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Page 10 d^2 – d-6 7x - 14 12 +11j + 10 y2 + 13y - 48 c^2 - 1 b2 - 4b - 45 2x3 + 6x2 c2 +0-20 j^2 -p^2 4x? - 8x 3x5y + 4x+y - 5x^2y m2 - m 16 - 81y? 25a2 - 256 9x2 - 4 100 - k x2 - 8x + 16 3x (2x - 1) + 4(2x - 1) Write the polynomial in the shaded cells in the column that best describes the method of factoring that should be used. Then factor the polynomial. Greatest Common Factor swol Difference of Perfect Squares Trinomials (no GCF) Polynomial Factored Form Polynomial Factored Form Polynomial Factored Form Polynomial Factored Form Polynomial Factored Form Polynomial Factored Form Does the sight of a number or expression accompanied by the instructions, "Factor completely," strike fear into your heart? Wish you paid attention in algebra? Well, this instructable will teach you how to factor any number, or eligible expression such as Ax^2 + Bx + C. First off, what is a factor? "Natural number factors" are the complete set of whole numbers, where if you multiply one number in the set by another in the set, you get the number that you're factoring. For example, the number 5 has two factors: 1, and 5. The number 6 has four factors: 1, 2, 3, and 6. "Integer factors" include negative numbers. The number 5 in this case would have four factors: -5, -1, 1, and 5. 6 would have eight factors: -6, -3, -2, -1, 1, 2, 3, and 6. (Natural numbers are numbers without fractions, starting from 1, 2, 3, 4, 5... all the way up to infinity. Integers are natural numbers, as well as their negative counterparts and 0, or ...-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5...) Factoring numbers with the natural number set is simple. Every number has at least two factors. To find other factors, start dividing the number starting from two and working your way up until you reach that number divided by 2. Any quotient that does not have a remainder means that both the divisor and the quotient are factors of that number. Say you need to factor the number 9. You can't divide by two evenly, so we skip it. (Note the solution, 4.5, so you know when to stop later on.) 9 is divisible by 3, so add 3 to your list of factors. Work your way up until you divide by 5 (9 divided by 2, rounded up). You'll end up with 1, 3, and 9 as a list of factors. When factoring numbers in the integer set, you can just add the negative equivalent of your solutions from natural number factoring in. So 9 would have factors of -9, -3, -1, 1, 3, and 9. Factoring negative numbers can only be done with integer factoring. The solution is the same one you get factoring the positive version of the number. -9 has factors of -9, -3, -1, 1, 3, and 9. Zero is the only integer that has an infinite amount of factors, and is the only one that has zero as a factor. And no, I don't mean factoring the expression of your boss as you tell him you accidentally flooded the break room with coffee. Algebraic expressions consist of numbers, which are called coefficients, and variables, which can be raised to a power. In the expression x^2 + 6x + 8, 1 is the coefficient of x^2, the variable. (If you do not see a coefficient before a variable, it's a 1, because x^2 is multiplied by 1.) Likewise, 6 is a coefficient of x^1. (A lone variable is raised to a power of one.) 8 is called a constant - it is not multiplied by a variable. (You can visualize it being multiplied by x^0, and any number raised to the 0th power is equal to 1). To factor an expression, you have to start by factoring out the GCF, or Greatest Common Factor. List the factors of each component of the expression. Here we are interested in finding the natural number factors. The expression x^2 + 6x + 8 would have factors that look like this: x^2: 1 6x: 1, 2, 3, 6 8: 1, 2, 4, 8 If you look at the three lists, there is only one thing that they all share in common, the number one. This means there is no coefficient greater than one to factor out. Then you look at the exponents' powers. 2, 1, and 0. If you see a zero, the expression cannot be factored by a variable. This expression is ready for the next step. Here is an example that does have a GCF that needs to be factored out: 2x^3 + 18x^2 + 10x. Factor each part: 2x^3: 1, 2 18x^2: 1, 2, 3, 6, 9, 18 10x: 1, 2, 5, 10 Here we can see that the parts have 1 and 2 in common. We find the largest number, 2. Then we look at the powers of exponents: 3, 2, and 1. Find the smallest number that isn't 0, in this case the number one. That means x^1, or simply x, can be divided into the expression. Multiply the number and variable together to get 2x. Then divide each part of the expression by 2x. 2x^3 / 2x = x^2 18x^2 / 2x = 9x 10x / 2x = 5 The expression with the GCF factored out is 2x (x^2 + 9x + 5). Note that you must put the factored expression in parentheses and write the GCF next to it. Binomials are expressions with only two terms being added. 2x^2 - 4x is an example of a binomial. (You can say that a negative 4x is being added to 2x2.) First, factor out the GCF, 2x. You're left with 2x (x - 2). This is as far as this binomial can go. Any binomial in the form 1x +/- n cannot be factored further. When you have a binomial that is a variable with an even exponent, added to a negative number that has a square root that is a natural number, it's called a perfect square. x^2 - 4 is an example of this. It can be expressed as the product of the square root of the variable plus the square root of the positive constant, and the square root of the variable minus the square root of the positive constant. Huh? Basically, take the square root of the variable. You'll end up with x. Then square root the 4. You'll end up with 2. If you add them together, you'll get x+2. Subtract them, and you'll get x-2. Multiply the two, and you'll get (x+4)(x-4). You've just factored a perfect square. If you multiply (x+2)(x-2) together using FOIL, you'll end back up with x^2-4. (FOIL: First Outer Inner Last, a way of multiplying two binomials together. Multiply the first terms of the binomials (x and x in this case), then the outer two (x and -2), then the inner two (2 and x), then the last terms (2 and -2), then add them all up. x^2 - 2x + 2x - 4 = x^2 - 4.) This can be done again if one of the binomials is a perfect square, as in this instance: x^4 - 16 = (x^2 + 4) (x^2 - 4) = (x^2 + 4) (x + 2) (x - 2). This can be factored further if you bring in irrational numbers, see step [9]. How to factor binomials in the form of (x^3+ b^3): Just plug into (a - b) (a^2 +ab + b^2). For example, (x^3 + 8) = (x - 2) (x^2 + 2x + 4). How to factor binomials in the form of (x^3- b^3): Plug into (a + b) (a^2 - ab + b2). Note that the first two signs in the expression are switched. (x^3 - 8) = (x + 2) (x^2 - 2x + 4). Both examples can be factored further once you learn how to factor trinomials in step [4]. Trinomials: An expression with three terms added together. 2x^2 + 6x - 8 will serve as our lucky demonstrator. First, factor out the GCF. This will ALWAYS be your first step when factoring ANY expression. 2 (x^2 + 3x - 4) If you end up with a power of x greater than two after factoring out the GCF, move on to another step. List the integer factors of the constant. You'll want two pair them up like so: -4, 1 -2, 2 -1, 4 You want to find one of these that when added up equals the coefficient of the second term, 3. -1 + 4 = 3. From here, write out two sets of parentheses with x's inside: (x) (x) Then stick the two terms that worked into the parentheses. (x - 1) (x + 4) Don't forget to add the GCF back. 2 (x - 1) (x + 4) That's how you factor a trinomial. Here's another one: 2x^2 + 11x - 6. There's a twist this time: The coefficient of x^2 is not 1. This means that we will be adding another step: List factors of the constant, -6, as well as the coefficient of x2, 2. -6, 1 -3, 2 -2, 3 -1, 6 1, 2 Now, you'll want to multiply each of the factors on the left side by 1, and on the right by 2. Repeat by switching the 1 and 2. You'll end up with -6, 2 -3, 4 -2, 6 -1, 12 -12, 1 -6, 2 -4, 3 -2, 6 Find the pair that adds up to the middle term's coefficient, in this case, -1 + 12 = 11. Set up the parentheses: (x) (x) Stick in the original numbers (that you had before multiplying by 1 and 2): (x - 1) (x + 6) Then stick in the one and two as coefficients of x so that when you multiply the outer and inner terms and add them together, you'll get 11. (2x - 1) (x + 6) If you check your work by FOILing it out, you'll end up with 2x^2 + 11x - 6, the expression you started with. Congrats! 9x^4 + 45x^2 + 14. Don't you think this expression would be easier to factor with smaller numbers and variable powers? You can substitute a lower number and variable power like so: Set n = 3x^2 (the GCF of the variable powers, and the square root of the GCF of the coefficients of numbers multiplied by a power of x). Then substitute it in by dividing the terms in the original expression by n. n^2 + 15n + 14. Now you can easily factor. (n + 14) (n + 1). Stick the 3x^2 back into the expression where the n's are. (3x^2 + 14) (3x^2 + 1). If none of the combinations you get (from step 4) add up right, you'll have to use the quadratic equation. (-b +/- sqrt (b^2 - 4ac))/2a (sqrt (#) = square root of #) Where a trinomial has the form ax^2 + bx + c. So, if you wanted to use the quadratic formula with 1x^2 + 3x + 2, you'd plug in like so: (-3 +/- sqrt (3^2 - 4 (-2) (1)) / 2. This simplifies down to (-3 +/- sqrt 17)/2. The factors of 1x^2 + 3x + 2 would be (x - ((-3 + sqrt 17)/2)) (x - ((-3 - sqrt 17)/2)). (You stick the answer to the right of an "x - ". More on why that works, in step [8].) Sometimes you will get four or more terms, that look something like this: 2x^2 + 6x^3 + 5x^7 + 15x^8 There is no common coefficient, and factoring out x^2 doesn't help much. This is where you would use grouping to factor. Grouping means factoring out the GCF of only two terms of the expression. You can see that 2x^2 + 6x^3 and 5x^7 + 15x^8 both can have a GCF taken out. Do so. 2x^2 (1 + 3x) + 5x^7 (1 + 3x) Note that there is a common factor, 1+3x. This expression can be rephrased to (2x^2 + 5x^7) (1 + 3x). There's your answer. Note that (2x^2 + 5x^7) (1 + 3x) can be factored further by factoring out an x^2 from the first binomial: x^2 (2 + 5x^5) (1 + 3x). Sometimes you'll get beastly polynomials that look like they have no hope. 3x^3 + 8x^2 - 9x + 2 is an example. You can't use grouping to factor out a GCF in a way that would produce a common factor. In order to explain how this works, you need to know that when solving an equation by factoring, you need to set the factored out thing equal to 0 and find out what X equals so that it equals zero. For example, 0 = (x - 2) (x + 1). The solutions are 2 and -1. If a polynomial has integer coefficients, every zero, or solution, has the form P/Q, where P = a factor of the constant term, and Q = a factor of the leading coefficient. Basically, if you list all the factors of the constant, and divide them by the factors of the leading coefficient (the coefficient next to the variable with the highest power) in every combination, you will get a list of possible rational solutions. How does this help you factor? If you get 2 as a solution, you can work backwards and say that one of the factors of the equation was (x - 2). So, back to the example: Factors of 2: +/- 1, +/- 2 (you need to include negatives) Factors of 3: +/- 1, +/- 3 P/Q: +/- 1, +/- 1/3, +/- 2, +/- 2/3 Once you have your list, you'll use something called synthetic division to see which of those P/Q's are actually solutions. Synthetic division is a way of dividing polynomials by a binomial of the form x-k. I'm not going to explain how it works, but just show how to use it for factoring. First, put one of your P/Q's in a little box or set of parentheses, then list the coefficients and constant in a row next to it. If the polynomial skips a power (x^2 + 2) then you need to add a 0 for where x1 should have been. (Expression: 3x^3 + 8x^2 - 9x + 2) (Ignore the asterisks, they're used as placeholders. Better yet, see the first picture.) (1) 3 8 -9 2 Leave a blank space, draw a line, then drop the first term, 3, down. (1) 3 8 -9 2 ***3 Then multiply it by the number in the box and put it beneath the next term. (1) 3 8 -9 2 ******3 ***3 Add 8 + 3 (1) 3 8 -9 2 ******3 ***3 11 Multiply. (1) 3 8 -9 2 ******3 11 ***3 11 Add. (1) 3 8 -9 2 ******3 11 ***3 11 2 Multiply. (1) 3 8 -9 2 ******3 11 2 ***3 11 2 Add. (1) 3 8 -9 2 ******3 11 2 ***3 11 2 4 That string of numbers, 3, 11, 2, 4, gives you an expression with one degree less (if the highest exponent in the original expression is 3, the highest exponent in the quotient will be a 2) as well as a remainder. (Original Expression: 3x^3 + 8x^2 - 9x + 2) Quotient: 3x^2 + 11x + 2 Remainder 4 If you get a remainder, then the number in the box you tried is not a solution for the equation. Cross that number off your list, and try again with another number. It's pretty much guess and check. Eventually you'll try 1/3 and you'll find that it divides through cleanly. You'll end up with: (x - 1/3) (3x^2 + 9x - 6). Now that you have a trinomial of power two, you can go back and factor it. Don't forget to take out the GCF first! You're left with (x - 1/3) (3) (1x^2 + 3x + 2). Factor out the trinomial via the quadratic equation (this equation was used as an example in step [6], so refer back if you need to). You'll end up with (3) (x - 1/3) (x - ((-3 + sqrt 17)/2)) (x - ((-3 - sqrt 17)/2)). Very ugly, but that's how you do it. Binomials number without a perfect root being subtracted from a squared variable like (x^2 - 2) can be factored further using square roots. (x + sqrt (2)) (x - sqrt (2)). This brings in the irrational set of numbers. Binomials with a number added to a squared variable like (x^2 + 1) can be factored further using imaginary numbers. "i" stands for the square root of negative one. So (x^2 + 1) can be factored into (x + i) (x - i). This brings in the imaginary set of numbers. You now know how to factor any number or expression you'll probably ever come across. Good for you! There are also programs out there that can do this for you. If you google "polyroot" you'll get links to a few programs for your computer. The HP 39/40gs graphing calculators have the polyroot function built in. If you have a TI-89 graphing calculator, it also has a factoring function. Earlier model TI graphing calculators don't have it built in, but they do have factoring programs. Google "ti quadratic solver" for programs you can transfer to your TI graphing calculator. You can also find real solutions to quadratic equations by graphing them and using the 'zero' function to calculate where the graph intersects the x-axis. You can then stick that number next to a "x -". Disclaimer: Most math classes either disallow calculators that can factor, or make you clear the memory (along with programs) of programmable calculators. Also, if any solutions have a non-natural root in them, you'll get a long string of decimals which is unsuitable as an answer. Just learn how to do it by hand.