SKILLS

9–16 ■ Radicals and Exponents Write each radical expression using exponents, and each exponential expression using radicals.

	Radical expression	Exponential expression
9.	$\dfrac{1}{\sqrt{3}}$	
10.	$\sqrt[3]{7^2}$	
11.		$4^{2/3}$
12.		$10^{-3/2}$
13.	$\sqrt[5]{5^3}$	
14.		$2^{-1.5}$
15.		$a^{2/5}$
16.	$\dfrac{1}{\sqrt{x^5}}$	

17–28 ■ Radicals and Exponents Evaluate each expression.

17. (a) -2^6 (b) $(-2)^6$ (c) $\left(\frac{1}{5}\right)^2 \cdot (-3)^3$

18. (a) $(-5)^3$ (b) -5^3 (c) $(-5)^2 \cdot \left(\frac{2}{5}\right)^2$

19. (a) $\left(\frac{5}{3}\right)^0 \cdot 2^{-1}$ (b) $\dfrac{2^{-3}}{3^0}$ (c) $\left(\frac{2}{3}\right)^{-2}$

20. (a) $-2^3 \cdot (-2)^0$ (b) $-2^{-3} \cdot (-2)^0$ (c) $\left(\frac{-3}{5}\right)^{-3}$

21. (a) $5^3 \cdot 5$ (b) $5^4 \cdot 5^{-2}$ (c) $(2^2)^3$

22. (a) $3^8 \cdot 3^5$ (b) $\dfrac{10^7}{10^4}$ (c) $(3^5)^4$

23. (a) $3\sqrt[3]{16}$ (b) $\dfrac{\sqrt{18}}{\sqrt{81}}$ (c) $\sqrt{\frac{27}{4}}$

24. (a) $2\sqrt[3]{81}$ (b) $\dfrac{\sqrt{18}}{\sqrt{25}}$ (c) $\sqrt{\frac{12}{49}}$

25. (a) $\sqrt{3}\sqrt{15}$ (b) $\dfrac{\sqrt{48}}{\sqrt{3}}$ (c) $\sqrt[3]{24}\sqrt[3]{18}$

26. (a) $\sqrt{10}\sqrt{32}$ (b) $\dfrac{\sqrt{54}}{\sqrt{6}}$ (c) $\sqrt[3]{15}\sqrt[3]{75}$

27. (a) $\dfrac{\sqrt{132}}{\sqrt{3}}$ (b) $\sqrt[3]{2}\sqrt[3]{32}$ (c) $\sqrt[4]{\frac{1}{4}}\sqrt[4]{\frac{1}{64}}$

28. (a) $\sqrt[5]{\frac{1}{8}}\sqrt[5]{\frac{1}{4}}$ (b) $\sqrt[6]{\frac{1}{2}}\sqrt[6]{128}$ (c) $\dfrac{\sqrt[3]{4}}{\sqrt[3]{108}}$

29–34 ■ Exponents Simplify each expression, and eliminate any negative exponents.

29. (a) $x^3 \cdot x^4$ (b) $(2y^2)^3$ (c) $y^{-2}y^7$

30. (a) $y^5 \cdot y^2$ (b) $(8x)^2$ (c) $x^4 x^{-3}$

31. (a) $x^{-5} \cdot x^3$ (b) $w^{-2}w^{-4}w^5$ (c) $\dfrac{x^{16}}{x^{10}}$

32. (a) $y^2 \cdot y^{-5}$ (b) $z^5 z^{-3} z^{-4}$ (c) $\dfrac{y^7 y^0}{y^{10}}$

33. (a) $\dfrac{a^9 a^{-2}}{a}$ (b) $(a^2 a^4)^3$ (c) $\left(\dfrac{x}{2}\right)^3 (5x^6)$

34. (a) $\dfrac{z^2 z^4}{z^{-1} z^{-1}}$ (b) $(2a^1 a^2)^4$ (c) $(-3z^2)^3(2z^3)$

35–44 ■ Exponents Simplify each expression, and eliminate any negative exponents.

35. (a) $(3x^3y^2)(2y^1)$ (b) $(5w^2z^{-2})^2(z^3)$

36. (a) $(8m^{-2}n^4)(\frac{1}{2}n^{-2})$ (b) $(3a^4b^{-2})^3(a^2b^{-1})$

37. (a) $\dfrac{x^2y^{-1}}{x^{-5}}$ (b) $\left(\dfrac{a^3}{2b^2}\right)^3$

38. (a) $\dfrac{y^{-2}z^{-3}}{y^{-1}}$ (b) $\left(\dfrac{x^3y^{-2}}{x^{-3}y^2}\right)^{-2}$

39. (a) $\left(\dfrac{a^2}{b}\right)^5\left(\dfrac{a^3b^2}{c^3}\right)^3$ (b) $\dfrac{(u^{-1}v^2)^2}{(u^3v^{-2})^3}$

40. (a) $\left(\dfrac{x^4z^{-2}}{4y^5}\right)\left(\dfrac{2x^3y^2}{z^3}\right)^2$ (b) $\dfrac{(rs^2)^3}{(r^{-3}s^2)^2}$

41. (a) $\dfrac{8a^3b^{-4}}{2a^{-5}b^5}$ (b) $\left(\dfrac{y}{5x^{-2}}\right)^{-3}$

42. (a) $\dfrac{5xy^{-2}}{x^{-1}y^{-3}}$ (b) $\left(\dfrac{2a^{-1}b}{a^2b^{-3}}\right)^{-3}$

43. (a) $\left(\dfrac{3a}{b^3}\right)^{-1}$ (b) $\left(\dfrac{q^{-1}r^{-1}s^{-2}}{r^{-5}sq^{-8}}\right)^{-1}$

44. (a) $\left(\dfrac{s^2t^{-4}}{5s^{-1}t}\right)^{-2}$ (b) $\left(\dfrac{xy^{-2}z^{-3}}{x^2y^3z^{-4}}\right)^{-3}$

45–48 ■ Radicals Simplify the expression. Assume that the letters denote any positive real numbers.

45. (a) $\sqrt[4]{x^4}$ (b) $\sqrt[4]{16x^8}$

46. (a) $\sqrt[5]{x^{10}}$ (b) $\sqrt[3]{x^3y^6}$

47. (a) $\sqrt[6]{64a^6b^7}$ (b) $\sqrt[3]{a^2b}\sqrt[3]{64a^4b}$

48. (a) $\sqrt[4]{x^4y^2z^2}$ (b) $\sqrt[3]{\sqrt{64x^6}}$

49–54 ■ Radical Expressions Simplify the expression.

49. (a) $\sqrt{32} + \sqrt{18}$ (b) $\sqrt{75} + \sqrt{48}$

50. (a) $\sqrt{125} + \sqrt{45}$ (b) $\sqrt[3]{54} - \sqrt[3]{16}$

51. (a) $\sqrt{9a^3} + \sqrt{a}$ (b) $\sqrt{16x} + \sqrt{x^5}$

52. (a) $\sqrt[3]{x^4} + \sqrt[3]{8x}$ (b) $4\sqrt{18rt^3} + 5\sqrt{32r^3t^5}$

53. (a) $\sqrt{81x^2 + 81}$ (b) $\sqrt{36x^2 + 36y^2}$

54. (a) $\sqrt{27a^2 + 63a}$ (b) $\sqrt{75t + 100t^2}$

55–60 ■ Rational Exponents Evaluate each expression.

55. (a) $16^{1/4}$ (b) $-8^{1/3}$ (c) $9^{-1/2}$

56. (a) $27^{1/3}$ (b) $(-8)^{1/3}$ (c) $-\left(\frac{1}{8}\right)^{1/3}$

57. (a) $32^{2/5}$ (b) $\left(\frac{4}{9}\right)^{-1/2}$ (c) $\left(\frac{16}{81}\right)^{3/4}$

58. (a) $125^{2/3}$ (b) $\left(\frac{25}{64}\right)^{3/2}$ (c) $27^{-4/3}$

59. (a) $5^{2/3} \cdot 5^{1/3}$ (b) $\dfrac{3^{3/5}}{3^{2/5}}$ (c) $\left(\sqrt[3]{4}\right)^3$

60. (a) $3^{2/7} \cdot 3^{12/7}$ (b) $\dfrac{7^{2/3}}{7^{5/3}}$ (c) $\left(\sqrt[5]{6}\right)^{-10}$

61–70 ■ **Rational Exponents**   Simplify the expression and eliminate any negative exponent(s). Assume that all letters denote positive numbers.

61. (a) $x^{3/4}x^{5/4}$ (b) $y^{2/3}y^{4/3}$

62. (a) $(4b)^{1/2}(8b^{1/4})$ (b) $(3a^{3/4})^2(5a^{1/2})$

63. (a) $\dfrac{w^{4/3}w^{2/3}}{w^{1/3}}$ (b) $\dfrac{a^{5/4}(2a^{3/4})^3}{a^{1/4}}$

64. (a) $(8y^3)^{-2/3}$ (b) $(u^4v^6)^{-1/3}$

65. (a) $(8a^6b^{3/2})^{2/3}$ (b) $(4a^6b^8)^{3/2}$

66. (a) $(x^{-5}y^{1/3})^{-3/5}$ (b) $(4r^8s^{-1/2})^{1/2}(32s^{-5/4})^{-1/5}$

67. (a) $\dfrac{(8s^3t^3)^{2/3}}{(s^4t^{-8})^{1/4}}$ (b) $\dfrac{(32x^5y^{-3/2})^{2/5}}{(x^{5/3}y^{2/3})^{3/5}}$

68. (a) $\left(\dfrac{x^8y^{-4}}{16y^{4/3}}\right)^{-1/4}$ (b) $\left(\dfrac{4s^3t^4}{s^2t^{9/2}}\right)^{-1/2}$

69. (a) $\left(\dfrac{x^{3/2}}{y^{-1/2}}\right)^4\left(\dfrac{x^{-2}}{y^3}\right)$ (b) $\left(\dfrac{4y^3z^{2/3}}{x^{1/2}}\right)^2\left(\dfrac{x^{-3}y^6}{8z^4}\right)^{1/3}$

70. (a) $\left(\dfrac{a^{1/6}b^{-3}}{x^{-1}y}\right)^3\left(\dfrac{x^{-2}b^{-1}}{a^{3/2}y^{1/3}}\right)$ (b) $\dfrac{(9st)^{3/2}}{(27s^3t^{-4})^{2/3}}\left(\dfrac{3s^{-2}}{4t^{1/3}}\right)^{-1}$

71–78 ■ **Radicals**   Simplify the expression, and eliminate any negative exponents(s). Assume that all letters denote positive numbers.

71. (a) $\sqrt{x^3}$ (b) $\sqrt[5]{x^6}$

72. (a) $\sqrt{x^5}$ (b) $\sqrt[4]{x^6}$

73. (a) $\sqrt[6]{y^5}\sqrt[3]{y^2}$ (b) $\left(5\sqrt[3]{x}\right)\left(2\sqrt[4]{x}\right)$

74. (a) $\sqrt[4]{b^3}\sqrt{b}$ (b) $\left(2\sqrt{a}\right)\left(\sqrt[3]{a^2}\right)$

75. (a) $\sqrt{4st^3}\sqrt[6]{s^3t^2}$ (b) $\dfrac{\sqrt[4]{x^7}}{\sqrt[4]{x^3}}$

76. (a) $\sqrt[5]{x^3y^2}\sqrt[10]{x^4y^{16}}$ (b) $\dfrac{\sqrt[3]{8x^2}}{\sqrt{x}}$

77. (a) $\sqrt[3]{y}\sqrt{y}$ (b) $\sqrt{\dfrac{16u^3v}{uv^5}}$

78. (a) $\sqrt{s}\sqrt{s^3}$ (b) $\sqrt[3]{\dfrac{54x^2y^4}{2x^5y}}$

79–82 ■ **Rationalize**   Put each fractional expression into standard form by rationalizing the denominator.

79. (a) $\dfrac{1}{\sqrt{6}}$ (b) $\sqrt{\dfrac{3}{2}}$ (c) $\dfrac{9}{\sqrt[4]{2}}$

80. (a) $\dfrac{12}{\sqrt{3}}$ (b) $\sqrt{\dfrac{12}{5}}$ (c) $\dfrac{8}{\sqrt[3]{5^2}}$

81. (a) $\dfrac{1}{\sqrt{5x}}$ (b) $\sqrt{\dfrac{x}{5}}$ (c) $\sqrt[5]{\dfrac{1}{x^3}}$

82. (a) $\sqrt{\dfrac{s}{3t}}$ (b) $\dfrac{a}{\sqrt[6]{b^2}}$ (c) $\dfrac{1}{c^{3/5}}$

83–84 ■ **Scientific Notation**   Write each number in scientific notation.

83. (a) 69,300,000   (b) 7,200,000,000,000
    (c) 0.000028536   (d) 0.0001213

84. (a) 129,540,000   (b) 7,259,000,000
    (c) 0.0000000014   (d) 0.0007029

85–86 ■ **Decimal Notation**   Write each number in decimal notation.

85. (a) 3.19×10^5 (b) 2.721×10^8
    (c) 2.670×10^{-8} (d) 9.999×10^{-9}

86. (a) 7.1×10^{14} (b) 6×10^{12}
    (c) 8.55×10^{-3} (d) 6.257×10^{-10}

87–88 ■ **Scientific Notation**   Write the number indicated in each statement in scientific notation.

87. (a) A light-year, the distance that light travels in one year, is about 5,900,000,000,000 mi.
    (b) The diameter of an electron is about 0.0000000000004 cm.
    (c) A drop of water contains more than 33 billion billion molecules.

88. (a) The distance from the earth to the sun is about 93 million miles.
    (b) The mass of an oxygen molecule is about 0.000000000000000000000053 g.
    (c) The mass of the earth is about 5,970,000,000,000,000,000,000,000 kg.

89–94 ■ **Scientific Notation**   Use scientific notation, the Laws of Exponents, and a calculator to perform the indicated operations. State your answer rounded to the number of significant digits indicated by the given data.

89. $(7.2 \times 10^{-9})(1.806 \times 10^{-12})$

90. $(1.062 \times 10^{24})(8.61 \times 10^{19})$

91. $\dfrac{1.295643 \times 10^9}{(3.610 \times 10^{-17})(2.511 \times 10^6)}$

92. $\dfrac{(73.1)(1.6341 \times 10^{28})}{0.0000000019}$

93. $\dfrac{(0.0000162)(0.01582)}{(594,621,000)(0.0058)}$

94. $\dfrac{(3.542 \times 10^{-6})^9}{(5.05 \times 10^4)^{12}}$

SKILLS Plus

95. Let a, b, and c be real numbers with $a > 0$, $b < 0$, and $c < 0$. Determine the sign of each expression.

    (a) b^5 (b) b^{10} (c) ab^2c^3

    (d) $(b - a)^3$ (e) $(b - a)^4$ (f) $\dfrac{a^3c^3}{b^6c^6}$

96. Comparing Roots   Without using a calculator, determine which number is larger in each pair.

    (a) $2^{1/2}$ or $2^{1/3}$ (b) $\left(\tfrac{1}{2}\right)^{1/2}$ or $\left(\tfrac{1}{2}\right)^{1/3}$
    (c) $7^{1/4}$ or $4^{1/3}$ (d) $\sqrt[3]{5}$ or $\sqrt{3}$

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