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Subscribe to our ▶ YouTube channel for the latest videos, updates, and tips. Exponent is used to indicate repeated multiplication of the same number.An expression like 54 is called a power. The number 5 is the base and 4 is the exponent.54 = 5 · 5 · 5 · 5The exponent 4, indicates the number of times the base appears as a factor. An exponent is also called a powerIn evaluating the power of 54, we have four factors of 5.54 is read "5 to the fourth power". Laws of Exponents • Product Law :The product of two powers with the same base equals that base raised to the sum of the exponents. If x is any nonzero real number and m and n are integers, thenxm · xn = xm + nExample :34 · 35 = 34 + 5= 39• Quotient Law :The quotient of two non zero powers with the same base equals the base raised to the difference of the exponents.If x is any nonzero real number and m and n are integers, thenxm ÷ xn = xm - nExample :37 ÷ 35 = 37 - 5= 32• Power Law :A power raised to another power equals that base raised to the product of the exponents.If x is any nonzero real number and m and n are integers, then(xm)n = xmnExample :(32)4 = 32(4)= 38Some other laws of exponents : 1. A product raised to a power equals the product of each factor raised to that power. If x and y are any nonzero real numbers and m is any integer, then(xy)m = xm · ymExample :(3 · 5)2 = 32 · 52= 9 · 25= 2252. A quotient raised to a positive power equals the quotient of each base raised to that power.If x and y are any nonzero real numbers and m is a positive integer, then(x/y)m = xm/ymExample :(3/5)2 = 32/523. A quotient raised to a negative power equals the reciprocal of the quotient raised to the opposite (positive) power.If x and y are any nonzero real numbers and m is a positive integer, then(x/y)-m = (y/x)mExample :(5/3)-2 = (3/5)24. If a power is moved from numerator to denominator or denominator to numerator, the sign of the exponent has to be changed.x-m = 1/xmExample :3-2 = 1/325. For any nonzero base, if the exponent is zero, its value is 1.x0 = 1Example :30 = 16. For any base base, if there is no exponent, the exponent is assumed to be 1.x1 = xExample :31 = 37. If an exponent is transferred from one side of the equation to the other side of the equation, reciprocal of the exponent has to be taken. xm/n = y ----> x = yn/mExample :x2/3 = 3x = 33/28. If two powers are equal with the same base, exponents can be equated.ax = ay ----> x = yExample :3m = 35 ----> m = 59. If two powers are equal with the same exponent, bases can be equated.xa = ya ----> x = yExample :k3 = 53 ----> k = 5Note :Many students do not know the difference between(-3)2 and -32Order of operations (PEMDAS) dictates that parentheses take precedence.(-3)2 = (-3) · (-3)(-3)2 = 9Without parentheses, exponents take precedence :-32 = -3 · 3-32 = -9The negative is not applied until the exponent operation is carried through. We have to make sure that we understand this. So, we will not make this common mistake.Sometimes, the result turns out to be the same, as in.(-2)3 and -23We have to make sure why they yield the same result. Solving Problems on Exponents Problem 1 :If 42n + 3 = 8n + 5, then find the value of n.Solution :42n + 3 = 8n + 5(22)2n + 3 = (23)n + 522(2n + 3) = 23(n + 5)Equate the exponents.2(2n + 3) = 3(n + 5)4n + 6 = 3n + 15n = 9Problem 2 :If 2x/2y = 23, then find the value x in terms of y.Solution :2x/2y = 232x - y = 23x - y = 3x = y + 3Problem 3 :If ax = b, by = c and cz = a, then find the value of xyz.Solution :ax = bSubstitute a = cz.(cz)x = bczx = bSubstitute c = by.(by)zx = bbxyz = bbxyz = b1xyz = 1Problem 4 :If k(2x) = 2x+3 - 2x, then solve for k.Solution :Using laws of exponents, we havek(2x) = 2x · 23 - 2xk(2x) = 2x · 8 - 2xk(2x) = 2x(8 - 1)k(2x) = 2x(7)Divide each side by 2x.k = 7 Radicals "Radicals" is a common concept in algebra. In fact, we think of radicals as reversing the operation of an exponent. Hence, instead of the “square” of a number, we “square root” a number; instead of the “cube” of a number, we “cube root” a number to reverse the square to find the base. Square roots are the most common type of radical used in algebra.If 'a' is a positive real number, then the principal square root of a number 'a' is defined as√a = b if and only if a = b2If something is given like 3√a, then 3 is called the root or index; hence, 3√a is called the cube root or third root of 'a'.In general,n√a = b if and only if a = bnIf n is even, then 'a' and 'b' must be greater than or equal to zero. If n is even, then 'a' and 'b' must be any real number.n√a can be written as a1/n.orn√a = a1/n Laws of Radicals Law 1 :n√(ab) = n√an√bLaw 2 :n√(a/b) = n√a/n√bLaw 3 :n√(an) = aLaw 4 :n√(am) = am/nNote :n√a + n√b ≠ n√(a + b)n√a - n√b ≠ n√(a - b) Solving Problems on Radicals Problem 5 :Evaluate :√64 + √196Solution :Because 64 and 196 are perfect squares, we can find the square root of 64 and 194 as shown below. √64 = √(8 · 8)√64 = 8 √196 = √(14 · 14)√196 = 14 √64 + √196 = 8 + 14= 22Problem 6 : (√3)3 + √27Answer :(√3)3 + √27 = (√3 · √3 · √3) + √(3 · 3 · 3)= (3 · √3) + 3√3= 3√3 + 3√3Problem 7 : Solve for x :1/3√x = 2Solution :1/3√x = 21/x1/3 = 2x-1/3 = 2x = 2-3x = 1/23x = 1/8Problem 8 : Simplify :3√(x6y9)Solution := 3√(x6y9)= (x6y9)1/3= (x6)1/3(y9)1/3= x6/3y9/3= x2y3 Subscribe to our ▶ YouTube channel for the latest videos, updates, and tips. Kindly mail your feedback to v4formath@gmail.comWe always appreciate your feedback. ©All rights reserved. onlinemath4all.com By M Bourne √(a + b)10 Exponents are a very important part of algebra. An exponent is just a convenient way of writing repeated multiplications of the same number. Radicals involve the use of the radical sign, `sqrt(\ )`. Sometimes these are called surds. If you learn the rules for exponents and radicals, then your enjoyment of mathematics will surely increase! (Yeah, right... :-) In this Chapter 1. Simplifying Expressions with Integral Exponents - defines exponents and shows how to use them when multiplying or dividing in algebra. 2. Fractional Exponents - shows how an fractional exponent means a root of a number 3. Simplest Radical Form - this technique can be useful when simplifying algebra 4. Addition and Subtraction of Radicals - shows how to add or subtract expressions involving the square root sign 5. Multiplication and Division of Radicals (Rationalizing the Denominator) - while this method is not as important as it was in the pre-calculator days, it is still a useful technique 6. Equations with Radicals - the fun starts! The chapter begins with 1. Simplifying Expressions with Integral Exponents » Exponents, Roots (such as square roots, cube roots etc) and Logarithms are all related! Let's start with the simple example of 3 × 3 = 9: 3 Squared = = 3 × 3 = 9 Using Exponents we write it as: 32 = 9 When any of those values are missing we have a question, each with a different notation: 32 = ? is the exponent question "what is 3 squared?": 32 = 9 ?2 = 9 is the root question "what is the square root of 9?": √9 = 3 3? = 9 is the logarithm question "what is log base 3 of 9?": log3(9) = 2 So when we are stuck trying to solve questions with logs, roots or exponents just remember this! Another example: 103 = 1000 103 = ? "What is 10 cubed?": 103 = 1000 ?3 = 1000 "What is the cube root of 1000?": ∛1000 = 10 10? = 1000 "What is log base 10 of 1000?": log10(1000) = 3 Copyright © 2023 Rod Pierce From Wolfram MathWorld: Exponents - An exponent is the power p in an expression of the form $$a^p$$ The process of performing the operation of raising a base to a given power is known as exponentiation. (where a ≠0) Radicals - The symbol $$\sqrt[n]{x}$$ used to indicate a root is called a radical and is therefore read "x radical n," or "the nth root of x." In the radical symbol, the horizontal line is called the vinculum, the quantity under the vinculum is called the radicand, and the quantity n written to the left is called the index. The special case $$\sqrt[2]{x}$$ is written $$\sqrt{x}$$ and is called the square root of x. $$\sqrt[3]{x}$$ is called the cube root. Radical -- from Wolfram MathWorld MORE: Radical - The √ symbol that is used to denote square root or nth roots. Radical Expression - A radical expression is an expression containing a square root. Radicand - A number or expression inside the radical symbol. Radical equation - An equation containing radical expressions with variables in the radicands. Radical inequality - An inequality containing a radical expression with the variable in the radicand. By the end of this section, you will be able to: Simplify expressions with roots Estimate and approximate roots Simplify variable expressions with roots Compute the following: \(4\cdot 4\) \(9 \cdot 9\) \(64 \div 8\) \(9\div 3\) Answer Exponents are notation we use to multiply a number to itself multiple times. We take the number we want to multiply by as the big number and how many times we want to multiply by it as the smaller one on top. For example, take \(4\cdot 4\) we can write this as \(4^2\) read as "4 to the 2". How about \(4\cdot 4\cdot 4\cdot 4\cdot 4\cdot 4\)? Here we have 4 multiplied to itself 5 times, so we can express this as \(4^5\) read "4 to the 5". We can see that if we have \(4^2\cdot 4\) then this would be \(4^3\) since \(4^2=4\cdot 4\) and that \(4^2\cdot 4=4\cdot 4\cdot 4=4^3\) as we have 4 multiplied to itself 3 times. (By the way \(4^3=64\) We can go back as well if we take \(4^3\div 4\) then this would be \(4^2\) since \(4^3=4\cdot 4\cdot 4\) and that \(4^3\div 4=4\cdot 4\cdot 4\div 4=4^2\) as we have 4 multiplied to itself 2 times. (By the way \(4^2=16\)) We see that multiplying by 4 we go up an exponent and down an exponent by dividing by 4. What if we divide \(4^2\) by 4, what would we get? We would get \(4^2\div 4=4\cdot 4\div 4=4^1\). Which make sense because we have only one 4. What if we do it again? What if we divide by 4 again to get \(4^0\)? What is \(4^0\)? Well \(4^1\div 4=4\div 4=1=4^0\). Do it again. What is \(4^{-1}\)? \(4^0\div 4=1\div 4=\frac{1}{4}=4^{-1}\) And again. What is \(4^{-2}\)? \(4^{-1}\div 4=1\div {4\cdot 4}=\frac{1}{16}=\frac{1}{4^2}=4^{-2}\) Instead of counting multiplying by 4 everytime, we can "jump" by multiplying by multiple copies of 4. For example, if we wanted to get from \(4^{-2}\) to \(4^3\) we would multiple by \(4^5\). Why? We notice that the difference between 3 and -2 is 5, i.e \(3-(-2)=3+2=5\), and so we would have to multiply by 4, five times, but we have notation for that! it is \(4^5=4\cdot4\cdot4\cdot4\cdot4\). So \(4^{-2}\cdot 4^5=4^3\) Same thing goes for going back. For example, going from \(4^4\) to 4, we would divide by \(4^3\) or multiply by \(4^{-3}\) i.e \(4^{4}\cdot 4^{-3}=4^1=4\) We don't need to use 4 for exponents. We can use any number. Given two numbers a and b. In \(a^b\), a is called the base and b is called the exponent. Let a,b, and c be real numbers then \(a^b\cdot a^c=a^{b+c}\) note: this only works for the same base. Compute the following (you should be able to do these with out a calculator) \(3^2\) \(3^3\) \(1^{32}\) \(5^{-2}\) \(7^3\cdot7^{-2}\) \(8^{-4}\cdot 8^{3}\) \(9^{-999}\cdot 9^{1000}\) Answer \(3\cdot 3=9\) \(3\cdot3\cdot3=27\) \(1\) \(\frac{1}{5\cdot 5}=\frac{1}{25}\) \(7^{3+(-2)}=7^1=7\) \(8^{-4+3}=8^{-1}=\frac{1}{8}\) \(9^{-999+1000}=9^1=9\) What happens when there are more than two operations in an expression? We follow the order of operations, which is parenthesis, exponents, multiplication, division, addition, subtraction. The order of operations still applies when negatives are included. Remember Please Excuse My Dear Aunt Sally? This is a way to remember the order of operations. The "P" in "Please" stands parenthesis, the "E" in "Excuse" stands for exponents and so on. Let’s try some examples. We’ll simplify expressions that use all four operations with integers—addition, subtraction, multiplication, and division. Remember to follow the order of operations. Simplify: \((2+3)^2\cdot 2-3\) \(2-3^2\) \((−7)^2\) \(−7^2\) Answer \((2+3)^2\cdot 2-3=(5)^2\cdot 2-3=25\cdot 2-3=50-3=47\) \(2-3^2=2-9=-7\) \((-7)^2=-7\cdot -7=49\) \(-7^2=(-1)\cdot 7^2=(-1)\cdot 7\cdot 7=(-1)\cdot 49=−49\) The last example showed us the difference between \((−2)^4\) and \(−2^4\). This distinction is important to prevent future errors. The next example reminds us to multiply and divide in order left to right. Simplify: \(8(−9)÷(−2)^3\) \(−30÷2+(−3)(−7)\) Answer \(\begin{array}{lc} \text{} & 8(−9)÷(−2)^3 \\ \text{Exponents first.} & 8(−9)÷(−8) \\ \text{Multiply.} & −72÷(−8) \\ \text{Divide.} & 9 \end{array}\) \(\begin{array}{lc} \text{} & −30÷2+(−3)(−7) \\ \text{Multiply and divide} \\ \text{left to right, so divide first.} & −15+(−3)(−7) \\ \text{Multiply.} & −15+21 \\ \text{Add.} & 6 \end{array}\) Simplify: \(12(−9)÷(−3)^3\) \(−27÷3+(−5)(−6).\) Answer Simplify: \(18(−4)÷(−2)^3\) \(−32÷4+(−2)(−7)\) Answer A natural and intimidating question is "can we put fractions in the exponent?" The answer is yes! Let's take a look at an example. Say we want to know what \(4^\frac{1}{2}\) is. Well we would know that, whatever that number was, that if we multiplied it by itself, then we would get 4. What number multiplied to itself would get us 4? 2 would work! \(2\cdot 2=4\). Note that -2 would also work since \(-2\cdot-2=4\) but in our picture, we have a positive number. So really, the fraction in the exponent is essentially asking to do the opposite of the whole number. That is, instead of \(2^2\) asking us "what is 2 times itself twice?" we have \(4^{\frac{1}{2}}\) asking us "what number, multiplied to itself twice, will give us 4?" What about \(27^\frac{1}{3}\)? This is asking us to find the number that when multiplied to itself 3 times, gives us 27. Well we know that \(3^3=27\) so 3 multiplied to itself 3 times gives us 27. Thus \(27^\frac{1}{3}=3\) Compute the following \(8^\frac{1}{3}\) \(9^\frac{1}{2}\) \(1^\frac{1}{36}\) \(49^\frac{1}{2}\) Answer Imagine a square with all sides of the same length, say 4. The area of this is \(4\cdot 4=4^2=16\) because of this we sometimes call \(4^2\) "4 squared". Square If \(n^{2}=m\), then \(m\) is the square of \(n\). Square Root If \(n^{2}=m\), then \(n\) is a square root of \(m\). The square root of a number is just that number raised to the \(\frac{1}{2}\) power. Notice \((−13)^{2} = 169\) also, so \(−13\) is also a square root of \(169\). Therefore, both \(13\) and \(−13\) are square roots of \(169\). So, every positive number has two square roots—one positive and one negative. What if we only wanted the positive square root of a positive number? We use a radical sign, and write, \(\sqrt{m}\), which denotes the positive square root of \(m\). The positive square root is also called the principal square root. We also use the radical sign for the square root of zero. Because \(0^{2}=0, \sqrt{0}=0\). Notice that zero has only one square root. \(\sqrt{m}\) is read "the square root of \(m\)." If \(n^{2}=m\), then \(n=\sqrt{m}\), for \(n\geq 0\). \[\color{cyan} \text{radical sign} \longrightarrow \color{black} \sqrt{m} \color{cyan} \longleftarrow \text{radicand} onumber\] Figure 8.1.1 What about if we have \(\frac{1}{3}\) in the exponent? Is there notation for that? If \(b^{n}=a\), then \(b\) is an \(n^{th}\) root of \(a\). The principal \(n^{th}\) root of \(a\) is written \(\sqrt[n]{a}\). The \(n\) is called the index of the radical. Let's redo the last example in this notation. Compute the following \(\sqrt[3]{8}\) \(\sqrt{9}\) \(\sqrt[36]{1}\) \(\sqrt{49}\) Answer What about negative numbers inside square roots? We are not ready to go there yet but we will in Chapter 4. Simplify: \(\sqrt{144}\) \(-\sqrt{289}\) Solution: a. \(\sqrt{144}\) Since \(12^{2}=144\). \(12\) b. \(-\sqrt{289}\) Since \(17^{2}=289\) and the negative is in front of the radical sign. \(-17\) So far we have only talked about squares and square roots. Let’s now extend our vocabulary to include higher powers and higher roots. \(\begin{array}{ll}{\text { We write: }} & {\text { We say: }} \\ {n^{2}} & {n \text { squared }} \\ {n^{3}} & {n \text { cubed }} \\ {n^{4}} & {n \text { to the fourth power }} \\ {n^{5}} & {n \text { to the fifth power }}\end{array}\) The terms ‘squared’ and ‘cubed’ come from the formulas for area of a square and volume of a cube. It will be helpful to have a table of the powers of the integers from \(−5\) to \(5\). See Figure 8.1.2 Figure 8.1.2 Notice the signs in the table. All powers of positive numbers are positive, of course. But when we have a negative number, the even powers are positive and the odd powers are negative. We’ll copy the row with the powers of \(−2\) to help you see this. Figure 8.1.3 When we see a number with a radical sign, we often don’t think about its numerical value. While we probably know that the \(\sqrt{4}=2\), what is the value of \(\sqrt{21}\) or \(\sqrt[3]{50}\)? In some situations a quick estimate is meaningful and in others it is convenient to have a decimal approximation. To get a numerical estimate of a square root, we look for perfect square numbers closest to the radicand. To find an estimate of \(\sqrt{11}\), we see \(11\) is between perfect square numbers \(9\) and \(16\), closer to \(9\). Its square root then will be between \(3\) and \(4\), but closer to \(3\). Figure 8.1.4 Similarly, to estimate \(\sqrt[3]{91}\), we see \(91\) is between perfect cube numbers \(64\) and \(125\). The cube root then will be between \(4\) and \(5\). Estimate each root between two consecutive whole numbers: \(\sqrt{105}\) \(\sqrt[3]{43}\) Solution: a. Think of the perfect square numbers closest to \(105\). Make a small table of these perfect squares and their squares roots. Table 8.1.1 \(\sqrt{105}\) Locate \(105\) between two consecutive perfect squares. \(100

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