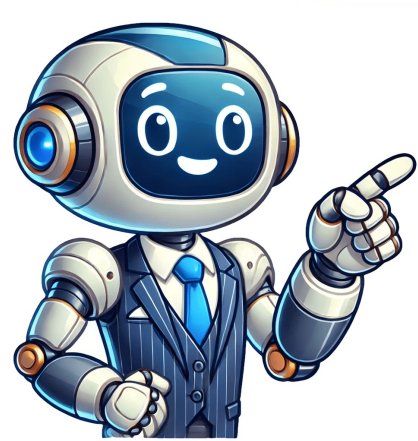


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Exponential Functions

Exponential Functions

Tech-enabled campusSanitized campus, spacious classrooms, and state-of-the-art technology for effective learning. Exponential functions are mathematical functions. These are widely used in many real-world situations, such as finding exponential decay or exponential growth. The exponential function decides whether an exponential curve will grow or decay. Here is all about the exponential function formula, graphs, and derivatives. Also, check out examples of exponential functions and important rules for solving problems. An exponential function is a mathematical function that is commonly used in real-world applications. It is primarily used to compute investments, model populations, and so on. This article will teach you about the formulas, rules, properties, graphs, derivatives, exponential series, and examples. Exponential functions are mathematical functions in form $f(x) = a^x$. Here " x " is a variable, and " a " is a constant. The constant ' a ' is the function's base, and its value should be greater than 0. The most common exponential function base is the Euler's number or mathematical number e . The value of e is approximately equal to 2.71828. $f(x)$ is any number such that $x > 0$ and $a > 1$, then the exponential function formula is: $f(x) = a^x$. Where the variable x occurs as the exponent. It is real number 17 is if is negative the function represents this $a^{\log(-x)} = -1/a^{\log(x)}$ Following exponential functions explain how the value of base ' a ' affects the equation. If the base value a is one or zero, the exponential function would be: $f(x) = 0x = 0$ or $f(x) = 1x = 1$. Thus, these become constant functions and do not possess properties similar to general exponential functions. If the base value is negative, we can get complex values on the function evaluation. $a = -4$ the function would be, $f(x) = (-4)^x = f(1/2) = (-4)^{-1/2} = -1/4 = -0.5$. So, we avoid $0, 1$, and negative base values because we want only real numbers to arise from the evaluation of exponential functions. Some examples of exponential functions are: $f(x) = 2x + 3$ $f(x) = 2x$ $f(x) = 3e2x$ $f(x) = (1/2)x = 2x$ $f(x) = 0.5x$ A function's exponential graph represents the exponential function properties. The exponential function $y = 2x$. The function $y = 2x$ graph is shown below. The derivative of exponential function $f(x) = a^x$, where $a > 0$ is the product of exponential function a^x and the natural log of a . This can be represented mathematically in terms of the integration of exponential functions as follows: $f'(x) = a^x \ln a$ When we plot a graph of the derivatives of an exponential function, it changes direction when $a > 1$ and when $a < 1$. Now we can also find the derivative of exponential function e^x using the above formula. Where e is a natural number called Euler's number. It is an important mathematical constant that equals 2.71828 (approx). So, $\ln e = \ln e = 1$ Hence the derivative of exponential function e^x is the function itself, i.e., if $f(x) = e^x$ then $f'(x) = e^x$ An exponential function graph helps in studying the properties of exponential functions. The following graph of exponents of x shows that as the exponent increases, the curve gets steeper. Also, the rate of growth increases. Mathematically, this means that for $x > 1$, the value of $f(x)$ increases exponentially. The value of $f(x)$ increases rapidly as x increases. The function $f(x) = a^x$ grows faster than that of $f(x)$. The exponential function with base > 1 , i.e., $a > 1$ can be written as $y = f(x) = a^x$. The set of entire real numbers will be the domain of the exponential function. Moreover, the range is the set of all the positive real numbers. If $a = b$ and $a > 1$, the logarithm of b to the base x is a . As a result, $\log_a b = x$ if $a = b$. This is referred to as a logarithmic function. The graph of an exponential function is an increasing or decreasing curve with a horizontal asymptote. The following graph of the basic exponential function $y = a^x$ will provide a clear understanding of the properties of exponential functions. When $a > 1$, the graph strictly increases as x . The graph will pass through $(0, 1)$ regardless of the value of a because $a^0 = 1$. We can note from this graph that the entire graph lies above the x -axis. This is because the range of y is all positive real numbers. When $0 < a < 1$, the graph increases as x . Thus, it is concave up. When 0 . These rules are vital for solving problems on exponential functions. When the base is the same, the exponents will get added upon the multiplication of the bases. The example illustrates the rule. $a^x \cdot a^y = a^{x+y}$, e.g., $52 \times 53 = 52+3 = 55 = 3125$ When the base is the same number, the exponents will be subtracted from the divisions. $a^x \cdot a^y = a^{x-y}$, e.g., $54 \times 52 = 54-2 = 52 = 25$ When power has an exponent, the base will be the same, and the exponents will multiply. $(a^x)^y = a^{xy}$, e.g., $(52)^3 = 52 \times 3 = 56 = 15,625$ When two different bases have the same exponents as power, the bases will multiply, and the product will have the same power. $axb^x = (ab)^x = 22 \times 3 = (2 \times 3)^2 = 6^2 = 36$ When a fraction is raised to a power, both the denominator and numerator will have the same power/exponent. $(a/b)^x = a^x/b^x = (6/2)^2 = 6^2/2^2 = 36/4 = 9$ Any exponent of the power zero is equal to 1. $a^0 = 1$ and $1^a = 1$ Exponential functions are relevant to applications that study various growth patterns and declines rates. Even quantity that decays or grows by a fixed percent over specific regular intervals possesses either exponential decay or exponential growth. Some common applications include plotting bacterial growth/decay, population growth and decline, and more. Exponential Growth refers to an increase in quantity over time, which is very slow at first and then increases rapidly. So, the rate of change increases over time. The rapid growth is an "exponential increase." The adjacent exponential growth curve shows the exponential increase in population over time. The following formula defines exponential growth: $y = a(1 + r)^x$ where r is the growth percentage. Exponential Decay is just the opposite of exponential growth. We widely use exponential growth and decay to study bacterial infections. Exponential decay refers to a decrease in quantity over time which is very rapid at first and then slows down. So, the rate of change decreases over time. The rapid decline is an "exponential decrease." The following formula defines exponential decay: $y = a(1 - r)^x$, where r is the decay percentage. Example 1: Simplify the following: $(2p^{2/3})^3 / 3(p^{2/3})^3$ $2p^{2/3 \times 3} / 3p^{2/3 \times 3} = 8p^2 / 3p^2 = 8p^2/3p^2$ To build an exponential function, you need to know what the base is and then use the power property. The base is whatever number you're going to multiply by itself over and over again to get your final answer. For example, if you want to build a function that represents 2^x where x is 5, then your base is 2 and your power is 5. If you have a function $f(x) = x^2 + 11x + 24$, then the base is 2 because it's the number being multiplied by itself to get your final answer (the exponent on x). Solving an exponential function is pretty similar to solving linear functions. To solve an exponential function, you need to isolate the variable on one side of the equation and then solve it, just like you would with a linear function. For example, suppose we have the following equation: $2x^2 + 3x - 5 = 0$. We can solve this by subtracting $3x$ from both sides of the equation: $2x^2 + 3x - 5 - 3x = 0 - 3x$. Now we can isolate x by dividing both sides by 2 : $2(2/2)x^2 + 3(6/6)x - 5(6/6) = 0(6/6)$. And finally, we can simplify the equation to $x^2 + 3x - 5 = 0$. Exponential functions are often used to describe the growth or decay of something over time, such as population growth or radioactive decay. Exponential functions show how quickly something increases or decreases over time. You can simplify an exponential equation by factoring out the term that is raised to the power of one. For example, if we have the following equation: $y = 2x^3 + 4x^2 - 4x$ You could factor out a common factor of x from both terms: $y = 2x^3 + 4x^2 - 4x = x(2x^2 + 4x - 4)$ To solve an exponential equation using a log, first, rewrite the expression as a logarithm. Then, use the properties of logs to solve for the variable. Example: Solve for x in equation $5x = 10^{15}$. First, write out the logarithmic form of the equation: $\log(5x) = 10^{15}$. Now, use the properties of logs to solve for x : $\log(5(10^{15})) = 5x / 10^{15} = 5$. How can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Favorites Looking for practice materials to master exponential and logarithmic equations? Our comprehensive worksheets provide ample opportunities to hone your skills! Each worksheet is designed with varied problems, accompanied by a detailed answer key. The PDF format is easy to check, rewrite, and print. Exponential Form The ability to convert between exponential and log logarithmic forms is an essential skill for solving logarithmic equations. An exponential equation typically expressed as $a^x = b$, where b is the base, x is the exponent, and x is the result, can be rewritten in logarithmic form. The logarithmic form highlights the exponent as the solution to the question: "To what power must we raise the base 'b' to obtain 'x'?" This transformation is expressed as $\log(b)x = x$. Understanding this relationship allows us to manipulate equations and apply appropriate solving techniques. For example, if we have $2x - 8 = 3$, we can rewrite it as $\log(2)(8) = 3$. This indicates that the logarithm base 2 of 8 is 3. Mastering this conversion is crucial because logarithmic equations are often easier to solve when expressed in logarithmic form, especially when dealing with unknown exponents. Practice converting various exponential equations to logarithmic form to build a strong foundation for more complex problem-solving. Recognize the base, the exponent, and the result, and then correctly position them in the logarithmic equation. Rewriting Logarithmic Equations in Exponential Form Just as important as converting exponential equations into logarithmic form is the ability to reverse the process. Rewriting logarithmic equations into exponential form allows us to simplify and solve for the unknown variable. A logarithmic equation, typically written as $\log(b)x = y$, states that the logarithm of x to the base b is equal to y . In other words, b raised to the power of y equals x . To convert this into exponential form, we express it as $b^y = x$. This transformation allows us to eliminate the logarithm and work with a more familiar exponential expression. For instance, consider the equation $\log(10)(100) = 2$. Rewriting this in exponential form gives us $10^2 = 100$. This simply states that 10 raised to the power of 2 equals 100, which is a true statement. This conversion is particularly useful when solving for x . Substituting the value of x into the equation allows us to check if the solution is correct. Exponential Equations Using the One-to-One Property The one-to-one property is a powerful tool for solving exponential equations, applicable when both sides of the equation can be expressed with the same base. This property states that if $b^x = b^y$, then $x = y$, where ' b ' is a positive number not equal to 1. In essence, if two exponential expressions with the same base are equal, then their exponents must also be equal. To effectively utilize this property, the first step is to manipulate the equation to have the same base on both sides. For example, consider the equation $2x = 8$. We can rewrite 8 as 2^3 , thus transforming the equation into $2x = 2^3$. Now, since the bases are the same, we can apply the one-to-one property and equate the exponents, giving us $x = 3$. This provides a direct and simple solution. However, not all exponential equations are immediately solvable using this property. Sometimes, algebraic manipulation or knowledge of common bases is required to rewrite the equation. For instance, in the equation $9x = 27$, we can recognize that both 9 and 27 are powers of 3. Rewriting the equation as $(3^2)x = 3^3$ simplifies to $3^{2x} = 3^3$. Applying the one-to-one property, we get $2x = 3$, which leads to $x = 3/2$. Practice identifying opportunities to express both sides of an equation with the same base to efficiently use this property. Solving Exponential Equations Using Logarithms When the one-to-one property cannot be directly applied because the bases are difficult or impossible to equalize, logarithms provide a powerful alternative method for solving exponential equations. The fundamental principle involves taking the logarithm of both sides of the equation, which allows us to bring the exponent down as a coefficient using the power rule of logarithms. This transforms the equation into a linear form, making it easier to solve for the variable. For example, consider the equation $2^x = 3x$. Taking the logarithm of both sides gives us $\log(2^x) = \log(3x)$. Using a calculator, we find that $x = 1.760$. The choice of logarithm base (common, natural, or any other) does not affect the final solution, although the natural logarithm (\ln) is often preferred for equations involving the constant ' e '. For example, in the equation $e^{2x} = 9$, taking the natural logarithm of both sides gives $\ln(e^{2x}) = \ln(9)$. This simplifies to $2x \ln(e) = \ln(9)$. Since $\ln(e) = 1$, we have $2x = \ln(9)$, and thus $x = \ln(9)/2 \approx 1.099$. This method is versatile and applicable to a wide range of exponential equations, making logarithms an indispensable tool in solving such problems. Solving Logarithmic Equations Using the One-to-One Property The one-to-one property of logarithms states that if $\log(b)x = \log(b)y$, then $x = y$, provided that $b > 0$ and $b \neq 1$, and both x and y are positive. This property allows us to solve logarithmic equations where we can express both sides of the equation as a single logarithm with the same base. For example, consider the equation $\log(2)(3x + 5) = \log(2)(x + 9)$. Since both sides are logarithms with the same base (2), we can apply the one-to-one property and set the arguments equal to each other: $3x + 5 = x + 9$. Solving for x , we subtract x from both sides to get $2x + 5 = 9$, then subtract 5 from both sides to get $2x = 4$. Finally, dividing by 2, we find $x = 2$. It is crucial to check the solution in the original equation to ensure that the arguments of the logarithms are positive. Plugging $x = 2$ into the original equation, we have $\log(2)(3(2) + 5) = \log(2)(11)$ and $\log(2)(2 + 9) = \log(2)(11)$, which confirms that $x = 2$ is a valid solution. However, if substituting the value of x results in a negative or zero argument within the logarithm, the solution is extraneous and must be discarded. This is because logarithms are only defined for positive arguments. For example, in the equation $\log(10)(x - 1) = 2$, if we find $x = 1$, it would result in $\log(10)(0)$, which is undefined. Therefore, we must always check for extraneous solutions. Applications of Exponential Equations Exponential equations are powerful tools for modeling various real-world phenomena. One prominent application lies in finance, specifically compound interest calculations. The formula $A = P(1 + r/n)^{nt}$ describes how an initial principal amount, P , grows over time with an interest rate, r , compounded n times per year for t years. Exponential equations help determine future account balances, investment growth, or loan repayment schedules. Another significant application is in population growth and decay models. For instance, bacterial growth, animal populations, and radioactive decay can often be modeled using exponential functions. Equations of the form $N(t) = N_0e^{kt}$ are used, where $N(t)$ is the population at time t , N_0 is the initial population, k is the growth or decay constant, and e is the base of the natural logarithm. A positive k indicates growth, while a negative k indicates decay. Furthermore, exponential equations are crucial in fields like epidemiology for modeling the spread of infectious diseases. They also appear in physics, describing phenomena like the discharge of a capacitor or the change in air pressure with altitude. Understanding and solving exponential equations allows us to make predictions and gain insights into these diverse and important processes. Carbon dating, for example, relies on the exponential decay of carbon-14. Applications of Logarithmic Equations Logarithmic equations find widespread applications in various scientific and engineering fields, notably in scenarios where dealing with very large or very small numbers is necessary. A classic example is the Richter scale, used to measure the magnitude of earthquakes. The scale is logarithmic, meaning each whole number increase represents a tenfold increase in amplitude. Logarithmic equations are also used in seismology to understand the relationship between the magnitude of an earthquake and the energy released. In chemistry, pH, a measure of acidity or alkalinity, is defined using a logarithmic scale. The pH of a solution is calculated as the negative logarithm of the concentration of hydrogen ions. In acoustics, sound intensity is measured on a logarithmic scale, and the sound level in decibels (dB) is related to the logarithm of the ratio of the sound intensity to a reference intensity. This logarithmic scale makes it easier to represent and compare the vast range of sound intensities that humans can perceive. Logarithmic equations also appear in information theory, particularly in measuring information entropy and data compression. These diverse applications highlight the importance of understanding logarithmic equations. Answer Keys and Worked Solutions for Practice Problems To facilitate effective learning and self-assessment, our comprehensive worksheet package includes detailed answer keys and worked solutions for all practice problems. The answer keys provide the final answers for each question, enabling students to quickly verify their work and identify areas where they may need additional practice. Beyond simply providing answers, we also offer step-by-step worked solutions, demonstrating the complete problem-solving process. These worked solutions are invaluable for understanding the underlying concepts and techniques required to solve exponential and logarithmic equations. Each step is clearly explained, allowing students to follow the logic and reasoning behind the solution. The worked solutions also highlight common mistakes and pitfalls, helping students avoid these errors in future problem-solving scenarios. By studying the worked solutions, students can develop a deeper understanding of the material and improve their problem-solving skills. Moreover, the availability of both answer keys and worked solutions promotes independent learning and allows students to learn at their own pace. They can use the answer keys for quick verification and refer to the worked solutions for detailed explanations when needed. This comprehensive approach ensures that students have all the resources necessary to master exponential and logarithmic equations effectively. The answer keys and worked solutions are available for all practice problems, including the ones on this page. Applications of Exponential Equations Exponential equations are powerful tools for modeling various real-world phenomena. One prominent application lies in finance, specifically compound interest calculations. The formula $A = P(1 + r/n)^{nt}$ describes how an initial principal amount, P , grows over time with an interest rate, r , compounded n times per year for t years. Exponential equations help determine future account balances, investment growth, or loan repayment schedules. Another significant application is in population growth and decay models. For instance, bacterial growth, animal populations, and radioactive decay can often be modeled using exponential functions. 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