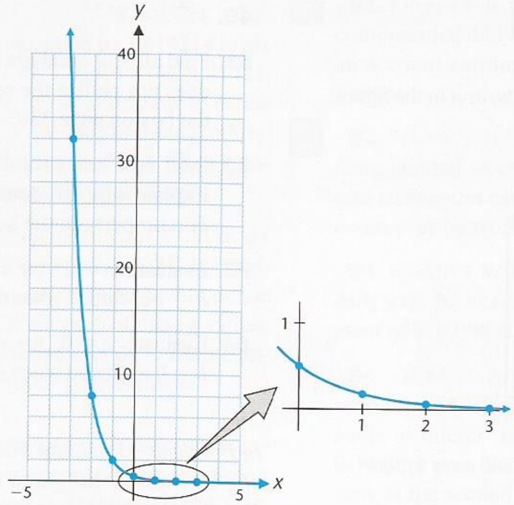
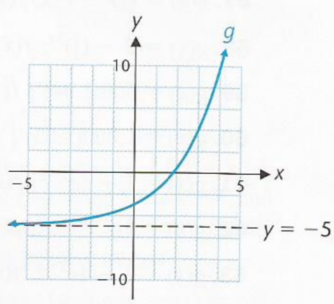
ANSWERS TO MATCHED PROBLEMS

1. The graph of g is the same as the graph of f reflected in the y axis and vertically shrunk by a factor of $\frac{1}{2}$.
x intercepts: none
y intercept: $\frac{1}{2}$
horizontal asymptote: $y = 0$ (x axis)
vertical asymptotes: none



2. $x = -\frac{1}{3}$

3. The graph of g is the same as the graph of f_1 stretched horizontally by a factor of 2, stretched vertically by a factor of 2, and shifted 5 units down; g is increasing.
horizontal asymptote: $y = -5$
vertical asymptote: none



4. \$2,707.04 **5.** After 23 quarters
6. Annually: \$1,762.34; quarterly: \$1,806.11; continuously: \$1,822.12

5-1 Exercises

1. What is an exponential function?

2. What is the significance of the symbol e in the study of exponential functions?

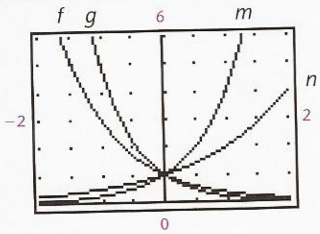
3. For a function $f(x) = b^x$, explain how you can tell if the graph increases or decreases without looking at the graph.

4. Explain why $f(x) = (1/4)^x$ and $g(x) = 4^{-x}$ are really the same function. Can you use this fact to add to your answer for Problem 3?

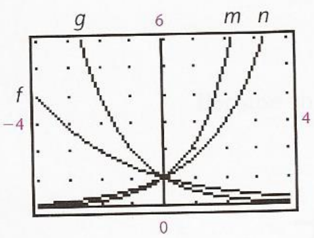
5. How do we know that the equation $e^x = 0$ has no solution?

6. Define the following terms related to compound interest: principal, interest rate, compounding period.

7. Match each equation with the graph of f, g, m, or n in the figure.
(A) $y = (0.2)^x$ (B) $y = 2^x$
(C) $y = (\frac{1}{3})^x$ (D) $y = 4^x$



8. Match each equation with the graph of f, g, m, or n in the figure.
(A) $y = e^{-1.2x}$ (B) $y = e^{0.7x}$
(C) $y = e^{-0.4x}$ (D) $y = e^{1.3x}$



In Problems 9–16, use a calculator to compute answers to four significant digits.

9. $5^{\sqrt{3}}$ **10.** $3^{-\sqrt{2}}$

11. $e^2 + e^{-2}$ **12.** $e - e^{-1}$

13. $\sqrt{e}$ **14.** $e^{\sqrt{2}}$

15. $\dfrac{2^{\pi} + 2^{-\pi}}{2}$ **16.** $\dfrac{3^{\pi} - 3^{-\pi}}{2}$

In Problems 17–24, simplify.

17. $10^{3x-1}10^{4-x}$ **18.** $(4^{3x})^{2y}$

19. $\dfrac{3^x}{3^{1-x}}$ **20.** $\dfrac{5^{x-3}}{5^{x-4}}$

21. $\left(\dfrac{4^x}{5^y}\right)^{3z}$ **22.** $(2^x3^y)^z$

23. $\dfrac{e^{5x}}{e^{2x+1}}$ **24.** $\dfrac{e^{4-3x}}{e^{2-5x}}$

In Problems 25–32, use transformations to explain how the graph of g is related to the graph of $f(x) = e^x$. Determine whether g is increasing or decreasing, find the asymptotes, and sketch the graph of g.

25. $g(x) = 3e^x$ **26.** $g(x) = 2e^{-x}$

27. $g(x) = \frac{1}{3}e^{-x}$ **28.** $g(x) = \frac{1}{5}e^x$

29. $g(x) = 2 + e^x$ **30.** $g(x) = -4 + e^x$

31. $g(x) = e^{x+2}$ **32.** $g(x) = e^{x-1}$

In Problems 33–50, solve for x.

33. $5^{3x} = 5^{4x-2}$ **34.** $10^{2-3x} = 10^{5x-6}$

35. $7^{x^2} = 7^{2x+3}$ **36.** $4^{5x-x^2} = 4^{-6}$

37. $(\frac{4}{5})^{6x+1} = \frac{5}{4}$ **38.** $(\frac{7}{3})^{2-x} = \frac{3}{7}$

39. $(1 - x)^5 = (2x - 1)^5$ **40.** $5^3 = (x + 2)^3$

41. $2xe^{-x} = 0$ **42.** $(x - 3)e^x = 0$

43. $x^2e^x - 5xe^x = 0$ **44.** $3xe^{-x} + x^2e^{-x} = 0$

45. $9^{x^2} = 3^{3x-1}$ **46.** $4^{x^2} = 2^{x+3}$

47. $25^{x+3} = 125^x$ **48.** $4^{5x+1} = 16^{2x-1}$

49. $4^{2x+7} = 8^{x+2}$ **50.** $100^{2x+3} = 1{,}000^{x+5}$

51. Find all real numbers a such that $a^2 = a^{-2}$. Explain why this does not violate the second exponential function property in the box on page 330.

52. Find real numbers a and b such that $a \neq b$ but $a^4 = b^4$. Explain why this does not violate the third exponential function property in the box on page 330.

53. Evaluate $y = 1^x$ for $x = -3, -2, -1, 0, 1, 2$, and 3. Why is $b = 1$ excluded when defining the exponential function $y = b^x$?

54. Evaluate $y = 0^x$ for $x = -3, -2, -1, 0, 1, 2$, and 3. Why is $b = 0$ excluded when defining the exponential function $y = b^x$?

In Problems 55–64, use transformations to explain how the graph of g is related to the graph of the given exponential function f. Determine whether g is increasing or decreasing, find any asymptotes, and sketch the graph of g.

55. $g(x) = -(\frac{1}{2})^x$; $f(x) = (\frac{1}{2})^x$

56. $g(x) = -(\frac{1}{3})^{-x}$; $f(x) = (\frac{1}{3})^x$

57. $g(x) = (\frac{1}{4})^{x/2} + 3$; $f(x) = (\frac{1}{4})^x$

58. $g(x) = 5 - (\frac{2}{3})^{3x}$; $f(x) = (\frac{2}{3})^x$

59. $g(x) = 500(1.04)^x$; $f(x) = 1.04^x$

60. $g(x) = 1{,}000(1.03)^x$; $f(x) = 1.03^x$

61. $g(x) = 1 + 2e^{x-3}$; $f(x) = e^x$

62. $g(x) = 4e^{x+1} - 7$; $f(x) = e^x$

63. $g(x) = 3 - 4e^{2-x}$; $f(x) = e^x$

64. $g(x) = -2 - 5e^{4-x}$; $f(x) = e^x$

In Problems 65–68, simplify.

65. $\dfrac{-2x^3e^{-2x} - 3x^2e^{-2x}}{x^6}$ **66.** $\dfrac{5x^4e^{5x} - 4x^3e^{5x}}{x^8}$

67. $(e^x + e^{-x})^2 + (e^x - e^{-x})^2$

68. $e^x(e^{-x} + 1) - e^{-x}(e^x + 1)$

In Problems 69–76, use a graphing calculator to find local extrema, y intercepts, and x intercepts. Investigate the behavior as $x \to \infty$ and as $x \to -\infty$ and identify any horizontal asymptotes. Round any approximate values to two decimal places.

69. $f(x) = 2 + e^{x-2}$ **70.** $g(x) = -3 + e^{1+x}$

71. $s(x) = e^{-x^2}$ **72.** $r(x) = e^{x^2}$

73. $F(x) = \dfrac{200}{1 + 3e^{-x}}$

74. $G(x) = \dfrac{100}{1 + e^{-x}}$

75. $f(x) = \dfrac{2^x + 2^{-x}}{2}$

76. $g(x) = \dfrac{3^x + 3^{-x}}{2}$

77. Use a graphing calculator to investigate the behavior of $f(x) = (1 + x)^{1/x}$ as x approaches 0.

78. Use a graphing calculator to investigate the behavior of $f(x) = (1 + x)^{1/x}$ as x approaches ∞.

79. The irrational number $\sqrt{2}$ is approximated by 1.414214 to six decimal places. Each of $x = 1.4, 1.41, 1.414, 1.4142, 1.41421,$ and 1.414214 is a rational number, so we know how to define 2^x for each. Compute the value of 2^x for each of these x values, and use your results to estimate the value of $2^{\sqrt{2}}$. Then compute $2^{\sqrt{2}}$ using your calculator to check your estimate.

80. The irrational number $\sqrt{3}$ is approximated by 1.732051 to six decimal places. Each of $x = 1.7, 1.73, 1.732, 1.7321, 1.73205,$ and 1.732051 is a rational number, so we know how to define 3^x for each. Compute the value of 3^x for each of these x values, and use your results to estimate the value of $3^{\sqrt{3}}$. Then compute $3^{\sqrt{3}}$ using your calculator to check your estimate.

It is common practice in many applications of mathematics to approximate nonpolynomial functions with appropriately selected polynomials. For example, the polynomials in Problems 81–84, called ***Taylor polynomials,*** *can be used to approximate the exponential function $f(x) = e^x$. To illustrate this approximation graphically, in each problem graph $f(x) = e^x$ and the indicated polynomial in the same viewing window, $-4 \le x \le 4$ and $-5 \le y \le 50$.*

81. $P_1(x) = 1 + x + \frac{1}{2}x^2$

82. $P_2(x) = 1 + x + \frac{1}{2}x^2 + \frac{1}{6}x^3$

83. $P_3(x) = 1 + x + \frac{1}{2}x^2 + \frac{1}{6}x^3 + \frac{1}{24}x^4$

84. $P_4(x) = 1 + x + \frac{1}{2}x^2 + \frac{1}{6}x^3 + \frac{1}{24}x^4 + \frac{1}{120}x^5$

85. Investigate the behavior of the functions $f_1(x) = x/e^x$, $f_2(x) = x^2/e^x$, and $f_3(x) = x^3/e^x$ as $x \to \infty$ and as $x \to -\infty$, and find any horizontal asymptotes. Generalize to functions of the form $f_n(x) = x^n/e^x$, where n is any positive integer.

86. Investigate the behavior of the functions $g_1(x) = xe^x$, $g_2(x) = x^2e^x$, and $g_3(x) = x^3e^x$ as $x \to \infty$ and as $x \to -\infty$, and find any horizontal asymptotes. Generalize to functions of the form $g_n(x) = x^ne^x$, where n is any positive integer.

APPLICATIONS*

87. FINANCE A couple just had a new child. How much should they invest now at 6.25% compounded daily to have $100,000 for the child's education 17 years from now? Compute the answer to the nearest dollar.

88. FINANCE A person wants to have $25,000 cash for a new car 5 years from now. How much should be placed in an account now if the account pays 4.75% compounded weekly? Compute the answer to the nearest dollar.

*Round monetary amounts to the nearest cent unless specified otherwise. In all problems involving interest that is compounded daily, assume a 365-day year.

89. MONEY GROWTH If you invest $5,250 in an account paying 6.38% compounded continuously, how much money will be in the account at the end of
(A) 6.25 years? (B) 17 years?

90. MONEY GROWTH If you invest $7,500 in an account paying 5.35% compounded continuously, how much money will be in the account at the end of
(A) 5.5 years? (B) 12 years?

91. FINANCE If $3,000 is deposited into an account earning 8% compounded daily and, at the same time, $5,000 is deposited into an account earning 5% compounded daily, will the first account ever be worth more than the second? If so, when?

92. FINANCE If $4,000 is deposited into an account earning 9% compounded weekly and, at the same time, $6,000 is deposited into an account earning 7% compounded weekly, will the first account ever be worth more than the second? If so, when?

93. FINANCE Will an investment of $10,000 at 4.9% compounded daily ever be worth more at the end of any quarter than an investment of $10,000 at 5% compounded quarterly? Explain.

94. FINANCE A sum of $5,000 is invested at 7% compounded semiannually. Suppose that a second investment of $5,000 is made at interest rate r compounded daily. Both investments are held for 1 year. For which values of r, to the nearest tenth of a percent, is the second investment better than the first? Discuss.

95. PRESENT VALUE A promissory note will pay $30,000 at maturity 10 years from now. How much should you pay for the note now if the note gains value at a rate of 6% compounded continuously?

96. PRESENT VALUE A promissory note will pay $50,000 at maturity $5\frac{1}{2}$ years from now. How much should you pay for the note now if the note gains value at a rate of 5% compounded continuously?

97. MONEY GROWTH The website Bankrate.com publishes a weekly list of the top savings deposit yields. In the category of 3-year certificates of deposit, the following were listed:

Flagstar Bank, FSB	3.12% (CQ)
UmbrellaBank.com	3.00% (CD)
Allied First Bank	2.96% (CM)

where CQ represents compounded quarterly, CD compounded daily, and CM compounded monthly. Find the value of $5,000 invested in each account at the end of 3 years.

98. Refer to Problem 97. In the 1-year certificate of deposit category, the following accounts were listed:

GMAC Bank	2.91% (CD)
UFBDirect.com	2.86% (CM)

Find the value of $10,000 invested in each account at the end of 1 year.

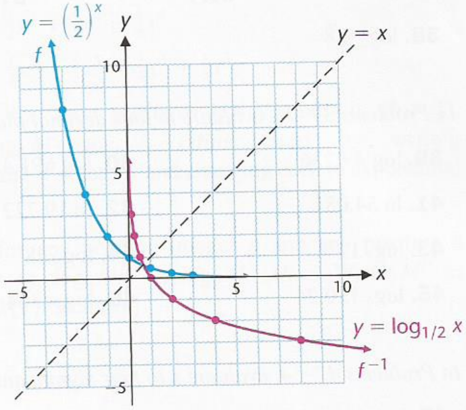
99. FINANCE Suppose $4,000 is invested at 6% compounded weekly. How much money will be in the account in
(A) $\frac{1}{2}$ year? (B) 10 years?

100. FINANCE Suppose $2,500 is invested at 4% compounded quarterly. How much money will be in the account in
(A) $\frac{3}{4}$ year? (B) 15 years?

ANSWERS TO MATCHED PROBLEMS

1.

f: x	$y = \left(\frac{1}{2}\right)^x$	f^{-1}: x	$y = \log_{1/2} x$
-3	8	8	-3
-2	4	4	-2
-1	2	2	-1
0	1	1	0
1	$\frac{1}{2}$	$\frac{1}{2}$	1
2	$\frac{1}{4}$	$\frac{1}{4}$	2
3	$\frac{1}{8}$	$\frac{1}{8}$	3



2. (A) $27 = 3^3$ (B) $6 = 36^{1/2}$ (C) $\frac{1}{9} = 3^{-2}$
3. (A) $\log_4 64 = 3$ (B) $\log_8 2 = \frac{1}{3}$ (C) $\log_4 (\frac{1}{16}) = -2$
4. (A) $y = \frac{3}{2}$ (B) $x = \frac{1}{8}$ (C) $b = 10$
5. (A) -5 (B) 2 (C) 0 (D) $m + n$ (E) 4 (F) $x^4 + 1$
6. (A) $-1.868\ 734$ (B) $3.356\ 663$ (C) Not possible
7. (A) 14.275 (B) 1.022 (C) 1.022
8. (A) $x = 0.006\ 333$ (B) $x = 1.208 \times 10^{12}$ **9.** 4.7486

5-3 Exercises

1. Describe the relationship between logarithmic functions and exponential functions in your own words.

2. Explain why there are infinitely many different logarithmic functions.

3. Why are logarithmic functions undefined for zero and negative inputs?

4. Why is $\log_b 1 = 0$ for any base?

5. Explain how to calculate $\log_5 3$ on a calculator that only has log buttons for base 10 and base e.

6. Using the word "inverse," explain why $\log_b b^x = x$ for any x and any acceptable base b.

Rewrite Problems 7–12 in equivalent exponential form.

7. $\log_3 81 = 4$ **8.** $\log_5 125 = 3$

9. $\log_{10} 0.001 = -3$ **10.** $\log_{10} 1{,}000 = 3$

11. $\log_6 \frac{1}{36} = -2$ **12.** $\log_2 \frac{1}{64} = -6$

Rewrite Problems 13–18 in equivalent logarithmic form.

13. $8 = 4^{3/2}$ **14.** $9 = 27^{2/3}$

15. $\frac{1}{2} = 32^{-1/5}$ **16.** $\frac{1}{8} = 2^{-3}$

17. $(\frac{2}{3})^3 = \frac{8}{27}$ **18.** $(\frac{5}{2})^{-2} = 0.16$

In Problems 19–22, make a table of values similar to the one in Example 1, then use it to graph both functions by hand.

19. $f(x) = 3^x$ $f^{-1}(x) = \log_3 x$

20. $f(x) = (\frac{1}{3})^x$ $f^{-1}(x) = \log_{1/3} x$

21. $f(x) = (\frac{2}{3})^x$ $f^{-1}(x) = \log_{2/3} x$

22. $f(x) = 10^x$ $f^{-1}(x) = \log x$

In Problems 23–38, simplify each expression using Theorem 2.

23. $\log_{16} 1$ **24.** $\log_{25} 1$ **25.** $\log_{0.5} 0.5$

26. $\log_7 7$ **27.** $\log_e e^4$ **28.** $\log_{10} 10^5$

29. $\log_{10} 0.01$ **30.** $\log_{10} 100$ **31.** $\log_3 27$

32. $\log_4 256$ **33.** $\log_{1/2} 2$ **34.** $\log_{1/5} (\frac{1}{25})$

35. $e^{\log_e 5}$ **36.** $e^{\log_e 10}$ **37.** $\log_5 \sqrt[3]{5}$

38. $\log_2 \sqrt{8}$

In Problems 39–46, evaluate to four decimal places.

39. $\log 49{,}236$ **40.** $\log 691{,}450$

41. $\ln 54.081$ **42.** $\ln 19.722$

43. $\log_7 13$ **44.** $\log_9 78$

45. $\log_5 120.24$ **46.** $\log_{17} 304.66$

In Problems 47–54, evaluate x to four significant digits.

47. $\log x = 5.3027$ **48.** $\log x = 1.9168$

49. $\log x = -3.1773$ **50.** $\log x = -2.0411$

51. $\ln x = 3.8655$ **52.** $\ln x = 5.0884$

53. $\ln x = -0.3916$ **54.** $\ln x = -4.1083$

Find x, y, or b, as indicated in Problems 55–72.

55. $\log_2 x = 2$ **56.** $\log_3 x = 3$

57. $\log_4 16 = y$ **58.** $\log_8 64 = y$

59. $\log_b 16 = 2$ **60.** $\log_b 10^{-3} = -3$

61. $\log_b 1 = 0$ **62.** $\log_b b = 1$

63. $\log_4 x = \frac{1}{2}$ **64.** $\log_8 x = \frac{1}{3}$

65. $\log_{1/3} 9 = y$ **66.** $\log_{49} (\frac{1}{7}) = y$

67. $\log_b 1{,}000 = \frac{3}{2}$ **68.** $\log_b 4 = \frac{2}{3}$

69. $\log_8 x = -\frac{4}{3}$ **70.** $\log_{25} x = -\frac{3}{2}$

71. $\log_{16} 8 = y$ **72.** $\log_9 27 = y$

In Problems 73–78, evaluate to three decimal places.

73. $\dfrac{\log 2}{\log 1.15}$ **74.** $\dfrac{\log 2}{\log 1.12}$

75. $\dfrac{\ln 3}{\ln 1.15}$ **76.** $\dfrac{\ln 4}{\ln 1.2}$

77. $\dfrac{\ln 150}{2 \ln 3}$ **78.** $\dfrac{\log 200}{3 \log 2}$

In Problems 79–82, rewrite the expression in terms of log x and log y.

79. $\log\left(\dfrac{x}{y}\right)$ **80.** $\log (xy)$

81. $\log (x^4 y^3)$ **82.** $\log\left(\dfrac{x^2}{\sqrt{y}}\right)$

In Problems 83–86, rewrite the expression as a single log.

83. $\ln x - \ln y$ **84.** $\log_3 x + \log_3 y$

85. $2 \ln x + 5 \ln y - \ln z$ **86.** $\log a - 2 \log b + 3 \log c$

In Problems 87–90, given that $\log x = -2$ and $\log y = 3$, find:

87. $\log (xy)$ **88.** $\log\left(\dfrac{x}{y}\right)$

89. $\log\left(\dfrac{\sqrt{x}}{y^3}\right)$ **90.** $\log (x^5 y^3)$

In Problems 91–98, use transformations to explain how the graph of g is related to the graph of the given logarithmic function f. Determine whether g is increasing or decreasing, find its domain and asymptote, and sketch the graph of g.

91. $g(x) = 3 + \log_2 x$; $f(x) = \log_2 x$

92. $g(x) = -4 + \log_3 x$; $f(x) = \log_3 x$

93. $g(x) = \log_{1/3} (x - 2)$; $f(x) = \log_{1/3} x$

94. $g(x) = \log_{1/2} (x + 3)$; $f(x) = \log_{1/2} x$

95. $g(x) = -1 - \log x$; $f(x) = \log x$

96. $g(x) = 2 - \log x$; $f(x) = \log x$

97. $g(x) = 5 - 3 \ln x$; $f(x) = \ln x$

98. $g(x) = -3 - 2 \ln x$; $f(x) = \ln x$

In Problems 99–102, find f^{-1}.

99. $f(x) = \log_5 x$ **100.** $f(x) = \log_{1/3} x$

101. $f(x) = 4 \log_3 (x + 3)$ **102.** $f(x) = 2 \log_2 (x - 5)$

103. Let $f(x) = \log_3 (2 - x)$.
(A) Find f^{-1}. (B) Graph f^{-1}.
(C) Reflect the graph of f^{-1} in the line $y = x$ to obtain the graph of f.

104. Let $f(x) = \log_2 (-3 - x)$.
(A) Find f^{-1}. (B) Graph f^{-1}.
(C) Reflect the graph of f^{-1} in the line $y = x$ to obtain the graph of f.

105. What is wrong with the following "proof" that 3 is less than 2?

$$1 < 3 \quad \text{Divide both sides by 27.}$$
$$\tfrac{1}{27} < \tfrac{3}{27}$$
$$\tfrac{1}{27} < \tfrac{1}{9}$$
$$(\tfrac{1}{3})^3 < (\tfrac{1}{3})^2$$
$$\log (\tfrac{1}{3})^3 < \log (\tfrac{1}{3})^2$$
$$3 \log \tfrac{1}{3} < 2 \log \tfrac{1}{3} \quad \text{Divide both sides by } \log \tfrac{1}{3}.$$
$$3 < 2$$

through the point (1, 0) and has the y axis as a vertical asymptote. The following **properties of logarithmic functions** are useful:

1. $\log_b 1 = 0$
2. $\log_b b = 1$
3. $\log_b b^x = x$
4. $b^{\log_b x} = x, x > 0$
5. $\log_b MN = \log_b M + \log_b N$
6. $\log_b \frac{M}{N} = \log_b M - \log_b N$
7. $\log_b M^p = p \log_b M$
8. $\log_b M = \log_b N$ if and only if $M = N$

Logarithms to the base 10 are called **common logarithms** and are denoted by $\log x$. Logarithms to the base e are called **natural logarithms** and are denoted by $\ln x$. So $\log x = y$ is equivalent to $x = 10^y$, and $\ln x = y$ is equivalent to $x = e^y$.

The **change-of-base formula,** $\log_b N = (\log_a N)/(\log_a b)$, relates logarithms to two different bases and can be used, along with a calculator, to evaluate logarithms to bases other than e or 10.

5-4 Logarithmic Models

The following applications involve logarithmic functions:

1. The **decibel** is defined by $D = 10 \log (I/I_0)$, where D is the **decibel level** of the sound, I is the **intensity** of the sound, and $I_0 = 10^{-12}$ watts per square meter is a standardized sound level.
2. The **magnitude** M of an earthquake on the **Richter scale** is given by $M = \frac{2}{3}\log (E/E_0)$, where E is the energy released by the earthquake and $E_0 = 10^{4.40}$ joules is a standardized energy level.
3. The **velocity** v of a rocket at burnout is given by the **rocket equation** $v = c \ln (W_t/W_b)$, where c is the exhaust velocity, W_t is the takeoff weight, and W_b is the burnout weight.

Logarithmic regression can be used to fit a function of the form $y = a + b \ln x$ to a set of data points.

5-5 Exponential and Logarithmic Equations

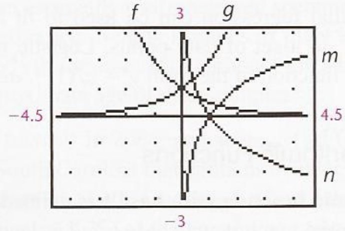
Exponential equations are equations in which the variable appears in an exponent. If the exponential expression is isolated, applying a logarithmic function to both sides and using the property $\log_b N^p = p \log_b N$ will enable you to remove the variable from the exponent. If the exponential expression is not isolated, we can use previously developed techniques to first solve for the exponential, then solve as above.

Logarithmic equations are equations in which the variable appears inside a logarithmic function. In most cases, the key to solving them is to change the equation to the equivalent exponential expression. For equations with multiple log expressions, properties of logarithms can be used to combine the expressions before solving.

CHAPTER 5 Review Exercises

Work through all the problems in this chapter review and check answers in the back of the book. Answers to all review problems are there, and following each answer is a number in italics indicating the section in which that type of problem is discussed. Where weaknesses show up, review appropriate sections in the text.

1. Match each equation with the graph of f, g, m, or n in the figure.
(A) $y = \log_2 x$ (B) $y = 0.5^x$
(C) $y = \log_{0.5} x$ (D) $y = 2^x$



2. Write in logarithmic form using base 10: $m = 10^n$.

3. Write in logarithmic form using base e: $x = e^y$.

Write the expression in Problems 4 and 5 in exponential form.

4. $\log x = y$ **5.** $\ln y = x$

6. (A) Plot at least five points, then draw a hand sketch of the graph of $y = (\frac{4}{3})^x$.
(B) Use your result from part A to sketch the graph of $y = \log_{4/3} x$.

In Problems 7 and 8, simplify.

7. $\dfrac{7^{x+2}}{7^{2-x}}$ **8.** $\left(\dfrac{e^x}{e^{-x}}\right)^x$

In Problems 9–11, solve for x exactly.

9. $\log_2 x = 3$ **10.** $\log_x 25 = 2$ **11.** $\log_3 27 = x$