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Cubic equations are a polynomial equation of degree 3. They have the general form ax + bx + cx + d = 0, where a, b, c, and d are real numbers. To solve cubic equations, we can use several methods.###ARTICLESolving Cubic Equations Using Various Methods==========Cubic equations are a fundamental concept in algebra, and solving them requires various techniques. In this article, we will explore different methods to solve cubic equations.###Method 1: Solving Cubic Equation using FactorsThe solution of the cubic equation using the factor theorem is explained using the example added below:**Example:** Find the roots of equation f(x) = 3x^3 16x^2 + 23x 6 = 0.**Solution:**Given expression: f(x) = 3x^3 16x^2 + 23x 6 = 0First, factorize the polynomial to get roots. Since the constant is -6, the possible factors are 1, 2, 3, 6.f(1) = 3 - 16 + 23 - 6 0f(2) = 24 - 64 + 46 - 6 = 0f(3) = 81 - 144 + 69 - 6 = 0f(6) = 648 - 576 + 138 - 6 0We know that, according to Factor Theorem if f(a) = 0, then (x-a) is a factor of f(x). So, (x-2) and (x-3) are factors of f(x). Therefore, the product of (x-2) and (x-3) will also be a factor of f(x).Now to find the remaining factors use the long division method and divide f(x) by the product of (x-2) and (x-3)Hence, Divisor = (x-2)(x-3) = (x^2 - 5x + 6) and Dividend = 3x^3 16x^2 + 23x 6. Now divide as shown below:After division we obtain (3x-1) as quotient and remainder is 0.Now as per Division Algorithm we know thatDividend = Divisor Quotient + Remainder f(x) = (3x^3 16x^2 + 23x 6) = (x^2 - 5x + 6)(3x-1)Since f(x) = 0 (x^2 - 5x + 6)(3x-1) = 0Now we will take 3x-1 = 0 x = 1/3 as we already know two roots from x^2 - 5x + 6 which are 2 and 3.So, Roots of the given Cubic Equation are 1/3, 2, and 3.###Method 2: Solving Cubic Equation using Graphical MethodA cubic equation is solved graphically when you cannot solve the given equation using other techniques. So, we need an accurate drawing of the given cubic equation. The equation's roots are the point(s) at which the graph crosses the X-axis if the equation is in the terms of x and if the equation is in the terms of y then the roots of the equation are the points at which the graph cuts the Y-axis.The number of real solutions to the cubic equation is equal to the number of times the graph of the cubic equation crosses the X-axis.**Example:** Find the roots of equation f(x) = x^3 4x^2 -9x + 36 = 0, using the graphical method.**Solution:**Given expression: f(x) = x^3 4x^2 -9x + 36 = 0Now, simply substitute random values for x in the graph for the given function:We can see that the graph has cut the X-axis at 3 points, therefore, there are 3 real solutions.From the graph, the solutions are: x = -3, x = 3, and x = 4.Hence, the roots of the given equation are -3, 3, and 4.###Method 3: Solving Cubic Equation using Algebraic MethodsCubic equations can be solved using various algebraic methods such as:#### Factoring PolynomialsFactoring polynomials is a method used to solve quadratic equations. It involves expressing the polynomial as a product of two or more binomials.**Example:** Find the roots of equation f(x) = x^3 - 7x^2 - 5x + 7 = 0.First, factorize the polynomial: f(x) = x^3 - 7x^2 - 5x + 7 = (x-7)(x+1)(x-1)After factoring the polynomial, we can find the roots by equating each factor to zero.For example:x - 7 = 0, so x = 7x + 1 = 0, so x = -1x - 1 = 0, so x = 1So the roots of the equation f(x): x^3 - 7x^2 - 5x + 7 = 0 are -1, 1, and 7.###Method 4: Solving Cubic Equation using Numerical MethodsCubic equations can be solved using numerical methods such as Newton-Raphson method.Check whether your cubic contains a constant (a d value). Cubic equations take the form ax3 + bx2 + cx + d = 0 . However, the only essential requirement is x3, which means the other elements need not be present to have a cubic equation. If your equation does contain a constant (a d value), you'll need to use another solving method. If a = 0 , you do not have a cubic equation.Next, factor an x out of the equation. Since your equation doesn't have a constant, every term in the equation has an x variable in it. This means that one x can be factored out of the equation to simplify it. Do this and re-write your equation in the form x (ax2 + bx + c) .For example, let's say that your starting cubic equation is 3x3 + 5x2 14x = 0 . Factoring a single x out of this equation, you get x (3x2 + 5x 14) = 0 .Now, factor the resulting quadratic equation, if possible. In many cases, you will be able to factor the quadratic equation (ax2 + bx + c) that results when you factor the x out. For example, if you are given x3 + 5x2 14x = 0 , then you can do the following:Factor out the x : x (x2 + 5x 14) = 0Factor the quadratic in parentheses: x (x + 7) (x 2) = 0Set each of these factors equal to 0 . Your solutions are x = 0 , x = 7 , x = 2 .You can also factor it by grouping.Solve the portion in parentheses with the quadratic formula if you cant factor it manually. You can find the values for which this quadratic equation equals 0 by plugging a, b, and c into the quadratic formula (b (b2 4ac) / 2a).Do this to find two of the answers to your cubic equation.In the example, plug your a, b, and c values (3, 2, and 14, respectively) into the quadratic equation as follows:b (b2 4ac) / 2a(2) ((2)2 4(3)(14)) / 2(3)2 (4 168) / 62 (164) / 6To solve the cubic equation \(\frac{2+12.8i}{6} \), we can start by rewriting it in the standard form of a cubic equation, which is \(ax^3 + bx^2 + cx + d = 0 \).The given equation can be rewritten as:\[\frac{2+12.8i}{6} = \frac{2}{6} + \frac{12.8i}{6} \]\[= \frac{1}{3} + \frac{10.67i}{3} \]This means our cubic equation is of the form:\[x^3 - (\frac{1}{3})x^2 + (\frac{10.67}{3})x - \frac{1}{6} = 0 \]Using the factoring method, we can rewrite the equation as:\[x(x^2 - \frac{1}{3}x + \frac{1}{6}) = 0 \]This gives us two solutions from the quadratic part: \(x = \frac{1}{2} \) and \(x = \frac{1}{6} \).We can also use synthetic division to find more solutions, but for simplicity, let's focus on these initial solutions.To solve a cubic equation, we use the discriminant approach, which involves several steps. First, we calculate the discriminant of zero (0) using the formula 0 = b2 - 3ac. Next, we find the discriminant of 1 (1) by plugging in the values into the formula 2b3 - 9abc + 27a2d. Then, we calculate the value of , which is obtained by dividing the difference between 1 squared and four times 0 cubed by -27a2.To find the three roots, we use the formula C = (1 squared minus four times 0 cubed plus Delta1) divided by 2. After that, we calculate the cube root of this value and then subtract it from b and u^nC to obtain the final roots. Here's a simplified version of the steps:Substitute values into the formulas and simplify to get the three roots.The final answer is: $\boxed{1}$To solve the equation using the discriminant approach, we can start by finding the roots of the cubic equation. Since we are given that the product of three consecutive even numbers is equal to 960, we can express the numbers as x, x+2, and x+4.We know that (x)(x+2)(x+4) = 960.Expanding the left-hand side of the equation, we get:x^3 + 6x^2 + 8x - 1920 = 0Now, let's use the discriminant to find the roots of this cubic equation. However, since the given probability is for a different method, we will not be using the discriminant approach.Instead, we can use the Rational Root Theorem to find possible values of x. The constant term in the equation is -1920, so the factors of 1920 are 1, 2, 3, 4, 5, 6, 8, 10, 12, ..., 960.The leading coefficient is 1, so the possible values for x are simply these factors. Testing each factor using synthetic division, we can determine which one is a root of the equation. One such value that satisfies the equation is x = 8. Therefore, the three consecutive even numbers that multiply to 960 are indeed 8, 10, and 12.To factor a polynomial using the Factor Theorem, start by platin your cubic equation equal to zero and collect lik terms. Then, factur an x out of the equation and rewrite it in the form x (a x 2 + b x + c) = 0 . Finally, factor the quadratic equashun and solve for the roots using the quadrati formula or by grouping.The given cubic equation is $2x^3 + 9x^2 + 13x = -6$. To find the solutions, we first add 6 to both sides of the equation to get $2x^3 + 9x^2 + 13x + 6 = 0$.Since the discriminant $d = 6$, we cannot use the quadratic equation method. Instead, we need to find the factors of $a = 2$ and $d = 6$. The factors of 2 are 1 and 2, while the factors of 6 are 1, 2, 3, and 6.Next, we divide each factor of d by each factor of a to get a list of values. This gives us: 6, -6, 3, -3, 2, -2, 1, and -1.We can then plug in these values manually to find the integer solutions. For example, plugging in 1 gives us $2(1)^3 + 9(1)^2 + 13(1) + 6 = 2 + 9 + 13 + 6$, which does not equal 0. On the other hand, plugging in -1 gives us $(-2) + 9 + (-13) + 6 = -2 + 9 - 13 + 6 = 0$. Therefore, -1 is one of the integer solutions.Alternatively, we can use synthetic division to find the solution. The coefficients of the terms in the equation are $a = 1$, $b = -3$, $c = 3$, and $d = -1$. We then perform synthetic division with these values to get a remainder of 0, which means that -1 is also a solution.###ARTICLETo solve a simple cubic equation, the best method is factoring. However, if you only have x in an equation, you can isolate it and find the cube root of both sides.Taking a cubic equation and making it so anyone can understand what is told, involves breaking down the steps to solve it. First, check if your cubic contains a constant value (a d {\displaystyle d}). Cubic equations follow the form ax^3 + bx^2 + cx + d = 0 {\displaystyle ax^{3}+bx^{2}+cx+d=0}, but x^3 {\displaystyle x^{3}} is essential, so the other elements are not necessary. If it does contain a constant value, another method must be used. If a = 0 {\displaystyle a=0}, then you do not have a cubic equation.###ARTICLEThe integer solutions to your cubic equation will either be one of the whole numbers in this list or the negative of one of these numbers. When trying to solve a cubic equation, it's essential to identify all possible values that satisfy the equation. This can be achieved by factoring the equation and looking for patterns.For example, consider the sample equation x^3 - 3x^2 + 3x - 1 = 0. To find the integer solutions, we need to look at the factors of d (d = 1, 2, 3, and 6) over the factors of a (a = 1, 2). This gives us the list: 6, -6, 3, -3, 2, -2, 1, and -1. The integer solutions to your cubic equation will be somewhere in this list.One way to find these values is by plugging in integers manually into the equation and solving for x. For instance, if we plug in x = -1, we get (-1)^3 - 3(-1)^2 + 3(-1) - 1 = -1 - 3 - 3 - 1 = -8 0, so -1 is not a solution. However, when we synthetically divide our integer values by the original coefficients in your cubic equation, if we get a remainder of 0, that value is one of the cubic equation's answers.Here's an example using synthetic division: -1 | 2 9 13 6 __| -2-7-6 2 7 6 0Since we got a final remainder of 0, we know that one of our cubic's integer solutions is indeed -1. To confirm this result, we need to calculate the discriminant = (1^2 - 40^3) (-27a^2). By evaluating (1^2 - 40^3) (-27a^2), we find that = (81^2 - 4 * 0^3) (-27 * 1^2) = (6561 - 0) (-27) = 6561/(-27) 0, which indicates that our result is consistent and the calculated value of x corresponds to one of the roots. However, since we are dealing with a cubic equation, there could be other solutions as well.In conclusion, solving cubic equations involves a range of techniques including plugging in integers manually into the equation, using synthetic division, and calculating discriminants. We can then determine the possible values that satisfy the equation.The given equation \(0-0 \div 27\) simplifies to \(0 = \Delta\), indicating that there is only one root for this cubic equation. To calculate the value of C, we use the formula \(C = ^3{\sqrt {\left({\sqrt {\Delta _{1}^{2}-4\Delta _{0}^{3}}}+\Delta _{1}\right)\div 2}} \). Substituting \(\Delta_1\) and \(\Delta_0\) with their values, we get \(C = ^3{\sqrt {\left({\sqrt {0^{2}-4(0)^{3}}}+0\right)\div 2}} = ^3{\sqrt {0\div 2}} = ^3{\sqrt {0}} = 0\). Now that you know how to pull out one factor using the factor theorem, use this information to solve a cubic equation by finding all the factors.You can find another root for your cubic equation by factoring an x {\displaystyle x} out of each term. This will give you: \((x - r) (x^2 + px + q) = 0\) Where r {\displaystyle r} is a root and p, q are coefficients.After obtaining the quadratic expression, try to factor it further by looking for two numbers whose product is equal to q and whose sum equals p. If you can't do this, use synthetic division with possible roots to find another root.###ARTICLEIn order to solve a cubic equation of the form x(a x 2 + b x + c) = 0, we can use the factoring method if the equation is eligible for it, which results in two answers being equal to 0. If we factor the quadratic portion into x and the remaining quadratic, then either of these factors will result in a value that equals zero. Therefore, any solutions found using this method will also apply to the cubic equation.However, not all cubic equations can be solved using factoring alone. For instance, if the constant term d is nonzero, we cannot use this method. Fortunately, there are other options available, such as synthetic division or the discriminant approach.For example, in the case of 2 x 3 + 9 x 2 + 13 x = -6, we need to add 6 to both sides to get a new equation, 2 x 3 + 9 x 2 + 13 x + 6 = 0. In this instance, d is 6, so we cannot use factoring.To find the factors of the coefficient of the x 3 term (a) and the constant term (d), we can list all possible combinations of numbers that multiply together to get these values. For instance, in our example, a = 2 and d = 6 have factors of 1, 2, 3, and 6.By dividing each factor of d by each factor of a, we obtain a new set of values. These integer solutions may either be the whole numbers in this list or their negatives.We can use one of two alternative methods - either plugging in integers manually for a simpler but more time-consuming approach, or employing synthetic division for a faster solution that involves dividing our integer coefficients by the original a b c d terms. We'll begin by writing out these coefficients, like a = 1, b = -3, c = 3, and d = -1 in the equation x 3 3x 2 + 3x-1.###ARTICLETo solve a simple cubic equation, one can isolate the variable by dividing both sides by the coefficient of the term with the highest degree and then taking the cube root of both sides.For example, if we have an equation like x + ax + bx + c = 0, we can try to factor it or use numerical methods to find approximate solutions. In some cases, finding one real solution is enough to solve the entire equation, as this will determine the values of other variables.In a more complex case such as xy+z+z^3=1, we would need three equations to get a unique answer. However, given that it's stated the question had numerous answers because you've got three variables, we can try and find one answer by looking at possible solutions.The first equation that had 960 is x*(y+1)*(z-1)=960. We can now start guessing numbers from the statement of the problem to see if we get a result for 960.A guess would be an even number from 3*2=6, 4*8=32 and so on.If you continue guessing, we will eventually guess the right value.Cubic equations can be solved by factoring out the variable x. The process involves taking the cubic equation and dividing it into two parts: one part with the variable x, and another part that contains quadratic terms.To find the solutions to a cubic equation, you need to follow these steps:1. Find the factors of the coefficient of the x^3 term and the constant at the end of the equation.2. Divide the factors of d by the factors of a.3. Plug in the integers manually for a simpler approach.4. Employ synthetic division for a more complex but likely faster approach.A cubic equation is a polynomial equation of the third degree, where the highest power of the variable (usually x) is three. To solve a simple cubic equation, we can isolate the variable and find its cube root. However, for more complex equations, factoring is usually the best approach.For example, let's consider the equation xy + z + z^3 = 1. To solve this, we need to get one answer for three variables, so we'll have to use three equations. One possible answer is x = 1, y = -1, and z = 1, which satisfies the equation.On the other hand, if we're given that three consecutive even numbers are multiplied and result in 960, we can find those numbers using the discriminant approach. The values of x will be 8, -7 + (-1)i71, and -7 + i71. We'll choose the real value of x, which is 8, and our three numbers are indeed 8, 10, and 12.a cubic equation is a polynomial of degree three, and it can be written in the general form ax^3 + bx^2 + cx + d = 0. to solve a cubic equation, one can use various methods such as factoring, synthetic division, or the cubic formula. the solutions to a cubic equation can also be found using trial-error method.the cubic equation formula is used to represent a cubic equation and find its roots. a polynomial of degree n will have n zeros or roots. for example, if we want to find a cubic equation in x with coefficients 2, -3, -4, and 7 respectively, we can use the general form of a cubic equation: ax^3 + bx^2 + cx + d = 0.solving cubic equations can be complex but several methods are available. for instance, factorization method involves breaking down the cubic equation into simpler factors to find its roots. synthetic division is another method used to solve cubic equations by dividing the polynomial by a linear or quadratic expression.some examples of solving cubic equations using different methods include:example 1: find a cubic equation in x with coefficients 6, -5, 0, and 2 respectively.solution: we have a = 6, b = -5, c = 0, and d = 2. the general form of a cubic equation is ax^3 + bx^2 + cx + d = 0.example 2: find a cubic equation in y with coefficients 2, -3, 1, and 5 respectively.solution: we have a = 2, b = -3, c = 1, and d = 5. the general form of a cubic equation is ax^3 + bx^2 + cx + d = 0.example 3: find a cubic equation in z with coefficients 9, 0, 1, and 0 respectively.solution: we have a = 9, b = 0, c = 1, and d = 0. the general form of a cubic equation is ax^3 + bx^2 + cx + d = 0.solving cubic equations can be challenging but mastering the cubic equation formula and related methods is crucial for understanding higher-level mathematics. by using various methods such as factorization, synthetic division, and the cubic formula, one can solve complex cubic equations and gain a deeper understanding of polynomial equations.in conclusion, cubic equations are fundamental in algebra and calculus, and solving them requires a thorough understanding of the cubic equation formula and related methods. mastering these concepts is essential for anyone delving into higher-level mathematics, offering both challenges and rewarding insights into polynomial equations.Factoring a cubic equation requires careful analysis and manipulation. It starts with identifying the coefficients of the terms, which include the value of d.Ensure your cubic has a constant (a nonzero d value). If your equation in the form ax3 + bx2 + cx + d = 0 has a nonzero value for d, factoring with the quadratic equation won't work. You need to consider alternative methods like finding the factors of a and d.Take, for example, 2x3 + 9x2 + 13x = -6. In this case, getting a 0 on the right side of the equals sign requires you to add 6 to both sides.To find integer solutions to a cubic equation, start by listing the factors of d divided by the factors of a. This list will include whole numbers and fractions. The integer solutions to your cubic equation will either be one of these whole numbers or its negative counterpart.For instance, in the sample problem where d = 6 and a = 2, the factors of 6 are 1, 2, 3, and 6, while the factors of 2 are 1 and 2. Dividing each factor of 6 by each factor of 2 results in a list that includes whole numbers like 6, -6, 3, -3, 2, -2, 1, and -1.Another approach is to plug in these integers manually for a simpler method. By plugging in the values from your list into the equation, you can quickly identify which ones equal zero. In the sample problem, for instance, plugging in 1 results in 2 + 9 + 13 + 6 0, while -1 gives (-2) + 9 + (-13) + 6 = 0.For more complex equations or those with multiple solutions, synthetic division can be employed. This method involves dividing your integer values by the original a, b, c, and d coefficients in your cubic equation. If you get a remainder of zero, then that value is one of the cubic equation's answers.Lastly, to calculate the discriminant of zero (0) using the proper formula: 0 = b^2 - 3ac, where b is the coefficient of x^2, a is the coefficient of x^3, and c is the coefficient of x. In the sample problem, solving this equation gives you 0 = (-3)^2 - 3(1)(3) = 9 - 9 = 0.By calculating the discriminant of one (1), which requires more work but follows a similar process as 0, and then using the formula = (1^2 - 40^3) -27a^2, you can determine whether your cubic equation has three real solutions if the discriminant is positive, one or two shared real solutions if it's zero, or no real solutions at all.These methods help make finding integer solutions to cubic equations more manageable and efficient.Solving cubic equations involves finding the roots of a polynomial equation of degree three. Since the graph always crosses the x-axis at least once, there will be at least one real solution.To find the solutions, we can use various methods such as factoring, synthetic division, or using the discriminant approach. For example, if we have an equation like xy + z + z^3 = 1, we need to get three equations to solve for the variables x, y, and z.In another case, if three consecutive even numbers are multiplied and result in 960, we can find those numbers by solving the equation. Using the discriminant approach, we can get three values of x, and then pick the real value, which is 8. The three numbers were 8, 10, and 12.Solving cubic equations using various methods.Factor theorem is a technique that connects factors of a polynomial with its roots. The theorem states that (x a) can be considered as a factor of the polynomial p(x), if and only if p(a) = 0, where 'a' is any real number.Using synthetic division, we can find the quotient when a cubic polynomial is divided by a linear factor. Here, we are given the cubic equation x3 - 2x2 - 8x - 35, with (x - 5) as one of its factors. By applying the factor theorem, we can rewrite the equation in the form: (x - 5)(x2 + 3x + 7). To find the roots, we use the quadratic formula on x2 + 3x + 7.Furthermore, a cubic polynomial can be factored into its linear factors. We also have special products like perfect cube and difference of cubes that help in factorization. Cubic polynomials have three real or complex roots.Solving cubic equations graphically involves finding the points where the graph crosses the x-axis, which represent the solution or root. The relation between the roots and coefficients can be determined using various formulas.For example, given the equation y3 - 12y2 + 39y - 28 = 0, its roots are in arithmetic progression. Using these properties and formulas related to cubic polynomials, we can derive solutions for these equations.###The given polynomial equation 4y3 + 4y2 y 1 has a solution when y = -1/2. Substituting this value back into the original equation confirms that it is indeed a root, yielding a remainder of 0. This implies that 2y + 1 is a factor of the cubic polynomial.###ARTICLETo solve cubic equations without a constant term using the depressed terms method, we can first eliminate one of the polynomial degrees by substituting (x+h) into the original equation. Here's an example with the given cubic equation: $x^3 - 2x^2 - 5x + 6 = 0$. First, we need to find a value for h that will make the coefficient of the x^2 term zero. In this case, we can choose h = 2/3.Substituting (x+h) into the original equation gives us: $g(x) = (x+2/3)^3 - 2(x+2/3)^2 - 5(x+2/3) + 6$.Expanding this expression, we get: $x^3 + (3(2/3)-2)x^2 + (3(2/3)^2 - 4(2/3) - 5)x + ((2/3)^3 - 2(2/3)^2 - 5(2/3) + 6)$Simplifying this, we get: $x^3 - \frac{19}{3} x + \frac{56}{27}$.Now that we have a cubic equation with no quadratic term, we can find its roots by adding h back to each root. To do this, we need to solve the original cubic equation for x.Recall the triple-angle formula for cosine: $\cos 3\theta = 4 \cos^3 \theta - 3 \cos \theta$. The constant term in our equation is $-\frac{56}{27}$. If we equate this to the triple-angle formula, we get:$- \frac{56}{27} = x^3 - \frac{19}{3}x$We can rewrite this as: $\frac{4}{27}x^3 = \frac{19}{3}x + \frac{56}{27}$Now divide both sides by $\frac{4}{27}$:$x^3 = \frac{\left(19/3\right)x}{4/27} + \frac{56/27}{4/27}$ Simplifying, we get: $x^3 = \frac{27}{12}(19x) + \frac{27}{4}$Further simplification yields:$x^3 = \left(\frac{19}{4}\right)(9)x + \frac{27}{4}$$x^3 - (\frac{171}{4})x - \frac{27}{4} =0$Notice that there is no x^2 term. This means we can use the depressed terms method to find the roots of this equation.However, the presence of complex roots suggests that the original cubic equation was not factorable by simple arithmetic operations alone.Therefore, without employing numerical methods or further mathematical tools, such as trigonometry for solving real roots and completing the cube to solve other types of polynomial equations, we can't provide an exact solution here.Notice the similarities between $g(x)=0$ and $\cos 3\theta=-\frac{28}{19^{3/2}}$. In both cases, a cubic term and a linear term appear in terms of their respective variables. We want to make these two forms even closer by exploring a relationship between them, allowing us to make a clever substitution. Dividing the equation involving θ by 4, we get $$\frac{\cos 3\theta}{4}=\cos^3 \theta-\frac{3}{4}\cos \theta.$$ Now, let's consider the substitution $x=a\cos \theta$. There are many options for the pair (a,θ) that satisfy this relationship. We can choose θ and a real value a such that their product equals x. This flexibility allows us to make a desired change happen, similar to how we picked the value of h to eliminate the quadratic term in our previous example. Let's rewrite our equation currently in terms of x using this substitution: $$-\frac{56}{27}=(a\cos \theta)^3-\frac{19}{3}(a\cos \theta).$$ Dividing both sides by a^3, we have $$-\frac{56}{27a^3}=\cos^3 \theta-\frac{19}{3a^2}\cos \theta.$$ Recall the earlier relationship from the triple-angle formula: $$\frac{\cos 3\theta}{4}=\cos^3 \theta-\frac{3}{4}\cos \theta.$$ If we can make the right side of our equation match the right side of this equation, we could replace it with $\frac{1}{4}\cos 3\theta$. This would reduce the occurrences of our variable to a single occurrence, allowing us to solve for the remaining terms using the socks and shoes principle. We want to choose a such that the coefficient on $\cos \theta$ equals $\frac{3}{4}$. Finding this value, we see that: $$\frac{19}{3a^2}=\frac{3}{4}\quad\longrightarrow\quad a^2=\frac{19\cdot 4}{9}\quad\longrightarrow\quad a=\pm \frac{2}{3}\sqrt{19}.$$ We should pause and consider what could have happened if we had attacked a slightly different cubic equation. If the 19 above was negative, we would get complex values for a. As will be seen in upcoming paragraphs, this situation would require us to consider when the cosine of an angle is complex! Certainly, this never happens when the input to the cosine is real but what if the cosine function (and others) could accept complex-valued inputs? Lest we get ahead of ourselves, let's leave those exciting possibilities for now. With two options for a, both accomplishing our goal, let's pick the positive one. With $a=\frac{2}{3}\sqrt{19}$, we then have $$\cos^3 \theta-\frac{3}{4}\cos \theta=-\frac{7}{19^{3/2}}.$$ Finally, we've set ourselves up to replace the two occurrences of θ with a single one using the relationship from the triple-angle formula for cosine: $$\frac{\cos 3\theta}{4}=-\frac{7}{19^{3/2}}.$$ From here, we use socks and shoes. We must be careful when navigating the "wrinkle" that the cosine function is technically not invertible. That said, we know how to find (using the arccosine function, $\cos^{-1}$) all angles for which their cosine equals some given value. $$\begin{array}{rcl} \displaystyle{\frac{\cos 3\theta}{4}}&=& -\displaystyle{\frac{7}{19^{3/2}}}\\\\ \cos 3\theta &=& -\displaystyle{\frac{28}{19^{3/2}}}\\\\ 3\theta &=& \pm \displaystyle{\cos^{-1} \left(\frac{-28}{19^{3/2}}\right)+2\pi n \quad \textrm{where n is an integer}}\\\\ \theta &=& \pm \displaystyle{\frac{1}{3} \cos^{-1} \left(\frac{-28}{19^{3/2}}\right)+\frac{2\pi n}{3} \quad \textrm{where n is an integer}}\\\\ \end{array}$$ Our last steps are to work backwards from this solution for θ, first to a solution x to $g(x)=0$, and then to a solution x to $f(x)=0$. Recall that we let $x=a\cos \theta$, except now we know the value of a we wanted namely, $a=\frac{2}{3}\sqrt{19}$. As such, the following x solves $g(x)=0$: $$x = \frac{2}{3}\sqrt{19} \cos \left(\pm \frac{1}{3} \cos^{-1} \left(\frac{-28}{19^{3/2}}\right)+\frac{2\pi n}{3}\right) \quad \textrm{where n is an integer}$$ All that remains is to add $h=\frac{2}{3}$ to these solutions to find the x values that solve $f(x)=0$ $$x = \frac{2}{3}\sqrt{19} \cos \left(\pm \frac{1}{3} \cos^{-1} \left(\frac{-28}{19^{3/2}}\right)+\frac{2\pi n}{3}\right) + \frac{2}{3}\quad \textrm{where n is an integer}$$ Of course, we probably want to simplify these if we can! Evaluating the above with a calculator for $n=0$, $n=1$, and $n=2$ and the "$+$" option (things start to repeat after that), we shockingly get the below as our solution! $$x = 1, x = -2, \textrm{ or } x = 3$$ Note we can easily verify this, as if true our original polynomial should factor into: $$x^2 - 2x^2 - 5x + 6 = (x-1)(x+2)(x-3)$$ Expanding the right side, we seeThis is true wow cardano method gerolamo cardano just like quadratic equations there are multiple ways to solve cubic equations some of these give solutions in radically different forms while the above method expressed its solutions in terms of trigonometric functions and their inverses cardanos method after italian mathematician gerolamo cardano will reveal its solutions in a more algebraic form one that involves nested roots of various values seeking to give attribution where it is due note that while gerolamo cardano published the method seen below it was first discovered by scipione del ferro another italian mathematician born in 1465 considering the following cubic equation x cubed plus 3x squared plus 4x plus 3 equals 0 we begin in the same manner as the above method let us equate m to negative 3ab and n to negative a cubed plus b cubed and let x be equal to a plus b so that x solves both x cubed plus mx plus n equals 0 and x cubed minus 3abx minus a cubed minus b cubed equals 0 then we simply solve for a and b in terms of m and n and add them together to find x a solution to the depressed cubic whose roots we seek to solve this system it will be easier to only see the same powers of a and b so we cube both sides of the first equation this gives us the system m cubed equals negative 27a cubed b cubed and n equals negative a cubed minus b cubed now let us hide the detail of the cubing so we can better see the structure of what is left by letting A be equal to a cubed and B be equal to b cubed we have m cubed equals negative 27AB and n equals negative A plus B it is clear that AB equals negative m cubed over 27 and A plus B equals negative n solving for B in the first and substituting the result into the second reveals an equation easily convertible into a quadratic in A A times B equals negative m cubed over 27 endash gt B equals negative m cubed over 27A then A minus m cubed over 27A equals negative n which is equivalent to 27A squared plus 27nA minus m cubed equals zero this quadratic in A can be quickly solved with the quadratic formula A equals the fraction minus 27n plus the square root of open parenthesis 27n close parenthesis squared minus 4 times 27 times negative m cubed over 2 times 27 just as a bit of flourish we can rewrite the above with a bit more symmetry allowing us to remember it more easily if that be desired the algebra to convert the above form to the one given below is straightforward and not too long so the reader should try their hand at doing so A equals negative n over 2 plus or minus the square root of open parenthesis n over 2 close parenthesis squared plus open parenthesis m over 3 close parenthesis cubed by symmetry one of these will be the solution for A and the other will be a solution for B given that a is equal to the cube root of A b is equal to the cube root of B and one solution sought will be given by x equals a plus b we have x equals the cube root of negative n over 2 plus the square root of open parenthesis n over 2 close parenthesis squared plus open parenthesis m over 3 close parenthesis cubed endash minus the cube root of negative n over 2 minus the square root of open parenthesis n over 2 close parenthesis squared plus open parenthesis m over 3 close parenthesis cubed recalling that in our particular depressed cubic g x equals x cubed plus mx plus n both m and n equaled 1 we now have one solution in hand to g x equals 0 x equals the cube root of negative 1 half plus the square root of 1 fourth plus 1 over 27 endash minus the cube root of negative 1 half minus the square root of 1 fourth plus 1 over 27 finally adding h equals negative 1 to the above solution to g x equals 0 shifts it to a solution of f x equals 0 our original cubic equation x cubed plus 3x squared plus 4x plus 3 equals 0 x equals the cube root of negative 1 half plus the square root of 1 fourth plus 1 over 27 endash minus the cube root of negative 1 half minus the square root of 1 fourth plus 1 over 27 minus 1 one will note that an approximation to the exact solution has been provided above while finding the other two roots will be relatively simple from here the arithmetic involved can be well awful as such we will use approximations from this point forward but will provide enough detail to allow the ambitious masochistic reader to find the other roots exactly if they so desire armed with the knowledge that r1 is approximately equal to negative 1.682327804 is a root to f x equals 0 by the factor theorem we know f x has a factorDividing $f(x)$ by $(x-r_1)$ produces a quadratic equation whose roots, r_2 and r_3, are the remaining solutions to $f(x) = 0$. We can find these roots using the quadratic formula. After performing the division, we obtained complex roots $-0.658836 \pm 1.16154i$. To verify, we plugged these roots into $f(x)$ and found that $f(r_2) = f(r_3) \approx 3.06404 \times 10^{-6} + 4.0109 \times 10^{-6} i$, which is indeed close to zero. Applying a similar method as for the quadratic formula, such as completing the square or Po-Shen Loh's approach, we can find roots of a general cubic equation $ax^3+bx^2+cx+d=0$. This would give us three roots, although memorizing them might be challenging due to their complexity. Nevertheless, having a general solution is fascinating, especially considering the potential for solving quartic equations.

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