

Chapter 3 Summary, Review, and Test

Summary

DEFINITIONS AND CONCEPTS

EXAMPLES

3.1 Exponential Functions

- | | |
|--|---------------------------------|
| a. The exponential function with base b is defined by $f(x) = b^x$, where $b > 0$ and $b \neq 1$. | Ex. 1, p. 389 |
| b. Characteristics of exponential functions and graphs for $0 < b < 1$ and $b > 1$ are shown in the box on page 391. | Ex. 2, p. 390;
Ex. 3, p. 390 |
| c. Transformations involving exponential functions are summarized in Table 3.1 on page 392. | Ex. 4, p. 392;
Ex. 5, p. 393 |
| d. The natural exponential function is $f(x) = e^x$. The irrational number e is called the natural base, where $e \approx 2.7183$. e is the value that $\left(1 + \frac{1}{n}\right)^n$ approaches as $n \rightarrow \infty$. | Ex. 6, p. 394 |
| e. Formulas for compound interest: After t years, the balance, A , in an account with principal P and annual interest rate r (in decimal form) is given by one of the following formulas: <ol style="list-style-type: none"> For n compoundings per year: $A = P\left(1 + \frac{r}{n}\right)^{nt}$ For continuous compounding: $A = Pe^{rt}$. | Ex. 7, p. 396 |

3.2 Logarithmic Functions

- | | |
|--|--|
| a. Definition of the logarithmic function: For $x > 0$ and $b > 0$, $b \neq 1$, $y = \log_b x$ is equivalent to $b^y = x$. The function $f(x) = \log_b x$ is the logarithmic function with base b . This function is the inverse function of the exponential function with base b . | Ex. 1, p. 401;
Ex. 2, p. 401;
Ex. 3, p. 402 |
| b. Graphs of logarithmic functions for $b > 1$ and $0 < b < 1$ are shown in Figure 3.8 on page 404. Characteristics of the graphs are summarized in the box on page 405. | Ex. 6, p. 404 |
| c. Transformations involving logarithmic functions are summarized in Table 3.4 on page 405. | Figures 3.9–3.12
pp. 405–406 |
| d. The domain of a logarithmic function of the form $f(x) = \log_b x$ is the set of all positive real numbers. The domain of $f(x) = \log_b g(x)$ consists of all x for which $g(x) > 0$. | Ex. 7, p. 406;
Ex. 10, p. 408 |
| e. Common and natural logarithms: $f(x) = \log x$ means $f(x) = \log_{10} x$ and is the common logarithmic function. $f(x) = \ln x$ means $f(x) = \log_e x$ and is the natural logarithmic function. | Ex. 8, p. 407;
Ex. 9, p. 408;
Ex. 11, p. 409 |
| f. Basic Logarithmic Properties | |

Base b ($b > 0$, $b \neq 1$)	Base 10 (Common Logarithms)	Base e (Natural Logarithms)
$\log_b 1 = 0$	$\log 1 = 0$	$\ln 1 = 0$
$\log_b b = 1$	$\log 10 = 1$	$\ln e = 1$
$\log_b b^x = x$	$\log 10^x = x$	$\ln e^x = x$
$b^{\log_b x} = x$	$10^{\log x} = x$	$e^{\ln x} = x$

Ex. 4, p. 402

Ex. 5, p. 403

3.3 Properties of Logarithms

- | | |
|---|---------------|
| a. <i>The Product Rule:</i> $\log_b(MN) = \log_b M + \log_b N$ | Ex. 1, p. 414 |
| b. <i>The Quotient Rule:</i> $\log_b\left(\frac{M}{N}\right) = \log_b M - \log_b N$ | Ex. 2, p. 415 |
| c. <i>The Power Rule:</i> $\log_b M^p = p \log_b M$ | Ex. 3, p. 416 |

DEFINITIONS AND CONCEPTS
EXAMPLES

 d. *The Change-of-Base Property:*

The General Property	Introducing Common Logarithms	Introducing Natural Logarithms
$\log_b M = \frac{\log_a M}{\log_a b}$	$\log_b M = \frac{\log M}{\log b}$	$\log_b M = \frac{\ln M}{\ln b}$

 Ex. 7, p. 420;
 Ex. 8, p. 420

e. Properties for expanding logarithmic expressions are given in the box on page 416.

Ex. 4, p. 417

f. Properties for condensing logarithmic expressions are given in the box on page 418.

 Ex. 5, p. 418;
 Ex. 6, p. 418

3.4 Exponential and Logarithmic Equations

 a. An exponential equation is an equation containing a variable in an exponent. Some exponential equations can be solved by expressing each side as a power of the same base: If $b^M = b^N$, then $M = N$. Details are in the box on page 424.

Ex. 1, p. 424

b. The procedure for using logarithms to solve exponential equations is given in the box on page 425. The solution procedure involves isolating the exponential expression. Take the natural logarithm on both sides for bases other than 10 and take the common logarithm on both sides for base 10. Simplify using

$$\ln b^x = x \ln b \quad \text{or} \quad \ln e^x = x \quad \text{or} \quad \log 10^x = x.$$

 Ex. 2, p. 425;
 Ex. 3, p. 426;
 Ex. 4, p. 426;
 Ex. 5, p. 427

 c. A logarithmic equation is an equation containing a variable in a logarithmic expression. Some logarithmic equations can be expressed in the form $\log_b M = c$. The definition of a logarithm is used to rewrite the equation in exponential form: $b^c = M$. See the box on page 427. When checking logarithmic equations, reject proposed solutions that produce the logarithm of a negative number or the logarithm of 0 in the original equation.

 Ex. 6, p. 427;
 Ex. 7, p. 428

 d. Some logarithmic equations can be expressed in the form $\log_b M = \log_b N$. Use the one-to-one property to rewrite the equation without logarithms: $M = N$. See the box on page 429.

Ex. 8, p. 429

3.5 Exponential Growth and Decay; Modeling Data

 a. Exponential growth and decay models are given by $A = A_0 e^{kt}$ in which t represents time, A_0 is the amount present at $t = 0$, and A is the amount present at time t . If $k > 0$, the model describes growth and k is the growth rate. If $k < 0$, the model describes decay and k is the decay rate.

 Ex. 1, p. 437;
 Ex. 2, p. 439

 b. The logistic growth model, given by $A = \frac{c}{1 + ae^{-bt}}$, describes situations in which growth is limited. $y = c$ is a horizontal asymptote for the graph, and growth, A , can never exceed c .

Ex. 3, p. 441

 c. Newton's Law of Cooling: The temperature, T , of a heated object at time t is given by

$$T = C + (T_0 - C)e^{kt},$$

 where C is the constant temperature of the surrounding medium, T_0 is the initial temperature of the heated object, and k is a negative constant.

Ex. 4, p. 442

 d. Scatter plots for exponential and logarithmic models are shown in Figure 3.24 on page 443. When using a graphing utility to model data, the closer that the correlation coefficient, r , is to -1 or 1 , the better the model fits the data.

 Ex. 5, p. 444;
 Ex. 6, p. 445

 e. Expressing an Exponential Model in Base e : $y = ab^x$ is equivalent to $y = ae^{(\ln b)x}$.

Ex. 7, p. 446

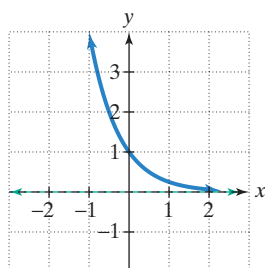
Review Exercises
3.1

In Exercises 1–4, the graph of an exponential function is given. Select the function for each graph from the following options:

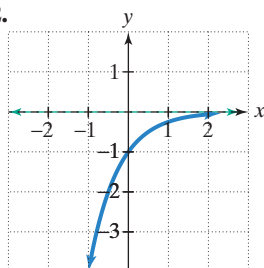
$$f(x) = 4^x, g(x) = 4^{-x},$$

$$h(x) = -4^{-x}, r(x) = -4^{-x} + 3.$$

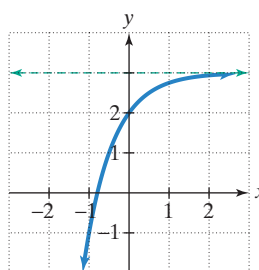
1.



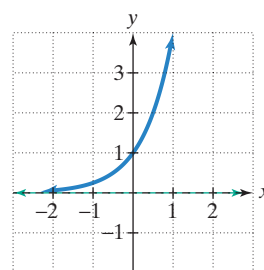
2.



3.



4.

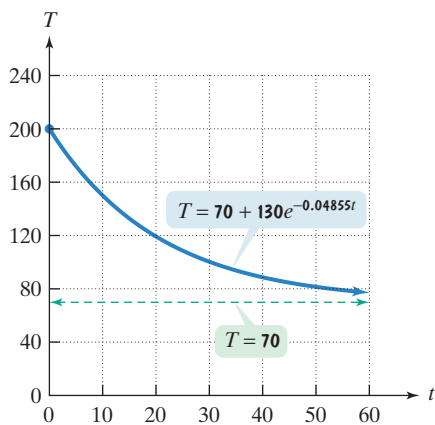

 In Exercises 5–9, graph f and g in the same rectangular coordinate system. Use transformations of the graph of f to obtain the graph of g . Graph and give equations of all asymptotes. Use the graphs to determine each function's domain and range.

5. $f(x) = 2^x$ and $g(x) = 2^{x-1}$

6. $f(x) = 3^x$ and $g(x) = 3^x - 1$
7. $f(x) = 3^x$ and $g(x) = -3^x$
8. $f(x) = \left(\frac{1}{2}\right)^x$ and $g(x) = \left(\frac{1}{2}\right)^{-x}$
9. $f(x) = e^x$ and $g(x) = 2e^{2x}$

Use the compound interest formulas to solve Exercises 10–11.

10. Suppose that you have \$5000 to invest. Which investment yields the greater return over 5 years: 5.5% compounded semiannually or 5.25% compounded monthly?
11. Suppose that you have \$14,000 to invest. Which investment yields the greater return over 10 years: 7% compounded monthly or 6.85% compounded continuously?
12. A cup of coffee is taken out of a microwave oven and placed in a room. The temperature, T , in degrees Fahrenheit, of the coffee after t minutes is modeled by the function $T = 70 + 130e^{-0.04855t}$. The graph of the function is shown in the figure.



Use the graph to answer each of the following questions.

- a. What was the temperature of the coffee when it was first taken out of the microwave?
- b. What is a reasonable estimate of the temperature of the coffee after 20 minutes? Use your calculator to verify this estimate.
- c. What is the limit of the temperature to which the coffee will cool? What does this tell you about the temperature of the room?

3.2

In Exercises 13–15, write each equation in its equivalent exponential form.

13. $\frac{1}{2} = \log_{49} 7$
14. $3 = \log_4 x$
15. $\log_3 81 = y$

In Exercises 16–18, write each equation in its equivalent logarithmic form.

16. $6^3 = 216$
17. $b^4 = 625$
18. $13^y = 874$

In Exercises 19–29, evaluate each expression without using a calculator. If evaluation is not possible, state the reason.

19. $\log_4 64$
20. $\log_5 \frac{1}{25}$
21. $\log_3(-9)$
22. $\log_{16} 4$
23. $\log_{17} 17$
24. $\log_3 3^8$

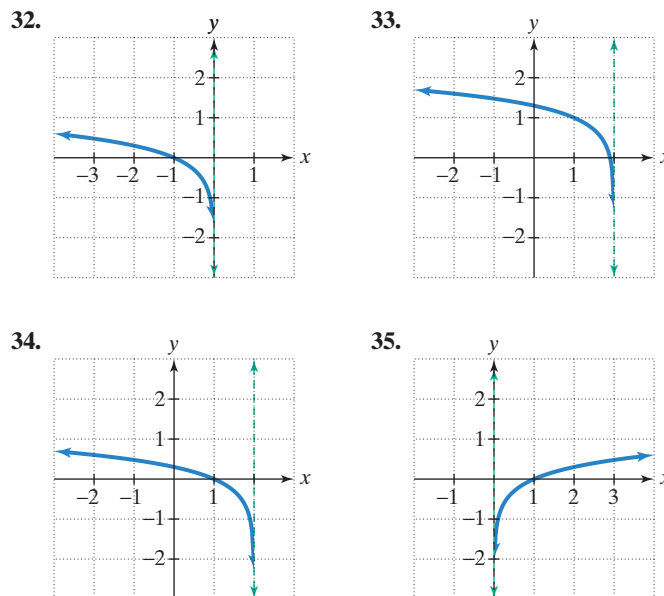
25. $\ln e^5$
26. $\log_3 \frac{1}{\sqrt{3}}$
27. $\ln \frac{1}{e^2}$
28. $\log \frac{1}{1000}$
29. $\log_3(\log_8 8)$

30. Graph $f(x) = 2^x$ and $g(x) = \log_2 x$ in the same rectangular coordinate system. Use the graphs to determine each function's domain and range.
31. Graph $f(x) = \left(\frac{1}{3}\right)^x$ and $g(x) = \log_{\frac{1}{3}} x$ in the same rectangular coordinate system. Use the graphs to determine each function's domain and range.

In Exercises 32–35, the graph of a logarithmic function is given. Select the function for each graph from the following options:

$$f(x) = \log x, g(x) = \log(-x),$$

$$h(x) = \log(2 - x), r(x) = 1 + \log(2 - x).$$



In Exercises 36–38, begin by graphing $f(x) = \log_2 x$. Then use transformations of this graph to graph the given function. What is the graph's x -intercept? What is the vertical asymptote? Use the graphs to determine each function's domain and range.

36. $g(x) = \log_2(x - 2)$
37. $h(x) = -1 + \log_2 x$
38. $r(x) = \log_2(-x)$

In Exercises 39–40, graph f and g in the same rectangular coordinate system. Use transformations of the graph of f to obtain the graph of g . Graph and give equations of all asymptotes. Use the graphs to determine each function's domain and range.

39. $f(x) = \log x$ and $g(x) = -\log(x + 3)$
40. $f(x) = \ln x$ and $g(x) = -\ln(2x)$

In Exercises 41–43, find the domain of each logarithmic function.

41. $f(x) = \log_8(x + 5)$
42. $f(x) = \log(3 - x)$
43. $f(x) = \ln(x - 1)^2$

In Exercises 44–46, use inverse properties of logarithms to simplify each expression.

44. $\ln e^{6x}$
45. $e^{\ln \sqrt{x}}$
46. $10^{\log 4x^2}$

47. On the Richter scale, the magnitude, R , of an earthquake of intensity I is given by $R = \log \frac{I}{I_0}$, where I_0 is the intensity of a barely felt zero-level earthquake. If the intensity of an earthquake is $1000I_0$, what is its magnitude on the Richter scale?

48. Students in a psychology class took a final examination. As part of an experiment to see how much of the course content they remembered over time, they took equivalent forms of the exam in monthly intervals thereafter. The average score, $f(t)$, for the group after t months is modeled by the function $f(t) = 76 - 18 \log(t + 1)$, where $0 \leq t \leq 12$.

- What was the average score when the exam was first given?
- What was the average score after 2 months? 4 months? 6 months? 8 months? one year?
- Use the results from parts (a) and (b) to graph f . Describe what the shape of the graph indicates in terms of the material retained by the students.

49. The formula

$$t = \frac{1}{c} \ln \left(\frac{A}{A - N} \right)$$

describes the time, t , in weeks, that it takes to achieve mastery of a portion of a task. In the formula, A represents maximum learning possible, N is the portion of the learning that is to be achieved, and c is a constant used to measure an individual's learning style. A 50-year-old man decides to start running as a way to maintain good health. He feels that the maximum rate he could ever hope to achieve is 12 miles per hour. How many weeks will it take before the man can run 5 miles per hour if $c = 0.06$ for this person?

3.3

In Exercises 50–53, use properties of logarithms to expand each logarithmic expression as much as possible. Where possible, evaluate logarithmic expressions without using a calculator.

$$50. \log_6(36x^3) \qquad 51. \log_4 \left(\frac{\sqrt{x}}{64} \right)$$

$$52. \log_2 \left(\frac{xy^2}{64} \right) \qquad 53. \ln \sqrt[3]{\frac{x}{e}}$$

In Exercises 54–57, use properties of logarithms to condense each logarithmic expression. Write the expression as a single logarithm whose coefficient is 1.

$$54. \log_b 7 + \log_b 3 \qquad 55. \log 3 - 3 \log x$$

$$56. 3 \ln x + 4 \ln y \qquad 57. \frac{1}{2} \ln x - \ln y$$

In Exercises 58–59, use common logarithms or natural logarithms and a calculator to evaluate to four decimal places.

$$58. \log_6 72,348 \qquad 59. \log_4 0.863$$

In Exercises 60–63, determine whether each equation is true or false. Where possible, show work to support your conclusion. If the statement is false, make the necessary change(s) to produce a true statement.

$$60. (\ln x)(\ln 1) = 0$$

$$61. \log(x + 9) - \log(x + 1) = \frac{\log(x + 9)}{\log(x + 1)}$$

$$62. (\log_2 x)^4 = 4 \log_2 x \qquad 63. \ln e^x = x \ln e$$

3.4

In Exercises 64–73, solve each exponential equation. Where necessary, express the solution set in terms of natural or common logarithms and use a calculator to obtain a decimal approximation, correct to two decimal places, for the solution.

$$64. 2^{4x-2} = 64 \qquad 65. 125^x = 25$$

$$66. 10^x = 7000 \qquad 67. 9^{x+2} = 27^{-x}$$

$$68. 8^x = 12,143 \qquad 69. 9e^{5x} = 1269$$

$$70. e^{12-5x} - 7 = 123 \qquad 71. 5^{4x+2} = 37,500$$

$$72. 3^{x+4} = 7^{2x-1} \qquad 73. e^{2x} - e^x - 6 = 0$$

In Exercises 74–79, solve each logarithmic equation.

$$74. \log_4(3x - 5) = 3$$

$$75. 3 + 4 \ln(2x) = 15$$

$$76. \log_2(x + 3) + \log_2(x - 3) = 4$$

$$77. \log_3(x - 1) - \log_3(x + 2) = 2$$

$$78. \ln(x + 4) - \ln(x + 1) = \ln x$$

$$79. \log_4(2x + 1) = \log_4(x - 3) + \log_4(x + 5)$$

80. The function $P(x) = 14.7e^{-0.21x}$ models the average atmospheric pressure, $P(x)$, in pounds per square inch, at an altitude of x miles above sea level. The atmospheric pressure at the peak of Mt. Everest, the world's highest mountain, is 4.6 pounds per square inch. How many miles above sea level, to the nearest tenth of a mile, is the peak of Mt. Everest?

81. The amount of carbon dioxide in the atmosphere, measured in parts per million, has been increasing as a result of the burning of oil and coal. The buildup of gases and particles traps heat and raises the planet's temperature, a phenomenon called the greenhouse effect. Carbon dioxide accounts for about half of the warming. The function $f(t) = 364(1.005)^t$ projects carbon dioxide concentration, $f(t)$, in parts per million, t years after 2000. Using the projections given by the function, when will the carbon dioxide concentration be double the preindustrial level of 280 parts per million?

82. The function $W(x) = 0.37 \ln x + 0.05$ models the average walking speed, $W(x)$, in feet per second, of residents in a city whose population is x thousand. Visitors to New York City frequently feel they are moving too slowly to keep pace with New Yorkers' average walking speed of 3.38 feet per second. What is the population of New York City? Round to the nearest thousand.

83. Use the formula for compound interest with n compoundings per year to solve this problem. How long, to the nearest tenth of a year, will it take \$12,500 to grow to \$20,000 at 6.5% annual interest compounded quarterly?

Use the formula for continuous compounding to solve Exercises 84–85.

84. How long, to the nearest tenth of a year, will it take \$50,000 to triple in value at 7.5% annual interest compounded continuously?

85. What interest rate, to the nearest percent, is required for an investment subject to continuous compounding to triple in 5 years?

3.5

86. According to the U.S. Bureau of the Census, in 1990 there were 22.4 million residents of Hispanic origin living in the United States. By 2000, the number had increased to 35.3 million. The exponential growth function $A = 22.4e^{kt}$ describes the U.S. Hispanic population, A , in millions, t years after 1990.
- Find k , correct to three decimal places.
 - Use the resulting model to project the Hispanic resident population in 2010.
 - In which year will the Hispanic resident population reach 60 million?

87. Use the exponential decay model, $A = A_0e^{kt}$, to solve this exercise. The half-life of polonium-210 is 140 days. How long will it take for a sample of this substance to decay to 20% of its original amount?

88. The function

$$f(t) = \frac{500,000}{1 + 2499e^{-0.92t}}$$

models the number of people, $f(t)$, in a city who have become ill with influenza t weeks after its initial outbreak.

- How many people became ill with the flu when the epidemic began?
 - How many people were ill by the end of the sixth week?
 - What is the limiting size of $f(t)$, the population that becomes ill?
89. Use Newton's Law of Cooling, $T = C + (T_0 - C)e^{kt}$, to solve this exercise. You are served a cup of coffee that has a temperature of 185°F. The room temperature is 65°F. After 2 minutes, the temperature of the coffee is 155°F.
- Write a model for the temperature of the coffee, T , after t minutes.
 - When will the temperature of the coffee be 105°F?

Exercises 90–91 present data in the form of tables. For each data set shown by the table,

- Create a scatter plot for the data.
- Use the scatter plot to determine whether an exponential function or a logarithmic function is the better choice for modeling the data.

90. Growth of the Human Brain

Age	Percentage of Adult Size Brain
1	30%
2	50%
4	78%
6	88%
8	92%
10	95%
11	99%

Source: Gerrig and Zimbardo, *Psychology and Life*, Eighteenth Edition, Allyn and Bacon, 2008

91. Text Messaging in the U.S.

Year	Monthly Text Messages (billions)
2002	0.9
2003	1.0
2004	2.1
2005	8.3
2006	14.2
2007	28.9

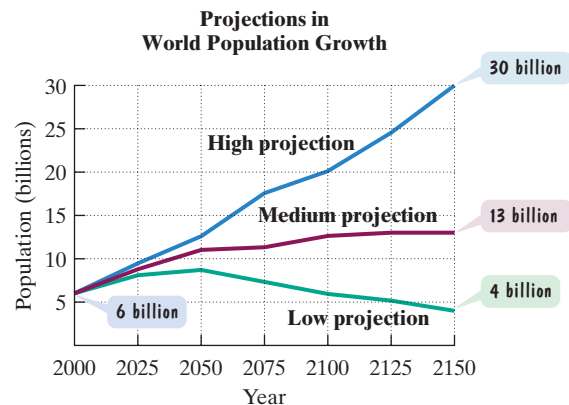
Source: CTIA

In Exercises 92–93, rewrite the equation in terms of base e . Express the answer in terms of a natural logarithm and then round to three decimal places.

92. $y = 73(2.6)^x$

93. $y = 6.5(0.43)^x$

94. The figure shows world population projections through the year 2150. The data are from the United Nations Family Planning Program and are based on optimistic or pessimistic expectations for successful control of human population growth. Suppose that you are interested in modeling these data using exponential, logarithmic, linear, and quadratic functions. Which function would you use to model each of the projections? Explain your choices. For the choice corresponding to a quadratic model, would your formula involve one with a positive or negative leading coefficient? Explain.



Source: U.N.


CHAPTER
Test Prep
VIDEOS
Chapter 3 Test

- Graph $f(x) = 2^x$ and $g(x) = 2^{x+1}$ in the same rectangular coordinate system.
- Graph $f(x) = \log_2 x$ and $g(x) = \log_2(x - 1)$ in the same rectangular coordinate system.
- Write in exponential form: $\log_5 125 = 3$.
- Write in logarithmic form: $\sqrt{36} = 6$.
- Find the domain: $f(x) = \ln(3 - x)$.

In Exercises 6–7, use properties of logarithms to expand each logarithmic expression as much as possible. Where possible, evaluate logarithmic expressions without using a calculator.

$$6. \log_4(64x^5) \qquad 7. \log_3\left(\frac{\sqrt[3]{x}}{81}\right)$$

In Exercises 8–9, write each expression as a single logarithm.

- $6 \log x + 2 \log y$
- $\ln 7 - 3 \ln x$
- Use a calculator to evaluate $\log_{15} 71$ to four decimal places.

In Exercises 11–18, solve each equation.

- $3^{x-2} = 9^{x+4}$
- $5^x = 1.4$
- $400e^{0.005x} = 1600$
- $e^{2x} - 6e^x + 5 = 0$
- $\log_6(4x - 1) = 3$
- $2 \ln(3x) = 8$
- $\log x + \log(x + 15) = 2$
- $\ln(x - 4) - \ln(x + 1) = \ln 6$
- On the decibel scale, the loudness of a sound, D , in decibels, is given by $D = 10 \log \frac{I}{I_0}$, where I is the intensity of the sound, in watts per meter², and I_0 is the intensity of a sound barely audible to the human ear. If the intensity of a sound is $10^{12}I_0$, what is its loudness in decibels? (Such a sound is potentially damaging to the ear.)

In Exercises 20–22, simplify each expression.

- $\ln e^{5x}$
- $\log_b b$
- $\log_6 1$

Use the compound interest formulas to solve Exercises 23–25.

- Suppose you have \$3000 to invest. Which investment yields the greater return over 10 years: 6.5% compounded semiannually or 6% compounded continuously? How much more (to the nearest dollar) is yielded by the better investment?
- How long, to the nearest tenth of a year, will it take \$4000 to grow to \$8000 at 5% annual interest compounded quarterly?
- What interest rate, to the nearest tenth of a percent, is required for an investment subject to continuous compounding to double in 10 years?

- The function

$$A = 82.4e^{-0.002t}$$

models the population of Germany, A , in millions, t years after 2006.

- What was the population of Germany in 2006?
 - Is the population of Germany increasing or decreasing? Explain.
 - In which year will the population of Germany be 81.5 million?
- The 1990 population of Europe was 509 million; in 2000, it was 729 million. Write the exponential growth function that describes the population of Europe, in millions, t years after 1990.
 - Use the exponential decay model, $A = A_0e^{kt}$, to solve this exercise. The half-life of iodine-131 is 7.2 days. How long will it take for a sample of this substance to decay to 30% of its original amount? Round to one decimal place.
 - The logistic growth function

$$f(t) = \frac{140}{1 + 9e^{-0.165t}}$$

describes the population, $f(t)$, of an endangered species of elk t years after they were introduced to a nonthreatening habitat.

- How many elk were initially introduced to the habitat?
- How many elk are expected in the habitat after 10 years?
- What is the limiting size of the elk population that the habitat will sustain?

In Exercises 30–33, determine whether the values in each table belong to an exponential function, a logarithmic function, a linear function, or a quadratic function.

30.

x	y
0	3
1	1
2	-1
3	-3
4	-5

31.

x	y
$\frac{1}{3}$	-1
1	0
3	1
9	2
27	3

32.

x	y
0	1
1	5
2	25
3	125
4	625

33.

x	y
0	12
1	3
2	0
3	3
4	12

- Rewrite $y = 96(0.38)^x$ in terms of base e . Express the answer in terms of a natural logarithm and then round to three decimal places.

Cumulative Review Exercises (Chapters P–3)

In Exercises 1–8, solve each equation or inequality.

1. $|3x - 4| = 2$
2. $x^2 + 2x + 5 = 0$
3. $x^4 + x^3 - 3x^2 - x + 2 = 0$
4. $e^{5x} - 32 = 96$
5. $\log_2(x + 5) + \log_2(x - 1) = 4$
6. $\ln(x + 4) + \ln(x + 1) = 2 \ln(x + 3)$
7. $14 - 5x \geq -6$
8. $|2x - 4| \leq 2$

In Exercises 9–14, graph each equation in a rectangular coordinate system. If two functions are indicated, graph both in the same system.

9. $(x - 3)^2 + (y + 2)^2 = 4$
10. $f(x) = (x - 2)^2 - 1$
11. $f(x) = \frac{x^2 - 1}{x^2 - 4}$
12. $f(x) = (x - 2)^2(x + 1)$
13. $f(x) = 2x - 4$ and $f^{-1}(x)$
14. $f(x) = \ln x$ and $g(x) = \ln(x - 2) + 1$

15. Write the point-slope form and the slope-intercept form of the line passing through $(1, 3)$ and $(3, -3)$.
16. If $f(x) = x^2$ and $g(x) = x + 2$, find $(f \circ g)(x)$ and $(g \circ f)(x)$.
17. You discover that the number of hours you sleep each night varies inversely as the square of the number of cups of coffee consumed during the early evening. If 2 cups of coffee are consumed, you get 8 hours of sleep. If the number of cups of coffee is doubled, how many hours should you expect to sleep?

A baseball player hits a pop fly into the air. The function

$$s(t) = -16t^2 + 64t + 5$$

models the ball's height above the ground, $s(t)$, in feet, t seconds after it is hit. Use the function to solve Exercises 18–19.

18. When does the baseball reach its maximum height? What is that height?
19. After how many seconds does the baseball hit the ground? Round to the nearest tenth of a second.
20. You are paid time-and-a-half for each hour worked over 40 hours a week. Last week you worked 50 hours and earned \$660. What is your normal hourly salary?