$$= \frac{3 + 12\sqrt{5} + 2\sqrt{5} + 8 \cdot 5}{1 - 16 \cdot 5} \quad \text{• Simplify.}$$

$$= \frac{43 + 14\sqrt{5}}{-79}$$

$$= -\frac{43 + 14\sqrt{5}}{79}$$

b. $\dfrac{2 + 4\sqrt{x}}{3 - 5\sqrt{x}} = \dfrac{2 + 4\sqrt{x}}{3 - 5\sqrt{x}} \cdot \dfrac{3 + 5\sqrt{x}}{3 + 5\sqrt{x}}$ • Multiply numerator and denominator by the conjugate of the denominator.

$$= \frac{2(3 + 5\sqrt{x}) + 4\sqrt{x}(3 + 5\sqrt{x})}{3^2 - (5\sqrt{x})^2}$$

$$= \frac{6 + 10\sqrt{x} + 12\sqrt{x} + 20x}{9 - 25x}$$

$$= \frac{6 + 22\sqrt{x} + 20x}{9 - 25x}$$

Try Exercise 116, page 29

EXERCISE SET P.2

Concept Check

In Exercises 1 to 8, evaluate each expression.

1. -5^3 -125
2. $(-5)^3$ -125
3. $\left(\frac{2}{3}\right)^0$ 1
4. -6^0 -1
5. 4^{-2} $\frac{1}{16}$
6. 3^{-4} $\frac{1}{81}$
7. $\frac{1}{2^{-5}}$ 32
8. $\frac{1}{3^{-3}}$ 27

In Exercises 9 to 12, write the number in scientific notation.

9. 2,011,000,000,000 2.011×10^{12}
10. 49,100,000,000 4.91×10^{10}
11. 0.000000000562 5.62×10^{-10}
12. 0.000000402 4.02×10^{-7}

In Exercises 13 to 16, change the number from scientific notation to decimal notation.

13. 3.14×10^7 31,400,000
14. 4.03×10^9 4,030,000,000
15. -2.3×10^{-6} -0.0000023
16. 6.14×10^{-8} 0.0000000614

In Exercises 17 to 22, evaluate each exponential expression.

17. $4^{3/2}$ 8
18. $-16^{3/2}$ -64
19. $-64^{2/3}$ -16
20. $125^{4/3}$ 625
21. $9^{-3/2}$ $\frac{1}{27}$
22. $32^{-4/5}$ $\frac{1}{16}$

In Exercises 23 to 52, write the exponential expression in simplest form.

23. $\frac{2^{-3}}{6^{-3}}$ 27
24. $\frac{4^{-2}}{2^{-3}}$ $\frac{1}{2}$
25. $-2x^0$ -2
26. $\frac{x^0}{4}$ $\frac{1}{4}$
27. $2x^{-4}$ $\frac{2}{x^4}$
28. $3y^{-2}$ $\frac{3}{y^2}$
29. $\frac{5}{z^{-6}}$ $5z^6$
30. $\frac{8}{x^{-5}}$ $8x^5$
31. $(x^3y^2)(xy^5)$ x^4y^7
32. $(uv^6)(u^2v)$ u^3v^7
33. $(-2ab^4)(-3a^2b^5)$ $6a^3b^9$
34. $(9xy^2)(-2x^2y^5)$ $-18x^3y^7$
35. $(-4x^{-3}y)(7x^5y^{-2})$ $-\frac{28x^2}{y}$
36. $(-6x^4y)(7x^{-3}y^{-5})$ $-\frac{42x}{y^4}$
37. $\frac{6a^4}{8a^8}$ $\frac{3}{4a^4}$
38. $\frac{12x^3}{16x^4}$ $\frac{3}{4x}$
39. $\frac{12x^3y^4}{18x^5y^2}$ $\frac{2y^2}{3x^2}$
40. $\frac{5v^4w^{-3}}{10v^8}$ $\frac{1}{2v^4w^3}$
41. $\frac{36a^{-2}b^3}{3ab^4}$ $\frac{12}{a^3b}$
42. $\frac{-48ab^{10}}{-32a^4b^3}$ $\frac{3b^7}{2a^3}$
43. $(-2m^3n^2)(-3mn^2)^2$ $-18m^5n^6$
44. $(2a^3b^2)^3(-4a^4b^2)$ $-32a^{13}b^8$

Indicates Try It Exercises

45. $(x^{-2}y)^2(xy)^{-2}$ $\frac{1}{x^6}$

46. $(x^{-1}y^2)^{-3}(x^2y^{-4})^{-3}$ $\frac{y^6}{x^3}$

47. $\left(\frac{3a^2b^3}{6a^4b^4}\right)^2$ $\frac{1}{4a^4b^2}$

48. $\left(\frac{2ab^2c^3}{5ab^2}\right)^3$ $\frac{8c^9}{125}$

49. $\frac{(-4x^2y^3)^2}{(2xy^2)^3}$ $2x$

50. $\frac{(-3a^2b^3)^2}{(-2ab^4)^3}$ $-\frac{9a}{8b^6}$

51. $\left(\frac{a^{-2}b}{a^3b^{-4}}\right)^2$ $\frac{b^{10}}{a^{10}}$

52. $\left(\frac{x^{-3}y^{-4}}{x^{-2}y}\right)^{-2}$ x^2y^{10}

In Exercises 53 to 60, perform the indicated operation and write the answer in scientific notation.

53. $(3 \times 10^{12})(9 \times 10^{-5})$ 2.7×10^8

54. $(8.9 \times 10^{-5})(3.4 \times 10^{-6})$ 3.026×10^{-10}

55. $\frac{9 \times 10^{-3}}{6 \times 10^8}$ 1.5×10^{-11}

56. $\frac{2.5 \times 10^8}{5 \times 10^{10}}$ 5×10^{-3}

57. $\frac{(3.2 \times 10^{-11})(2.7 \times 10^{18})}{1.2 \times 10^{-5}}$ 7.2×10^{12}

58. $\frac{(6.9 \times 10^{27})(8.2 \times 10^{-13})}{4.1 \times 10^{15}}$ 1.38×10^0

59. $\frac{(4.0 \times 10^{-9})(8.4 \times 10^5)}{(3.0 \times 10^{-6})(1.4 \times 10^{18})}$ 8×10^{-16}

60. $\frac{(7.2 \times 10^8)(3.9 \times 10^{-7})}{(2.6 \times 10^{-10})(1.8 \times 10^{-8})}$ 6×10^{19}

In Exercises 61 to 76, evaluate each exponential expression.

61. $\left(\frac{4}{9}\right)^{1/2}$ $\frac{2}{3}$

62. $\left(\frac{16}{25}\right)^{3/2}$ $\frac{64}{125}$

63. $\left(\frac{1}{8}\right)^{-4/3}$ 16

64. $\left(\frac{8}{27}\right)^{-2/3}$ $\frac{9}{4}$

65. $(4a^{2/3}b^{1/2})(2a^{1/3}b^{3/2})$ $8ab^2$

66. $(6a^{3/5}b^{1/4})(-3a^{1/5}b^{3/4})$ $-18a^{4/5}b$

67. $(-3x^{2/3})(4x^{1/4})$ $-12x^{11/12}$

68. $(-5x^{1/3})(-4x^{1/2})$ $20x^{5/6}$

69. $(81x^8y^{12})^{1/4}$ $3x^2y^3$

70. $(27x^3y^6)^{2/3}$ $9x^2y^4$

71. $\frac{16z^{3/5}}{12z^{1/5}}$ $\frac{4z^{2/5}}{3}$

72. $\frac{6a^{2/3}}{9a^{1/3}}$ $\frac{2a^{1/3}}{3}$

73. $(2x^{2/3}y^{1/2})(3x^{1/6}y^{1/3})$ $6x^{5/6}y^{5/6}$

74. $\frac{x^{1/3}y^{5/6}}{x^{2/3}y^{1/6}}$ $\frac{y^{2/3}}{x^{1/3}}$

75. $\frac{9a^{3/4}b}{3a^{2/3}b^2}$ $\frac{3a^{1/12}}{b}$

76. $\frac{12x^{1/6}y^{1/4}}{16x^{3/4}y^{1/2}}$ $\frac{3}{4x^{7/12}y^{1/4}}$

In Exercises 77 to 86, simplify each radical expression.

77. $\sqrt{45}$ $3\sqrt{5}$

78. $\sqrt{75}$ $5\sqrt{3}$

79. $\sqrt[3]{24}$ $2\sqrt[3]{3}$

80. $\sqrt[3]{135}$ $3\sqrt[3]{5}$

81. $\sqrt[3]{-135}$ $-3\sqrt[3]{5}$

82. $\sqrt[3]{-250}$ $-5\sqrt[3]{2}$

83. $\sqrt{24x^2y^3}$ $2|x|y\sqrt{6y}$

84. $\sqrt{18x^2y^5}$ $3|x|y^2\sqrt{2y}$

85. $\sqrt[3]{16a^3y^7}$ $2ay^2\sqrt[3]{2y}$

86. $\sqrt[3]{54m^2n^7}$ $3n^2\sqrt[3]{2m^2n}$

In Exercises 87 to 94, simplify each radical and then combine like radicals.

87. $2\sqrt{32} - 3\sqrt{98}$ $-13\sqrt{2}$

88. $5\sqrt[3]{32} + 2\sqrt[3]{108}$ $16\sqrt[3]{4}$

89. $-8\sqrt[4]{48} + 2\sqrt[4]{243}$ $-10\sqrt[4]{3}$

90. $2\sqrt[3]{40} - 3\sqrt[3]{135}$ $-5\sqrt[3]{5}$

91. $4\sqrt[3]{32y^4} + 3y\sqrt[3]{108y}$ $17y\sqrt[3]{4y}$

92. $-3x\sqrt[3]{54x^4} + 2\sqrt[3]{16x^7}$ $-5x^2\sqrt[3]{2x}$

93. $x\sqrt[3]{8x^3y^4} - 4y\sqrt[3]{64x^6y}$ $-14x^2y\sqrt[3]{y}$

94. $4\sqrt{a^5b} - a^2\sqrt{ab}$ $3a^2\sqrt{ab}$

In Exercises 95 to 104, find the indicated product and express each result in simplest form.

95. $(\sqrt{5} + 3)(\sqrt{5} + 4)$ $17 + 7\sqrt{5}$

96. $(\sqrt{7} + 2)(\sqrt{7} - 5)$ $-3 - 3\sqrt{7}$

97. $(\sqrt{2} - 3)(\sqrt{2} + 3)$ -7

98. $(2\sqrt{7} + 3)(2\sqrt{7} - 3)$ 19

99. $(3\sqrt{z} - 2)(4\sqrt{z} + 3)$ $12z + \sqrt{z} - 6$

100. $(4\sqrt{a} - \sqrt{b})(3\sqrt{a} + 2\sqrt{b})$ $12a + 5\sqrt{ab} - 2b$

101. $(\sqrt{x} + 2)^2$ $x + 4\sqrt{x} + 4$

102. $(3\sqrt{5y} - 4)^2$ $45y - 24\sqrt{5y} + 16$

103. $(\sqrt{x - 3} + 2)^2$ $x + 4\sqrt{x - 3} + 1$

104. $(\sqrt{2x + 1} - 3)^2$ $2x - 6\sqrt{2x + 1} + 10$

In Exercises 105 to 126, simplify each expression by rationalizing the denominator. Write the result in simplest form. Assume $x > 0$ and $y > 0$.

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

106. $\frac{3x}{\sqrt{3}}$ $x\sqrt{3}$

107. $\sqrt{\frac{5}{18}}$ $\frac{\sqrt{10}}{6}$

108. $\sqrt{\frac{7}{40}}$ $\frac{\sqrt{70}}{20}$

109. $\frac{3}{\sqrt[3]{2}}$ $\frac{3\sqrt[3]{4}}{2}$

110. $\frac{2}{\sqrt[3]{4}}$ $\sqrt[3]{2}$

111. $\frac{4}{\sqrt[3]{8x^2}}$ $\frac{2\sqrt[3]{x}}{x}$

112. $\frac{2}{\sqrt[4]{4y}}$ $\frac{\sqrt[4]{4y^3}}{y}$

113. $\frac{3}{\sqrt{3} + 4}$ $\frac{3\sqrt{3} - 12}{13}$

114. $\frac{2}{\sqrt{5} - 2}$ $2\sqrt{5} + 4$

115. $\frac{6}{2\sqrt{5} + 2}$ $\frac{3\sqrt{5} - 3}{4}$

116. $\frac{-7}{3\sqrt{2} - 5}$ $3\sqrt{2} + 5$

117. $\dfrac{3+2\sqrt{5}}{5-3\sqrt{5}}$ $\dfrac{45+19\sqrt{5}}{20}$ **118.** $\dfrac{6-3\sqrt{2}}{5-\sqrt{2}}$ $\dfrac{24-9\sqrt{2}}{23}$

119. $\dfrac{6\sqrt{3}-11}{4\sqrt{3}-7}$ $5+2\sqrt{3}$ **120.** $\dfrac{2\sqrt{7}+8}{12\sqrt{7}-6}$ $\dfrac{2+\sqrt{7}}{9}$

121. $\dfrac{2+\sqrt{x}}{3-2\sqrt{x}}$ $\dfrac{6+7\sqrt{x}+2x}{9-4x}$ **122.** $\dfrac{4-2\sqrt{x}}{5+3\sqrt{x}}$ $\dfrac{20-22\sqrt{x}+6x}{25-9x}$

123. $\dfrac{x-\sqrt{5}}{x+2\sqrt{5}}$ $\dfrac{x^2-3x\sqrt{5}+10}{x^2-20}$ **124.** $\dfrac{x+3\sqrt{7}}{x+2\sqrt{7}}$ $\dfrac{x^2+\sqrt{7}x-42}{x^2-28}$

125. $\dfrac{3}{\sqrt{5}+\sqrt{x}}$ $\dfrac{3\sqrt{5}-3\sqrt{x}}{5-x}$ **126.** $\dfrac{5}{\sqrt{y}-\sqrt{3}}$ $\dfrac{5\sqrt{y}+5\sqrt{3}}{y-3}$

127. **Weight of an Orchid Seed** An orchid seed weighs approximately 3.2×10^{-8} ounce. If a package of seeds contains 1 ounce of orchid seeds, how many seeds are in the package? $\approx 3.13 \times 10^{7}$ seeds

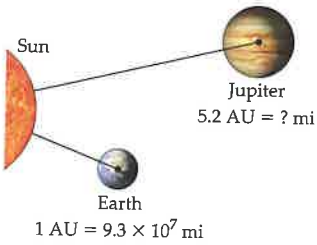
128. **Biology** The weight of one *E. coli* bacterium is approximately 670 femtograms, where 1 femtogram $= 1 \times 10^{-15}$ gram. If one *E. coli* bacterium can divide into two bacteria every 20 minutes, then after 24 hours there would be (assuming all bacteria survived) approximately 4.7×10^{21} bacteria. What is the weight, in grams, of these bacteria? 3.149×10^{9} g

129. **Doppler Effect** Astronomers can approximate the distance to a galaxy by measuring its *red shift*, which is a shift in the wavelength of light due to the velocity of the galaxy. This is similar to the way the sound of a siren coming toward you seems to have a higher pitch than the sound of the siren moving away from you. A formula for red shift is $\dfrac{\lambda_r - \lambda_s}{\lambda_s}$, where λ_r and λ_s are wavelengths of a certain frequency of light. Calculate the red shift for a galaxy for which $\lambda_r = 5.13 \times 10^{-7}$ meter and $\lambda_s = 5.06 \times 10^{-7}$ meter. $\approx 1.38 \times 10^{-2}$

130. **Laser Wavelength** The wavelength of a certain helium-neon laser is 800 nanometers. (1 nanometer is 1×10^{-9} meter.) The frequency, in cycles per second, of this wave is $\dfrac{1}{\text{wavelength}}$. What is the frequency of this laser? 1.25×10^{6} cycles per second

131. **Astronomy** The Sun is approximately 1.44×10^{11} meters from Earth. If light travels 3×10^{8} meters per second, how many minutes does it take light from the sun to reach Earth? 8 min

132. **Astronomical Unit** Earth's mean distance from the Sun is 9.3×10^{7} miles. This distance is called the *astronomical unit* (AU). Jupiter is 5.2 AU from the Sun. Find the distance in miles from Jupiter to the Sun. $\approx 4.84 \times 10^{8}$ mi



133. **Medicine** *Body surface area* (BSA) is a measure of the surface area of an adult human. A calculation of this number is important in prescribing medications for patients. One formula given by E. A. Gehan and S. L. George is $\text{BSA} = 0.0235h^{0.3964} \cdot w^{0.51456}$, where BSA is measured in meter^2, h is the height of a person in centimeters, and w is the weight of a person in kilograms. Find the BSA of a person who is 178 cm tall and weighs 73 kg. Round to the nearest hundredth. $1.67\ \text{m}^2$

134. **Drug Potency** The amount A (in milligrams) of digoxin, a drug taken by cardiac patients, remaining in the blood t hours after a patient takes a 2-milligram dose is given by $A = 2(10^{-0.0078t})$.

a. How much digoxin remains in the blood of a patient 4 hours after taking a 2-milligram dose? ≈ 1.86 mg

b. Suppose that a patient takes a 2-milligram dose of digoxin at 1:00 P.M. and another 2-milligram dose at 5:00 P.M. How much digoxin remains in the patient's blood at 6:00 P.M.? ≈ 3.79 mg

135. **Oceanography** The percent P of light that will pass to a depth d, in meters, at a certain place in the ocean is given by $P = 10^{2-(d/40)}$. Find, to the nearest percent, the amount of light that will pass to a depth of **a.** 10 meters and **b.** 25 meters below the surface of the ocean. **a.** 56% **b.** 24%

136. **Learning Theory** In a psychology experiment, students were given a nine-digit number to memorize. The percent P of students who remembered the number t minutes after it was read to them can be given by $P = 90 - 3t^{2/3}$. What percent of the students remembered the number after 1 hour? $\approx 44.02\%$

Enrichment Exercises

In Exercises 137 to 140, rationalize the numerator, a technique that is occasionally used in calculus. For Exercises 137 and 138, begin by writing the expression with a 1 in the denominator.

137. $\sqrt{n^2+4} - n$ $\dfrac{4}{\sqrt{n^2+4}+n}$ **138.** $\sqrt{n^2+3n} - n$ $\dfrac{3n}{\sqrt{n^2+3n}+n}$

139. $\dfrac{\sqrt{4+h}-2}{h}$ $\dfrac{1}{\sqrt{4+h}+2}$ **140.** $\dfrac{\sqrt{9+h}-3}{h}$ $\dfrac{1}{\sqrt{9+h}+3}$