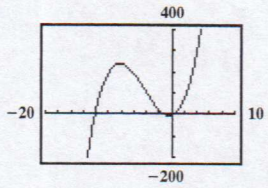
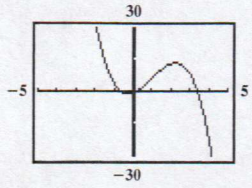
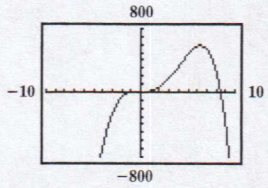
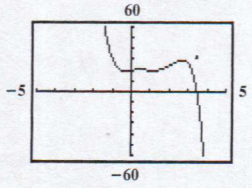
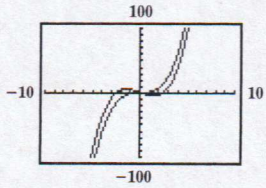
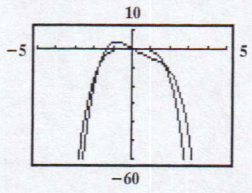
94. 

95. 

96. 

97. 

98. 

99. 

100. makes sense **101.** does not make sense **102.** does not make sense **103.** makes sense **104.** false **105.** false **106.** true

107. false **108.** $f(x) = x^3 + x^2 - 12x$ **109.** $f(x) = x^3 - 2x^2$ **110.** $35\frac{2}{21}$ **111.** $6x^3 - x^2 - 5x + 4$ **112.** $(x - 3)(2x - 1)(x + 2)$

Section 3.3

Check Point Exercises

1. $x + 5$ **2.** $2x^2 + 3x - 2 + \frac{1}{x - 3}$ **3.** $2x^2 + 7x + 14 + \frac{21x - 10}{x^2 - 2x}$ **4.** $x^2 - 2x - 3$ **5.** -105 **6.** $\left\{-1, -\frac{1}{3}, \frac{2}{5}\right\}$

Exercise Set 3.3

1. $x + 3$ **2.** $x + 5$ **3.** $x^2 + 3x + 1$ **4.** $x^2 + x - 2$ **5.** $2x^2 + 3x + 5$ **6.** $2x^2 + 3x + 5$ **7.** $4x + 3 + \frac{2}{3x - 2}$

8. $2x - 3 + \frac{3}{2x - 1}$ **9.** $2x^2 + x + 6 - \frac{38}{x + 3}$ **10.** $3x + 7 + \frac{26}{x - 3}$ **11.** $4x^3 + 16x^2 + 60x + 246 + \frac{984}{x - 4}$ **12.** $x^3 + 3x^2 + 9x + 27$

13. $2x + 5$ **14.** $x^2 + x - 3 - \frac{12}{x^2 + x - 2}$ **15.** $6x^2 + 3x - 1 - \frac{3x - 1}{3x^2 + 1}$ **16.** $x^2 - 4x + 1 + \frac{4x - 1}{2x^3 + 1}$ **17.** $2x + 5$

18. $x + 2$ **19.** $3x - 8 + \frac{20}{x + 5}$ **20.** $5x - 27 + \frac{73}{x + 3}$ **21.** $4x^2 + x + 4 + \frac{3}{x - 1}$ **22.** $5x^2 + 4x + 11 + \frac{33}{x - 2}$

23. $6x^4 + 12x^3 + 22x^2 + 48x + 93 + \frac{187}{x - 2}$ **24.** $x^4 + 7x^3 + 21x^2 + 60x + 182 + \frac{549}{x - 3}$ **25.** $x^3 - 10x^2 + 51x - 260 + \frac{1300}{x + 5}$

26. $x^3 - 12x^2 + 73x - 444 + \frac{2664}{x + 6}$ **27.** $x^4 + x^3 + 2x^2 + 2x + 2$ **28.** $x^6 - 2x^5 + 5x^4 - 10x^3 + 10x^2 - 20x + 40 - \frac{68}{x + 2}$

29. $x^3 + 4x^2 + 16x + 64$ **30.** $x^6 + 2x^5 + 4x^4 + 8x^3 + 16x^2 + 32x + 64$ **31.** $2x^4 - 7x^3 + 15x^2 - 31x + 64 - \frac{129}{x + 2}$

32. $x^4 - x^2 + x + 1 + \frac{3}{x - 2}$ **33.** -25 **34.** -27 **35.** -133 **36.** -4 **37.** 240 **38.** 0 **39.** 1 **40.** $\frac{7}{9}$

41. $x^2 - 5x + 6$; $x = -1$, $x = 2$, $x = 3$ **42.** $x^2 - 3x + 2$; $x = -1$, $x = 2$, $x = 1$ **43.** $\left\{-\frac{1}{2}, 1, 2\right\}$ **44.** $\left\{-2, \frac{1}{2}, 3\right\}$ **45.** $\left\{-\frac{3}{2}, -\frac{1}{3}, \frac{1}{2}\right\}$

46. $\left\{-4, -\frac{1}{3}, 2\right\}$ **47.** 2; The remainder is zero; $\{-3, -1, 2\}$ **48.** -3; The remainder is zero; $\left\{-3, \frac{1}{2}, 2\right\}$ **49.** 1; The remainder is zero; $\left\{\frac{1}{3}, \frac{1}{2}, 1\right\}$

50. 1; The remainder is zero; $\left\{-6, -\frac{1}{2}, 1\right\}$ **51. a.** The remainder is 0. **b.** 3 mm **52. a.** The remainder is 0. **b.** 2 in. by 4 in. by 9 in.

53. $0.5x^2 - 0.4x + 0.3$ **54.** $8x^2 - 12x + 4$ **55. a.** 70; When the tax rate is 30%, tax revenue is \$700 billion.; (30, 70)

b. $80 + \frac{800}{x - 110}$; $f(30) = 70$; yes **c.** No, f is a rational function because it is a quotient of two polynomials. **56. a.** $68\frac{4}{7}$; When the tax rate is 40%, tax revenue is $68\frac{4}{7}$ tens of billions dollars, or approximately \$685.7 billion dollars.; $\left(40, 68\frac{4}{7}\right)$ **b.** $80 + \frac{800}{x - 110}$; $f(40) \approx 68.57$; yes

c. No; f is a rational function because it is a quotient of two polynomials. **66.** does not make sense **67.** makes sense **68.** does not make sense

69. does not make sense **70.** false **71.** true **72.** true **73.** false **74.** $k = -12$ **75.** $x - 2$ **76.** $x^{2n} - x^n + 1$

78. The remainder is 0.; $\{-2, -1, 2, 5\}$ **79.** $\{-2 \pm \sqrt{5}\}$ **80.** $\{-2 \pm i\sqrt{2}\}$ **81.** -3

Section 3.4

Check Point Exercises

1. $\pm 1, \pm 2, \pm 3, \pm 6$ **2.** $\pm 1, \pm 3, \pm\frac{1}{2}, \pm\frac{1}{4}, \pm\frac{3}{2}, \pm\frac{3}{4}$ **3.** $\{-5, -4, 1\}$ **4.** $\left\{2, \frac{-3 - \sqrt{5}}{2}, \frac{-3 + \sqrt{5}}{2}\right\}$ **5.** $\{1, 2 - 3i, 2 + 3i\}$

6. $f(x) = x^3 + 3x^2 + x + 3$ **7.** 4, 2, or 0 positive zeros, no possible negative zeros

Exercise Set 3.4

1. $\pm 1, \pm 2, \pm 4$ **2.** $\pm 1, \pm 2, \pm 4, \pm 8$ **3.** $\pm 1, \pm 2, \pm 3, \pm 6, \pm\frac{1}{3}, \pm\frac{2}{3}$ **4.** $\pm 1, \pm 3, \pm 5, \pm 15, \pm\frac{1}{2}, \pm\frac{3}{2}, \pm\frac{5}{2}, \pm\frac{15}{2}$ **5.** $\pm 1, \pm 2, \pm 3, \pm 6, \pm\frac{1}{2}, \pm\frac{1}{4}, \pm\frac{3}{2}, \pm\frac{3}{4}$

6. $\pm1, \pm2, \pm4, \pm8, \pm\frac{1}{3}, \pm\frac{2}{3}, \pm\frac{4}{3}, \pm\frac{8}{3}$ **7.** $\pm1, \pm2, \pm3, \pm4, \pm6, \pm12$ **8.** $\pm1, \pm2, \pm\frac{1}{2}, \pm\frac{1}{4}$ **9. a.** $\pm1, \pm2, \pm4$ **b.** $-2, -1,$ or 2 **c.** $\{-2, -1, 2\}$

10. a. $\pm1, \pm2, \pm3, \pm4, \pm6, \pm12$ **b.** $-3, 1,$ or 4 **c.** $\{-3, 1, 4\}$ **11. a.** $\pm1, \pm2, \pm3, \pm6, \pm\frac{1}{2}, \pm\frac{3}{2}$ **b.** $-2, \frac{1}{2},$ or 3 **c.** $\left\{-2, \frac{1}{2}, 3\right\}$

12. a. $\pm1, \pm2, \pm\frac{1}{2}$ **b.** $-\frac{1}{2}, 1,$ or 2 **c.** $\left\{-\frac{1}{2}, 1, 2\right\}$ **13. a.** $\pm1, \pm2, \pm3, \pm6$ **b.** -1 **c.** $\left\{-1, \frac{-3-\sqrt{33}}{2}, \frac{-3+\sqrt{33}}{2}\right\}$

14. a. $\pm1, \pm\frac{1}{2}$ **b.** $\frac{1}{2}$ **c.** $\left\{\frac{1}{2}, \frac{-1-\sqrt{5}}{2}, \frac{-1+\sqrt{5}}{2}\right\}$ **15. a.** $\pm1, \pm\frac{1}{2}, \pm2$ **b.** -2 **c.** $\left\{-2, \frac{-1+i}{2}, \frac{-1-i}{2}\right\}$

16. a. $\pm1, \pm5$ **b.** 1 **c.** $\left\{1, \frac{3+i\sqrt{11}}{2}, \frac{3-i\sqrt{11}}{2}\right\}$ **17. a.** $\pm1, \pm2, \pm3, \pm4, \pm6, \pm12$ **b.** $-3, 1,$ or 4 **c.** $\{-3, 1, 4\}$

18. a. $\pm1, \pm2, \pm4$ **b.** -1 or 4 **c.** $\{-1, 4\}$ **19. a.** $\pm1, \pm2, \pm3, \pm4, \pm6, \pm12$ **b.** -2 **c.** $\{-2, 1+\sqrt{7}, 1-\sqrt{7}\}$

20. a. $\pm1, \pm13$ **b.** 1 **c.** $\{1, 2+3i, 2-3i\}$ **21. a.** $\pm1, \pm5, \pm\frac{1}{2}, \pm\frac{5}{2}, \pm\frac{1}{3}, \pm\frac{5}{3}, \pm\frac{1}{6}, \pm\frac{5}{6}$ **b.** $-5, \frac{1}{3},$ or $\frac{1}{2}$ **c.** $\left\{-5, \frac{1}{3}, \frac{1}{2}\right\}$

22. a. $\pm1, \pm2, \pm4, \pm\frac{1}{2}$ **b.** $\frac{1}{2}$ **c.** $\left\{\frac{1}{2}, 1+\sqrt{5}, 1-\sqrt{5}\right\}$ **23. a.** $\pm1, \pm2, \pm4$ **b.** -2 or 2 **c.** $\{-2, 2, 1+\sqrt{2}, 1-\sqrt{2}\}$

24. a. $\pm1, \pm3, \pm5, \pm15$ **b.** -1 or 3 **c.** $\{-1, 3, -1+2i, -1-2i\}$ **25.** $f(x) = 2x^3 - 2x^2 + 50x - 50$ **26.** $f(x) = 2x^3 - 8x^2 + 8x - 32$

27. $f(x) = x^3 - 3x^2 - 15x + 125$ **28.** $f(x) = 3x^3 + 12x^2 - 93x - 522$ **29.** $f(x) = x^4 + 10x^2 + 9$ **30.** $f(x) = 2x^4 + 5x^3 + 4x^2 + 5x + 2$

31. $f(x) = x^4 - 9x^3 + 21x^2 + 21x - 130$ **32.** $f(x) = 3x^4 - x^3 - 9x^2 + 159x - 52$ **33.** no positive real roots; 3 or 1 negative real roots

34. no positive real roots; 3 or 1 negative real roots **35.** 3 or 1 positive real roots; no negative real roots **36.** 3 or 1 positive real roots; no negative real roots **37.** 2 or 0 positive real roots; 2 or 0 negative real roots **38.** 3 or 1 positive real roots; 1 negative real root

39. $x = -2, x = 5, x = 1$ **40.** $x = -1, x = -10$ **41.** $\left\{-\frac{1}{2}, \frac{1+\sqrt{17}}{2}, \frac{1-\sqrt{17}}{2}\right\}$ **42.** $\left\{\frac{2}{3}, 1-\sqrt{5}, 1+\sqrt{5}\right\}$

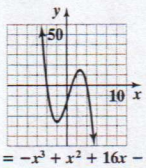
43. $-1, 2+2i,$ and $2-2i$ **44.** $-1, 3+i,$ and $3-i$ **45.** $\{-1, -2, 3+\sqrt{13}, 3-\sqrt{13}\}$ **46.** $\{-1, 2, 2i, -2i\}$

47. $x = -1, x = 2, x = -\frac{1}{3}, x = 3$ **48.** $x = 1, x = -\frac{5}{2}, x = \sqrt{3}, x = -\sqrt{3}$ **49.** $\left\{1, -\frac{3}{4}, i\sqrt{2}, -i\sqrt{2}\right\}$ **50.** $\left\{4, \frac{2}{3}, \frac{-1+i\sqrt{3}}{2}, \frac{-1-i\sqrt{3}}{2}\right\}$

51. $\left\{-2, \frac{1}{2}, \sqrt{2}, -\sqrt{2}\right\}$ **52.** $\left\{3, -2, -4, \frac{1}{2}, -\frac{1}{2}\right\}$

53. a. $-4, 1,$ and 4

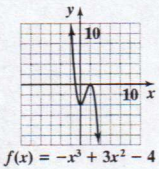
b.



$f(x) = -x^3 + x^2 + 16x - 16$

54. a. -1 and 2

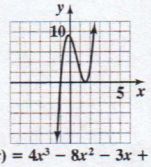
b.



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

55. a. -1 and $\frac{3}{2}$

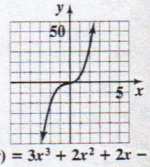
b.



$f(x) = 4x^3 - 8x^2 - 3x + 9$

56. a. $\frac{1}{3}, -\frac{1}{2} \pm \frac{\sqrt{3}}{2}i$

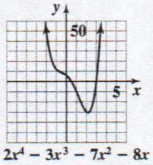
b.



$f(x) = 3x^3 + 2x^2 + 2x - 1$

57. a. $\frac{1}{2}, 3, -1 \pm i$

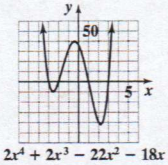
b.



$f(x) = 2x^4 - 3x^3 - 7x^2 - 8x + 6$

58. a. $-3, -2, 1,$ and 3

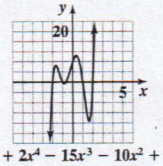
b.



$f(x) = 2x^4 + 2x^3 - 22x^2 - 18x + 36$

59. a. $-2, -1, -\frac{2}{3}, 1,$ and 2

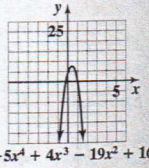
b.



$f(x) = 3x^5 + 2x^4 - 15x^3 - 10x^2 + 12x + 8$

60. a. $-\frac{1}{5}, 1, \pm 2i$

b.



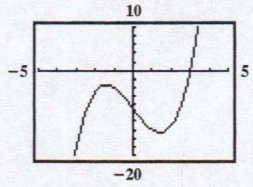
$f(x) = -5x^4 + 4x^3 - 19x^2 + 16x + 4$

61. 7.8 in., 10 in. **62.** 5 in., 12.2 in. **63. a.** (7.8, 2000), (10, 2000) **b.** (0, 15) **64. a.** (5, 1500), (12.2, 1500) **b.** (0, 15)

72. $\left\{-\frac{1}{2}, 3, 5\right\}$ **73.** $\left\{\frac{1}{2}, \frac{2}{3}, 2\right\}$ **74.** $\left\{-3, -\frac{3}{2}, -1, 2\right\}$ **75.** $\left\{\pm\frac{1}{2}\right\}$ **76.** no real zeros; no x-intercepts

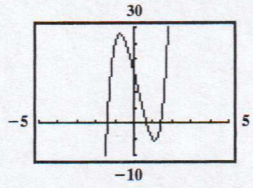
77. 5, 3, or 1 positive real zeros; no negative real zeros

79.



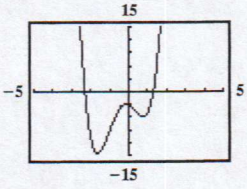
1 real zero, 2 nonreal complex zeros

80.



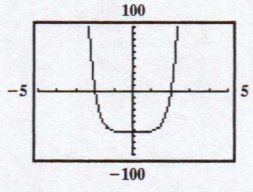
3 real zeros, 2 nonreal complex zeros

81.



2 real zeros, 2 nonreal complex zeros

82.



2 real zeros, 4 nonreal complex zeros

83. makes sense **84.** does not make sense **85.** makes sense **86.** makes sense **87.** false **88.** false **89.** true **90.** false

91. 3 in. **93.** 3 **94.** 3 **95.** 5 **96.** 5

98. $x = 1$ and $x = 2$ **99.** $x = 1$ **100.** $y = 0$