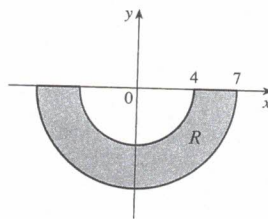
43.  $\int_0^{\ln 2} \int_{e^y}^2 f(x, y) dx dy$



45.  $\frac{1}{6}(e^9 - 1)$     47.  $\frac{1}{3} \ln 9$     49.  $\frac{1}{3}(2\sqrt{2} - 1)$     51. 1  
 53.  $(\pi/16)e^{-1/16} \leq \iint_D e^{-(x^2+y^2)^2} dA \leq \pi/16$     55.  $\frac{3}{4}$   
 59.  $8\pi$     61.  $2\pi/3$

EXERCISES 16.4 ■ PAGE 1014

1.  $\int_0^{3\pi/2} \int_0^4 f(r \cos \theta, r \sin \theta) r dr d\theta$     3.  $\int_{-1}^1 \int_0^{(x+1)^2} f(x, y) dy dx$   
 5.  $33\pi/2$



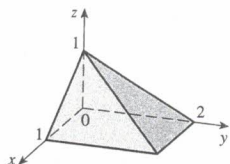
7. 0    9.  $\frac{1}{2}\pi \sin 9$     11.  $(\pi/2)(1 - e^{-4})$     13.  $\frac{3}{64}\pi^2$   
 15.  $\pi/12$     17.  $\frac{1}{8}(\pi - 2)$     19.  $\frac{16}{3}\pi$     21.  $\frac{4}{3}\pi$   
 23.  $\frac{4}{3}\pi a^3$     25.  $(2\pi/3)[1 - (1/\sqrt{2})]$   
 27.  $(8\pi/3)(64 - 24\sqrt{3})$   
 29.  $\frac{1}{2}\pi(1 - \cos 9)$     31.  $2\sqrt{2}/3$   
 33.  $1800\pi \text{ ft}^3$     35.  $\frac{15}{16}$     37. (a)  $\sqrt{\pi}/4$     (b)  $\sqrt{\pi}/2$

EXERCISES 16.5 ■ PAGE 1024

1.  $\frac{64}{3} C$     3.  $\frac{4}{3}, (\frac{4}{3}, 0)$     5.  $6, (\frac{3}{4}, \frac{3}{2})$   
 7.  $\frac{1}{4}(e^2 - 1), (\frac{e^2 + 1}{2(e^2 - 1)}, \frac{4(e^3 - 1)}{9(e^2 - 1)})$   
 9.  $L/4, (L/2, 16/(9\pi))$     11.  $(\frac{3}{8}, 3\pi/16)$     13.  $(0, 45/(14\pi))$   
 15.  $(2a/5, 2a/5)$  if vertex is  $(0, 0)$  and sides are along positive axes  
 17.  $\frac{1}{16}(e^4 - 1), \frac{1}{8}(e^2 - 1), \frac{1}{16}(e^4 + 2e^2 - 3)$   
 19.  $7ka^6/180, 7ka^6/180, 7ka^6/90$  if vertex is  $(0, 0)$  and sides are along positive axes  
 21.  $m = \pi^2/8, (\bar{x}, \bar{y}) = (\frac{2\pi}{3} - \frac{1}{\pi}, \frac{16}{9\pi})$ ,  $I_x = 3\pi^2/64$ ,  
 $I_y = \frac{1}{16}(\pi^4 - 3\pi^2)$ ,  $I_0 = \pi^4/16 - 9\pi^2/64$   
 23.  $pbh^3/3, pb^3h/3; b/\sqrt{3}, h/\sqrt{3}$   
 25.  $\rho a^4\pi/16, \rho a^4\pi/16; a/2, a/2$   
 27. (a)  $\frac{1}{2}$  (b) 0.375 (c)  $\frac{5}{48} \approx 0.1042$   
 29. (b) (i)  $e^{-0.2} \approx 0.8187$   
 (ii)  $1 + e^{-1.8} - e^{-0.8} - e^{-1} \approx 0.3481$  (c) 2, 5  
 31. (a)  $\approx 0.500$  (b)  $\approx 0.632$   
 33. (a)  $\iint_D (k/20)[20 - \sqrt{(x - x_0)^2 + (y - y_0)^2}] dA$ , where  $D$  is the disk with radius 10 mi 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 16.6 ■ PAGE 1034

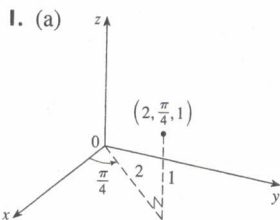
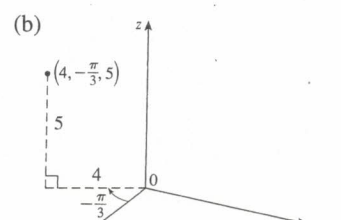
1.  $\frac{27}{4}$     3. 1    5.  $\frac{1}{3}(e^3 - 1)$     7.  $-\frac{1}{3}$     9. 4    11.  $\frac{65}{28}$   
 13.  $8/(3e)$     15.  $\frac{1}{60}$     17.  $16\pi/3$     19.  $\frac{16}{3}$     21.  $36\pi$   
 23. (a)  $\int_0^2 \int_0^x \int_0^{\sqrt{1-y^2}} dz dy dx$  (b)  $\frac{1}{4}\pi - \frac{1}{3}$   
 25. 60.533  
 27.

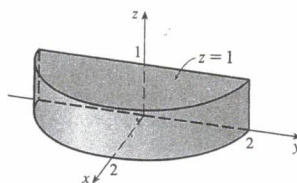


29.  $\int_{-2}^2 \int_0^{\sqrt{4-x^2}} \int_{-\sqrt{4-x^2-y/2}}^{\sqrt{4-x^2-y/2}} f(x, y, z) dz dy dx$   
 $= \int_0^4 \int_{-\sqrt{4-y}}^{\sqrt{4-y}} \int_{-\sqrt{4-x^2-y/2}}^{\sqrt{4-x^2-y/2}} f(x, y, z) dz dx dy$   
 $= \int_{-1}^1 \int_0^{4-4z^2} \int_{-\sqrt{4-y-4z^2}}^{\sqrt{4-y-4z^2}} f(x, y, z) dx dy dz$   
 $= \int_0^4 \int_{-\sqrt{4-y/2}}^{\sqrt{4-y/2}} \int_{-\sqrt{4-y-4z^2}}^{\sqrt{4-y-4z^2}} f(x, y, z) dx dz dy$   
 $= \int_{-2}^2 \int_{-\sqrt{4-x^2}/2}^{\sqrt{4-x^2}/2} \int_0^{4-x^2-4z^2} f(x, y, z) dy dz dx$   
 $= \int_{-1}^1 \int_{-\sqrt{4-4z^2}}^{\sqrt{4-4z^2}} \int_0^{4-x^2-4z^2} f(x, y, z) dy dx dz$   
 31.  $\int_{-2}^2 \int_{x^2}^4 \int_0^{2-y/2} f(x, y, z) dz dy dx$   
 $= \int_0^4 \int_{-\sqrt{y}}^{\sqrt{y}} \int_0^{2-y/2} f(x, y, z) dz dx dy$   
 $= \int_0^2 \int_0^{4-2z} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dy dz$   
 $= \int_0^4 \int_0^{2-y/2} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dz dy$   
 $= \int_{-2}^2 \int_0^{2-x^2/2} \int_{x^2}^{4-2z} f(x, y, z) dy dz dx$   
 $= \int_0^2 \int_{-\sqrt{4-2z}}^{\sqrt{4-2z}} \int_{x^2}^{4-2z} f(x, y, z) dy dx dz$

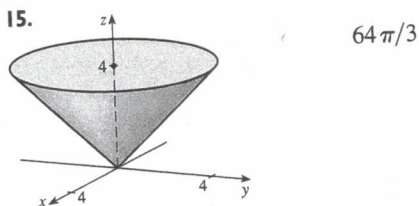
33.  $\int_0^1 \int_{\sqrt{x}}^1 \int_0^{1-y} f(x, y, z) dz dy dx$   
 $= \int_0^1 \int_0^y \int_0^{1-y} f(x, y, z) dz dx dy$   
 $= \int_0^1 \int_0^{1-z} \int_0^y f(x, y, z) dx dy dz$   
 $= \int_0^1 \int_0^{1-y} \int_0^y f(x, y, z) dx dz dy$   
 $= \int_0^1 \int_0^{1-\sqrt{x}} \int_{\sqrt{x}}^{1-z} f(x, y, z) dy dz dx$   
 $= \int_0^1 \int_0^{(1-z)^2} \int_{\sqrt{x}}^{1-z} f(x, y, z) dy dx dz$   
 35.  $\int_0^1 \int_y^1 \int_0^y f(x, y, z) dz dx dy = \int_0^1 \int_0^x \int_0^y f(x, y, z) dz dy dx$   
 $= \int_0^1 \int_y^1 \int_y^1 f(x, y, z) dx dy dz = \int_0^1 \int_0^y \int_y^1 f(x, y, z) dx dz dy$   
 $= \int_0^1 \int_x^1 \int_x^1 f(x, y, z) dy dz dx = \int_0^1 \int_x^1 \int_x^1 f(x, y, z) dy dz dx$   
 37.  $\frac{79}{30}, (\frac{358}{553}, \frac{33}{79}, \frac{571}{553})$     39.  $a^5, (7a/12, 7a/12, 7a/12)$   
 41.  $I_x = I_y = I_z = \frac{2}{3}kL^5$     43.  $\frac{1}{2}\pi kha^4$   
 45. (a)  $m = \int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_1^{5-y} \sqrt{x^2 + y^2} dz dy dx$   
 (b)  $(\bar{x}, \bar{y}, \bar{z})$ , where  
 $\bar{x} = (1/m) \int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_1^{5-y} x\sqrt{x^2 + y^2} dz dy dx$   
 $\bar{y} = (1/m) \int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_1^{5-y} y\sqrt{x^2 + y^2} dz dy dx$   
 $\bar{z} = (1/m) \int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_1^{5-y} z\sqrt{x^2 + y^2} dz dy dx$   
 (c)  $\int_{-3}^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_1^{5-y} (x^2 + y^2)^{3/2} dz dy dx$   
 47. (a)  $\frac{3}{32}\pi + \frac{11}{24}$   
 (b)  $(\bar{x}, \bar{y}, \bar{z}) = (\frac{28}{9\pi + 44}, \frac{30\pi + 128}{45\pi + 220}, \frac{45\pi + 208}{135\pi + 660})$   
 (c)  $\frac{1}{240}(68 + 15\pi)$   
 49. (a)  $\frac{1}{8}$  (b)  $\frac{1}{64}$  (c)  $\frac{1}{5760}$   
 51.  $L^3/8$   
 53. The region bounded by the ellipsoid  $x^2 + 2y^2 + 3z^2 = 1$

EXERCISES 16.7 ■ PAGE 1040

- I. (a)  (b)   
 (c)  $(\sqrt{2}, \sqrt{2}, 1)$     (d)  $(2, -2\sqrt{3}, 5)$   
 3. (a)  $(\sqrt{2}, 7\pi/4, 4)$  (b)  $(2, 4\pi/3, 2)$   
 5. Vertical half-plane through the z-axis    7. Circular paraboloid  
 9. (a)  $z = r^2$  (b)  $r = 2 \sin \theta$   
 II.

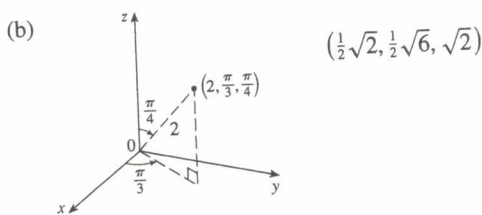
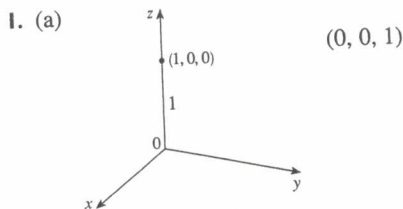


13. Cylindrical coordinates:  $6 \leq r \leq 7, 0 \leq \theta \leq 2\pi, 0 \leq z \leq 20$

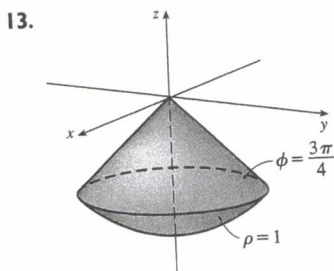
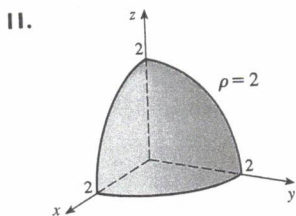


17.  $384\pi$     19.  $\pi(e^6 - e - 5)$     21.  $2\pi/5$   
 23. (a)  $162\pi$     (b)  $(0, 0, 15)$   
 25.  $\pi Ka^2/8, (0, 0, 2a/3)$     27. 0  
 29. (a)  $\iiint_C h(P)g(P) dV$ , where  $C$  is the cone  
 (b)  $\approx 3.1 \times 10^{19}$  ft-lb

EXERCISES 16.8 ■ PAGE 1046

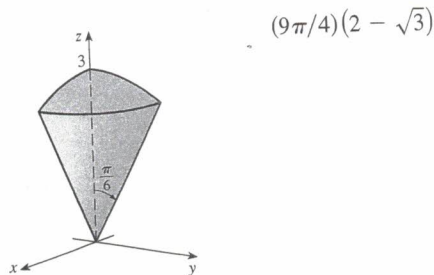


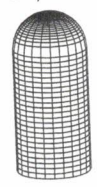
3. (a)  $(4, \pi/3, \pi/6)$     (b)  $(\sqrt{2}, 3\pi/2, 3\pi/4)$   
 5. Half-cone  
 7. Sphere, radius  $\frac{1}{2}$ , center  $(0, \frac{1}{2}, 0)$   
 9. (a)  $\cos^2\phi = \sin^2\phi$     (b)  $\rho^2(\sin^2\phi \cos^2\theta + \cos^2\phi) = 9$



15.  $0 \leq \phi \leq \pi/4, 0 \leq \rho \leq \cos\phi$

17.



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.  $312,500\pi/7$     23.  $15\pi/16$     25.  $1562\pi/15$   
 27.  $(\sqrt{3} - 1)\pi a^3/3$     29. (a)  $10\pi$     (b)  $(0, 0, 2.1)$   
 31.  $(0, \frac{525}{296}, 0)$   
 33. (a)  $(0, 0, \frac{3}{8}a)$     (b)  $4K\pi a^5/15$   
 35.  $(2\pi/3)[1 - (1/\sqrt{2})], (0, 0, 3/[8(2 - \sqrt{2})])$   
 37.  $5\pi/6$     39.  $(4\sqrt{2} - 5)/15$   
 41.     43.  $136\pi/99$

EXERCISES 16.9 ■ PAGE 1056

1. 16    3.  $\sin^2\theta - \cos^2\theta$     5. 0  
 7. The parallelogram with vertices  $(0, 0), (6, 3), (12, 1), (6, -2)$   
 9. The region bounded by the line  $y = 1$ , the  $y$ -axis, and  $y = \sqrt{x}$   
 11. -3    13.  $6\pi$     15.  $2 \ln 3$   
 17. (a)  $\frac{4}{3}\pi abc$     (b)  $1.083 \times 10^{12} \text{ km}^3$   
 19.  $\frac{8}{5} \ln 8$     21.  $\frac{3}{2} \sin 1$     23.  $e - e^{-1}$

CHAPTER 16 REVIEW ■ PAGE 1057

True-False Quiz

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

Exercises

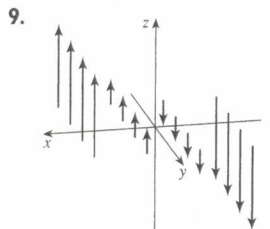
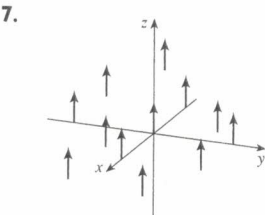
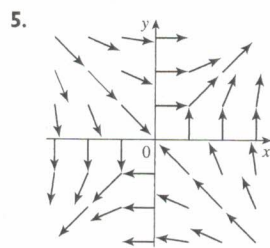
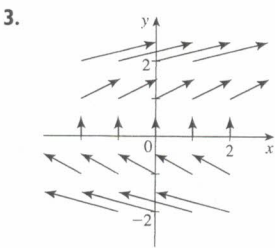
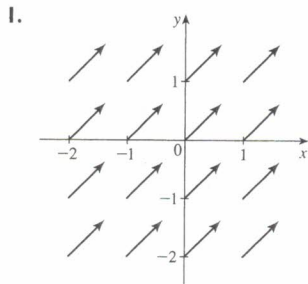
1.  $\approx 64.0$     3.  $4e^2 - 4e + 3$     5.  $\frac{1}{2} \sin 1$     7.  $\frac{2}{3}$   
 9.  $\int_0^\pi \int_2^4 f(r \cos\theta, r \sin\theta) r dr d\theta$   
 11. The region inside the loop of the four-leaved rose  $r = \sin 2\theta$  in the first quadrant  
 13.  $\frac{1}{2} \sin 1$     15.  $\frac{1}{2}e^6 - \frac{7}{2}$     17.  $\frac{1}{4} \ln 2$     19. 8  
 21.  $81\pi/5$     23. 40.5    25.  $\pi/96$     27.  $\frac{64}{15}$     29. 176  
 31.  $\frac{2}{3}$     33.  $2ma^3/9$   
 35. (a)  $\frac{1}{4}$     (b)  $(\frac{1}{3}, \frac{8}{15})$   
 (c)  $I_x = \frac{1}{12}, I_y = \frac{1}{24}, \bar{y} = 1/\sqrt{3}, \bar{x} = 1/\sqrt{6}$   
 37.  $(0, 0, h/4)$   
 39. 97.2    41. 0.0512  
 43. (a)  $\frac{1}{15}$     (b)  $\frac{1}{3}$     (c)  $\frac{1}{45}$   
 45.  $\int_0^1 \int_0^{1-z} \int_{-\sqrt{y}}^{\sqrt{y}} f(x, y, z) dx dy dz$     47.  $-\ln 2$     49. 0

PROBLEMS PLUS ■ PAGE 1060

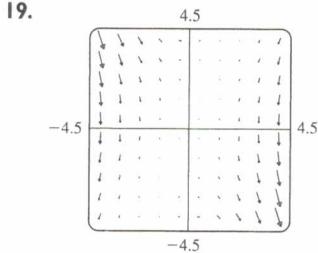
1. 30    3.  $\frac{1}{2} \sin 1$     7. (b) 0.90

CHAPTER 17

EXERCISES 17.1 ■ PAGE 1068



11. II    13. I    15. IV    17. III

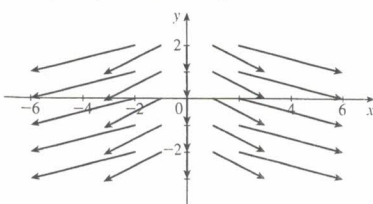


The line  $y = 2x$

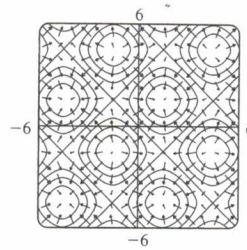
21.  $\nabla f(x, y) = (xy + 1)e^{xy} \mathbf{i} + x^2 e^{xy} \mathbf{j}$

23.  $\nabla f(x, y, z) = \frac{x}{\sqrt{x^2 + y^2 + z^2}} \mathbf{i} + \frac{y}{\sqrt{x^2 + y^2 + z^2}} \mathbf{j} + \frac{z}{\sqrt{x^2 + y^2 + z^2}} \mathbf{k}$

25.  $\nabla f(x, y) = 2x \mathbf{i} - \mathbf{j}$



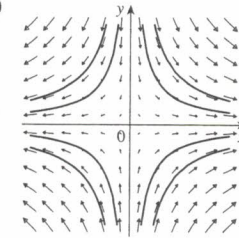
27.



29. III    31. II    33. (2.04, 1.03)

35. (a)

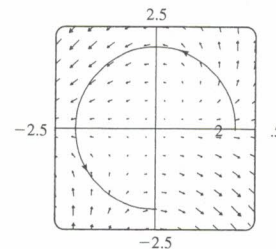
(b)  $y = 1/x, x > 0$



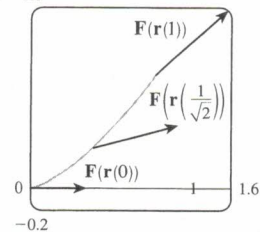
$y = C/x$

EXERCISES 17.2 ■ PAGE 1079

1.  $\frac{1}{54}(145^{3/2} - 1)$     3. 1638.4    5.  $\frac{243}{8}$     7.  $\frac{17}{3}$     9.  $\sqrt{5}\pi$   
 11.  $\frac{1}{12}\sqrt{14}(e^6 - 1)$     13.  $\frac{1}{5}$     15.  $\frac{97}{3}$   
 17. (a) Positive    (b) Negative  
 19. 45    21.  $\frac{6}{5} - \cos 1 - \sin 1$     23. 1.9633    25. 15.0074  
 27.  $3\pi + \frac{2}{3}$



29. (a)  $\frac{11}{8} - 1/e$     (b) 1.6



31.  $\frac{172,704}{5,632,705}\sqrt{2}(1 - e^{-14\pi})$     33.  $2\pi k, (4/\pi, 0)$

35. (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)  $(0, 0, 3\pi)$

37.  $I_x = k(\frac{1}{2}\pi - \frac{4}{3}), I_y = k(\frac{1}{2}\pi - \frac{2}{3})$

39.  $2\pi^2$     41. 26    43.  $1.67 \times 10^4$  ft-lb    45. (b) Yes

47.  $\approx 22$  J

EXERCISES 17.3 = PAGE 1089

1. 40    3.  $f(x, y) = x^2 - 3xy + 2y^2 - 8y + K$   
 5.  $f(x, y) = e^x \sin y + K$     7.  $f(x, y) = ye^x + x \sin y + K$   
 9.  $f(x, y) = x \ln y + x^2 y^3 + K$   
 11. (b) 16    13. (a)  $f(x, y) = \frac{1}{2}x^2 y^2$     (b) 2  
 15. (a)  $f(x, y, z) = xyz + z^2$     (b) 77  
 17. (a)  $f(x, y, z) = xy^2 \cos z$     (b) 0  
 19. 2    21. 30    23. No    25. Conservative  
 29. (a) Yes    (b) Yes    (c) Yes  
 31. (a) Yes    (b) Yes    (c) No

EXERCISES 17.4 = PAGE 1096

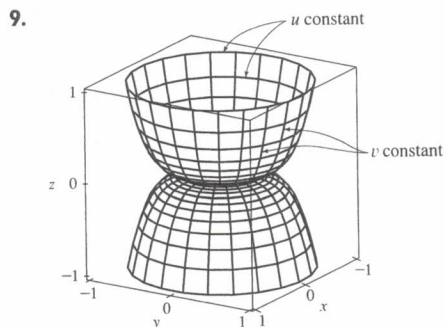
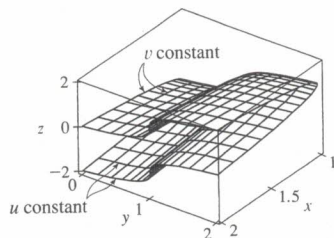
1.  $8\pi$     3.  $\frac{2}{3}$     5. 12    7.  $\frac{1}{3}$     9.  $-24\pi$     11.  $\frac{4}{3} - 2\pi$   
 13.  $\frac{625}{2}\pi$     15.  $-8e + 48e^{-1}$     17.  $-\frac{1}{12}$     19.  $3\pi$     21. (c)  $\frac{9}{2}$   
 23.  $(4a/3\pi, 4a/3\pi)$  if the region is the portion of the disk  $x^2 + y^2 = a^2$  in the first quadrant

EXERCISES 17.5 = PAGE 1104

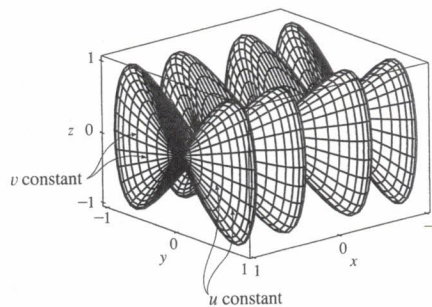
1. (a)  $-x^2 \mathbf{i} + 3xy \mathbf{j} - xz \mathbf{k}$     (b)  $yz$   
 3. (a)  $(x - y) \mathbf{i} - y \mathbf{j} + \mathbf{k}$     (b)  $z - 1/(2\sqrt{z})$   
 5. (a)  $\mathbf{0}$     (b)  $2/\sqrt{x^2 + y^2 + z^2}$   
 7. (a)  $\langle 1/y, -1/x, 1/x \rangle$     (b)  $1/x + 1/y + 1/z$   
 9. (a) Negative    (b)  $\text{curl } \mathbf{F} = \mathbf{0}$   
 11. (a) Zero    (b)  $\text{curl } \mathbf{F}$  points in the negative  $z$ -direction  
 13.  $f(x, y, z) = xy^2 z^3 + K$     15.  $f(x, y, z) = x^2 y + y^2 z + K$   
 17. Not conservative    19. No

EXERCISES 17.6 = PAGE 1114

1.  $P$ : no;  $Q$ : yes  
 3. Plane through  $(0, 3, 1)$  containing vectors  $\langle 1, 0, 4 \rangle, \langle 1, -1, 5 \rangle$   
 5. Hyperbolic paraboloid  
 7.

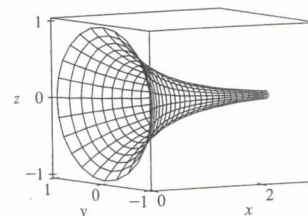


11.

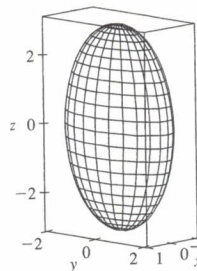


13. IV    15. II    17. III

19.  $x = 1 + u + v, y = 2 + u - v, z = -3 - u + v$   
 21.  $x = x, z = z, y = \sqrt{1 - x^2 + z^2}$   
 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.  $x = x, y = 4 \cos \theta, z = 4 \sin \theta, 0 \leq x \leq 5, 0 \leq \theta \leq 2\pi$   
 29.  $x = x, y = e^{-x} \cos \theta, z = e^{-x} \sin \theta, 0 \leq x \leq 3, 0 \leq \theta \leq 2\pi$



31. (a) Direction reverses    (b) Number of coils doubles  
 33.  $3x - y + 3z = 3$     35.  $-x + 2z = 1$     37.  $3\sqrt{14}$   
 39.  $\frac{4}{15}(3^{5/2} - 2^{7/2} + 1)$     41.  $(2\pi/3)(2\sqrt{2} - 1)$   
 43.  $(\pi/6)(17\sqrt{17} - 5\sqrt{5})$   
 45.  $\frac{1}{2}\sqrt{21} + \frac{17}{4}[\ln(2 + \sqrt{21}) - \ln \sqrt{17}]$     47. 4  
 49. 13.9783  
 51. (a) 24.2055    (b) 24.2476  
 53.  $\frac{45}{8}\sqrt{14} + \frac{15}{16} \ln[(11\sqrt{5} + 3\sqrt{70})/(3\sqrt{5} + \sqrt{70})]$   
 55. (b)



- (c)  $\int_0^{2\pi} \int_0^\pi \sqrt{36 \sin^4 u \cos^2 v + 9 \sin^4 u \sin^2 v + 4 \cos^2 u \sin^2 u} du dv$   
 57.  $4\pi$     59.  $2a^2(\pi - 2)$

EXERCISES 17.7 = PAGE 1127

1. 49.09    3.  $900\pi$     5.  $171\sqrt{14}$     7.  $\sqrt{3}/24$   
 9.  $5\sqrt{5}/48 + 1/240$     11.  $364\sqrt{2}\pi/3$   
 13.  $(\pi/60)(391\sqrt{17} + 1)$     15.  $16\pi$     17. 12



19.  $\frac{713}{180}$  21.  $-\frac{1}{6}$  23.  $-\frac{4}{3}\pi$  25. 0 27. 48

29.  $2\pi + \frac{8}{3}$  31. 0.1642 33. 3.4895

35.  $\iint_S \mathbf{F} \cdot d\mathbf{S} = \iint_D [P(\partial h/\partial x) - Q + R(\partial h/\partial z)] dA$ ,  
where  $D$  = projection of  $S$  on  $xz$ -plane

37.  $(0, 0, a/2)$

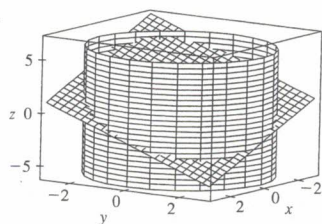
39. (a)  $I_z = \iint_S (x^2 + y^2)\rho(x, y, z) dS$  (b)  $4329\sqrt{2}\pi/5$

41. 0 kg/s 43.  $\frac{8}{3}\pi a^3 \epsilon_0$  45.  $1248\pi$

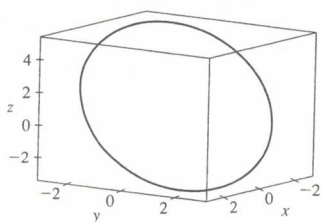
EXERCISES 17.8 ■ PAGE 1133

3. 0 5. 0 7. -1 9.  $80\pi$

11. (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. 3

EXERCISES 17.9 ■ PAGE 1139

5. 2 7.  $9\pi/2$

9. 0 11.  $32\pi/3$  13. 0

15.  $341\sqrt{2}/60 + \frac{81}{20}\arcsin(\sqrt{3}/3)$  17.  $13\pi/20$

19. Negative at  $P_1$ , positive at  $P_2$

21.  $\text{div } \mathbf{F} > 0$  in quadrants I, II;  $\text{div } \mathbf{F} < 0$  in quadrants III, IV

CHAPTER 17 REVIEW ■ PAGE 1142

True-False Quiz

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

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.  $f(x, y) = e^y + xe^{-xy}$  13. 0

17.  $-8\pi$  25.  $\frac{1}{6}(27 - 5\sqrt{5})$

27.  $(\pi/60)(391\sqrt{17} + 1)$  29.  $-64\pi/3$

33.  $-\frac{1}{2}$  37. -4 39. 21

CHAPTER 18

EXERCISES 18.1 ■ PAGE 1153

1.  $y = c_1 e^{3x} + c_2 e^{-2x}$  3.  $y = c_1 \cos 4x + c_2 \sin 4x$

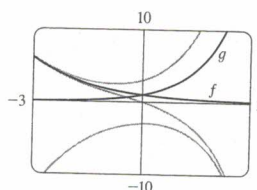
5.  $y = c_1 e^{2x/3} + c_2 x e^{2x/3}$  7.  $y = c_1 + c_2 e^{x/2}$

9.  $y = e^{2x}(c_1 \cos 3x + c_2 \sin 3x)$

11.  $y = c_1 e^{(\sqrt{3}-1)t/2} + c_2 e^{-(\sqrt{3}+1)t/2}$

13.  $P = e^{-t}[c_1 \cos(\frac{1}{10}t) + c_2 \sin(\frac{1}{10}t)]$

15.



All solutions approach either 0 or  $\pm\infty$  as  $x \rightarrow \pm\infty$ .

17.  $y = 2e^{-3x/2} + e^{-x}$  19.  $y = e^{x/2} - 2xe^{x/2}$

21.  $y = 3 \cos 4x - \sin 4x$  23.  $y = e^{-x}(2 \cos x + 3 \sin x)$

25.  $y = 3 \cos(\frac{1}{2}x) - 4 \sin(\frac{1}{2}x)$  27.  $y = \frac{e^{x+3}}{e^3 - 1} + \frac{e^{2x}}{1 - e^3}$

29. No solution

31.  $y = e^{-2x}(2 \cos 3x - e^\pi \sin 3x)$

33. (b)  $\lambda = n^2\pi^2/L^2$ ,  $n$  a positive integer;  $y = C \sin(n\pi x/L)$

EXERCISES 18.2 ■ PAGE 1160

1.  $y = c_1 e^{-2x} + c_2 e^{-x} + \frac{1}{2}x^2 - \frac{3}{2}x + \frac{7}{4}$

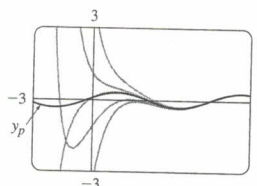
3.  $y = c_1 + c_2 e^{2x} + \frac{1}{40} \cos 4x - \frac{1}{20} \sin 4x$

5.  $y = e^{2x}(c_1 \cos x + c_2 \sin x) + \frac{1}{10}e^{-x}$

7.  $y = \frac{3}{2} \cos x + \frac{11}{2} \sin x + \frac{1}{2}e^x + x^3 - 6x$

9.  $y = e^x(\frac{1}{2}x^2 - x + 2)$

11.



The solutions are all asymptotic to  $y_p = \frac{1}{10} \cos x + \frac{3}{10} \sin x$  as  $x \rightarrow \infty$ . Except for  $y_p$ , all solutions approach either  $\infty$  or  $-\infty$  as  $x \rightarrow -\infty$ .

13.  $y_p = Ae^{2x} + (Bx^2 + Cx + D) \cos x + (Ex^2 + Fx + G) \sin x$

15.  $y_p = Ax + (Bx + C)e^{9x}$

17.  $y_p = xe^{-x}[(Ax^2 + Bx + C) \cos 3x + (Dx^2 + Ex + F) \sin 3x]$

19.  $y = c_1 \cos(\frac{1}{2}x) + c_2 \sin(\frac{1}{2}x) - \frac{1}{3} \cos x$

21.  $y = c_1 e^x + c_2 x e^x + e^{2x}$

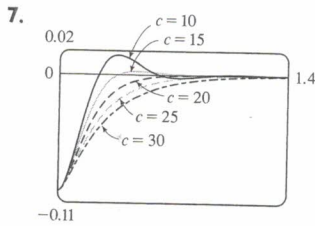
23.  $y = c_1 \sin x + c_2 \cos x + \sin x \ln(\sec x + \tan x) - 1$

25.  $y = [c_1 + \ln(1 + e^{-x})]e^x + [c_2 - e^{-x} + \ln(1 + e^{-x})]e^{2x}$

27.  $y = e^x[c_1 + c_2 x - \frac{1}{2} \ln(1 + x^2) + x \tan^{-1} x]$

EXERCISES 18.3 ■ PAGE 1168

1.  $x = 0.35 \cos(2\sqrt{5}t)$  3.  $x = -\frac{1}{5}e^{-6t} + \frac{6}{5}e^{-t}$  5.  $\frac{49}{12}$  kg



13.  $Q(t) = (-e^{-10t}/250)(6 \cos 20t + 3 \sin 20t) + \frac{3}{125}$   
 $I(t) = \frac{3}{5}e^{-10t} \sin 20t$

15.  $Q(t) = e^{-10t}[\frac{3}{250} \cos 20t - \frac{3}{500} \sin 20t]$   
 $-\frac{3}{250} \cos 10t + \frac{3}{125} \sin 10t$

EXERCISES 18.4 ■ PAGE 1173

1.  $c_0 \sum_{n=0}^{\infty} \frac{x^n}{n!} = c_0 e^x$     3.  $c_0 \sum_{n=0}^{\infty} \frac{x^{3n}}{3^n n!} = c_0 e^{x^3/3}$   
 5.  $c_0 \sum_{n=0}^{\infty} \frac{(-1)^n}{2^n n!} x^{2n} + c_1 \sum_{n=0}^{\infty} \frac{(-2)^n n!}{(2n+1)!} x^{2n+1}$   
 7.  $c_0 + c_1 \sum_{n=1}^{\infty} \frac{x^n}{n} = c_0 - c_1 \ln(1-x)$  for  $|x| < 1$   
 9.  $\sum_{n=0}^{\infty} \frac{x^{2n}}{2^n n!} = e^{x^2/2}$   
 11.  $x + \sum_{n=1}^{\infty} \frac{(-1)^n 2^{2n} 5^2 \cdots (3n-1)^2}{(3n+1)!} x^{3n+1}$

CHAPTER 18 REVIEW ■ PAGE 1174

True-False Quiz

1. True    3. True

Exercises

1.  $y = c_1 e^{5x} + c_2 e^{-3x}$     3.  $y = c_1 \cos(\sqrt{3}x) + c_2 \sin(\sqrt{3}x)$   
 5.  $y = e^{2x}(c_1 \cos x + c_2 \sin x + 1)$   
 7.  $y = c_1 e^x + c_2 x e^x - \frac{1}{2} \cos x - \frac{1}{2}(x+1) \sin x$   
 9.  $y = c_1 e^{3x} + c_2 e^{-2x} - \frac{1}{6} - \frac{1}{5} x e^{-2x}$   
 11.  $y = 5 - 2e^{-6(x-1)}$     13.  $y = (e^{4x} - e^x)/3$   
 15.  $\sum_{n=0}^{\infty} \frac{(-2)^n n!}{(2n+1)!} x^{2n+1}$   
 17.  $Q(t) = -0.02e^{-10t}(\cos 10t + \sin 10t) + 0.03$   
 19. (c)  $2\pi/k \approx 85$  min    (d)  $\approx 17,600$  mi/h

APPENDIXES

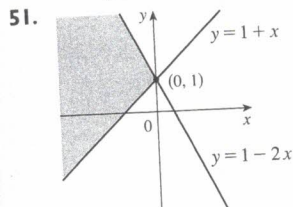
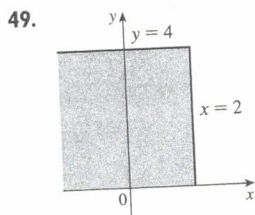
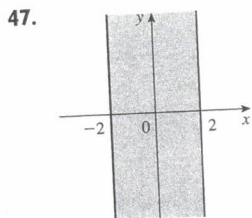
EXERCISES A ■ PAGE A9

1. 18    3.  $\pi$     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.  $[-1, \infty)$
- 
- 

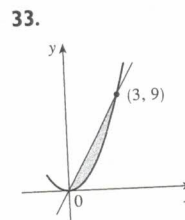
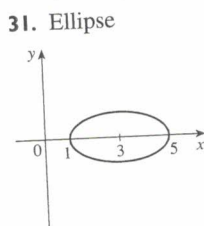
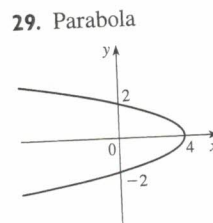
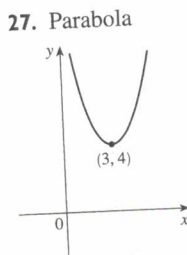
17.  $(3, \infty)$     19.  $(2, 6)$   
  
 21.  $(0, 1]$     23.  $[-1, \frac{1}{2})$   
  
 25.  $(-\infty, 1) \cup (2, \infty)$     27.  $[-1, \frac{1}{2}]$   
  
 29.  $(-\infty, \infty)$     31.  $(-\sqrt{3}, \sqrt{3})$   
  
 33.  $(-\infty, 1]$     35.  $(-1, 0) \cup (1, \infty)$   
  
 37.  $(-\infty, 0) \cup (\frac{1}{4}, \infty)$
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

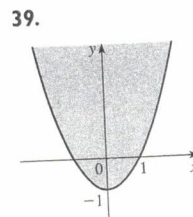
1. 5    3.  $\sqrt{74}$     5.  $2\sqrt{37}$     7. 2    9.  $-\frac{9}{2}$   
 17.    19.
21.  $y = 6x - 15$     23.  $2x - 3y + 19 = 0$   
 25.  $5x + y = 11$     27.  $y = 3x - 2$     29.  $y = 3x - 3$   
 31.  $y = 5$     33.  $x + 2y + 11 = 0$     35.  $5x - 2y + 1 = 0$   
 37.  $m = -\frac{1}{3}, b = 0$     39.  $m = 0, b = -2$     41.  $m = \frac{3}{4}, b = -3$
- 
- 
- 
43.    45.



53. (0, -4)    55. (a) (4, 9)    (b) (3.5, -3)    57. (1, -2)  
 59.  $y = x - 3$     61. (b)  $4x - 3y - 24 = 0$



35.  $y = x^2 - 2x$   
 37.

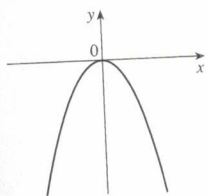


EXERCISES C ■ PAGE A23

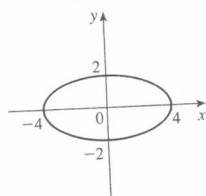
1.  $(x - 3)^2 + (y + 1)^2 = 25$   
 5. (2, -5), 4    7.  $(-\frac{1}{2}, 0), \frac{1}{2}$

3.  $x^2 + y^2 = 65$   
 9.  $(\frac{1}{4}, -\frac{1}{4}), \sqrt{10}/4$

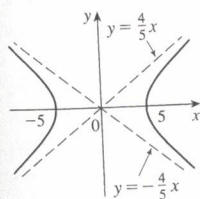
11. Parabola



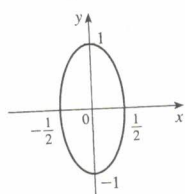
13. Ellipse



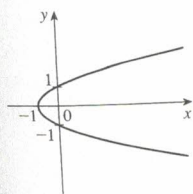
15. Hyperbola



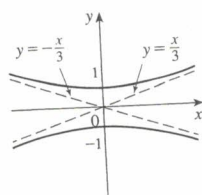
17. Ellipse



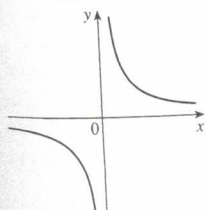
19. Parabola



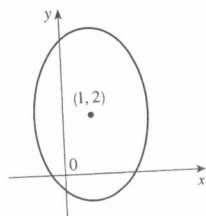
21. Hyperbola



23. Hyperbola

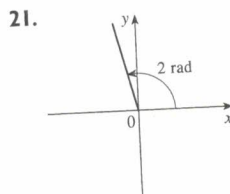
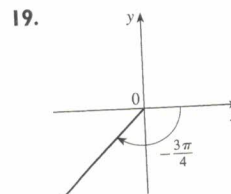
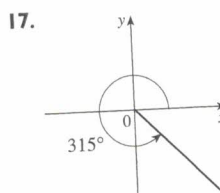


25. Ellipse



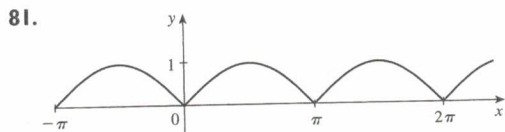
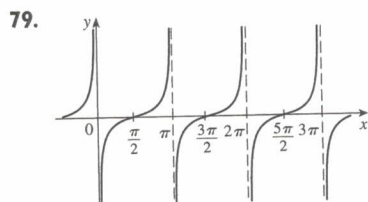
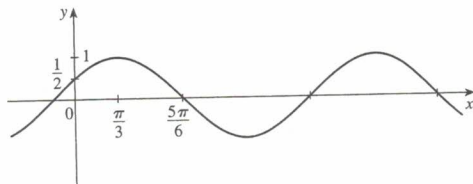
EXERCISES D ■ PAGE A32

1.  $7\pi/6$     3.  $\pi/20$     5.  $5\pi$     7.  $720^\circ$     9.  $75^\circ$   
 11.  $-67.5^\circ$     13.  $3\pi$  cm    15.  $\frac{2}{3}$  rad =  $(120/\pi)^\circ$



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.



89.  $14.34457 \text{ cm}^2$

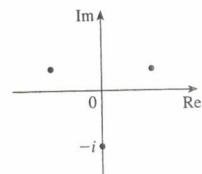
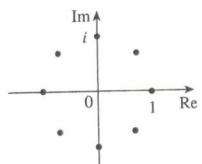
EXERCISES E ■ PAGE A38

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.  $2^{n+1} + n^2 + n - 2$

EXERCISES G ■ PAGE A55

1.  $8 - 4i$     3.  $13 + 18i$     5.  $12 - 7i$     7.  $\frac{11}{13} + \frac{10}{13}i$   
 9.  $\frac{1}{2} - \frac{1}{2}i$     11.  $-i$     13.  $5i$     15.  $12 + 5i, 13$   
 17.  $4i, 4$     19.  $\pm \frac{3}{2}i$     21.  $-1 \pm 2i$   
 23.  $-\frac{1}{2} \pm (\sqrt{7}/2)i$     25.  $3\sqrt{2}[\cos(3\pi/4) + i \sin(3\pi/4)]$   
 27.  $5\{\cos[\tan^{-1}(\frac{4}{3})] + i \sin[\tan^{-1}(\frac{4}{3})]\}$   
 29.  $4[\cos(\pi/2) + i \sin(\pi/2)], \cos(-\pi/6) + i \sin(-\pi/6),$   
 $\frac{1}{2}[\cos(-\pi/6) + i \sin(-\pi/6)]$   
 31.  $4\sqrt{2}[\cos(7\pi/12) + i \sin(7\pi/12)],$   
 $(2\sqrt{2})[\cos(13\pi/12) + i \sin(13\pi/12)], \frac{1}{4}[\cos(\pi/6) + i \sin(\pi/6)]$   
 33.  $-1024$     35.  $-512\sqrt{3} + 512i$   
 37.  $\pm 1, \pm i, (1/\sqrt{2})(\pm 1 \pm i)$     39.  $\pm(\sqrt{3}/2) + \frac{1}{2}i, -i$



41.  $i$     43.  $\frac{1}{2} + (\sqrt{3}/2)i$     45.  $-e^2$   
 47.  $\cos 3\theta = \cos^3 \theta - 3 \cos \theta \sin^2 \theta,$   
 $\sin 3\theta = 3 \cos^2 \theta \sin \theta - \sin^3 \theta$