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Problemas de crecimiento exponencial de bacterias resueltos

6.8.1 Use the exponential growth model in applications, including population growth and compound interest. 6.8.2 Explain the concept of doubling time. 6.8.3 Use the exponential decay model in applications, including radioactive decay and Newton’s law of cooling. 6.8.4 Explain the concept of half-life. One of the most prevalent applications of exponential functions involves growth and decay models. Exponential growth and decay show up in a host of natural applications. From population growth and continuously compounded interest to radioactive decay and Newton’s law of cooling, exponential functions are ubiquitous in nature. In this section, we examine exponential growth and decay in the context of some of these applications. Many systems exhibit exponential growth. These systems follow a model of the form y=y0ekt,y=y0ekt, where y0y0 represents the initial state of the system and kk is a positive constant, called the growth constant. Notice that in an exponential growth model, we have y′=ky0ekt=ky.y′=ky0ekt=ky. (6.27) That is, the rate of growth is proportional to the current function value. This is a key feature of exponential growth. Equation 6.27 involves derivatives and is called a differential equation. We learn more about differential equations in Introduction to Differential Equations. Systems that exhibit exponential growth increase according to the mathematical model where y0y0 represents the initial state of the system and k>0k>0 is a constant, called the growth constant. Population growth is a common example of exponential growth. Consider a population of bacteria, for instance. It seems plausible that the rate of population growth would be proportional to the size of the population. After all, the more bacteria there are to reproduce, the faster the population grows. Figure 6.79 and Table 6.1 represent the growth of a population of bacteria with an initial population of 200200 bacteria and a growth constant of 0.02.0.02. Notice that after only 22 hours (120(120 minutes), the population is 1010 times its original size! Figure 6.79 An example of exponential growth for bacteria. Time (min) Population Size (no. of bacteria) 1010 244244 2020 298298 3030 364364 4040 445445 5050 544544 6060 664664 7070 811811 8080 991991 9090 12101210 100100 14781478 110110 18051805 120120 22052205 Table 6.1 Exponential Growth of a Bacterial Population Note that we are using a continuous function to model what is inherently discrete behavior. At any given time, the real-world population contains a whole number of bacteria, although the model takes on noninteger values. When using exponential growth models, we must always be careful to interpret the function values in the context of the phenomenon we are modeling. Consider the population of bacteria described earlier. This population grows according to the function f(t)=200e0.02t,f(t)=200e0.02t, where t is measured in minutes. How many bacteria are present in the population after 55 hours (300(300 minutes)? When does the population reach 100,000100,000 bacteria? We have f(t)=200e0.02t.f(t)=200e0.02t. Then f (300) = 200 e 0.02 (300) ≈ 80,686 . f (300) = 200 e 0.02 (300) ≈ 80,686 . There are 80,68680,686 bacteria in the population after 55 hours. To find when the population reaches 100,000100,000 bacteria, we solve the equation 100,000 = 200 e 0.02 t 500 = e 0.02 t ln 500 = 0.02 t t = ln 500 0.02 ≈ 310.73. 100,000 = 200 e 0.02 t 500 = e 0.02 t ln 500 = 0.02 t t = ln 500 0.02 ≈ 310.73. The population reaches 100,000100,000 bacteria after 310.73310.73 minutes. Consider a population of bacteria that grows according to the function f(t)=500e0.05t,f(t)=500e0.05t, where tt is measured in minutes. How many bacteria are present in the population after 4 hours? When does the population reach 100100 million bacteria? Let’s now turn our attention to a financial application: compound interest. Interest that is not compounded is called simple interest. Simple interest is paid once, at the end of the specified time period (usually 11 year). So, if we put $1000$1000 in a savings account earning 2%2% simple interest per year, then at the end of the year we have 1000(1+0.02)=$1020.1000(1+0.02)=$1020. Compound interest is paid multiple times per year, depending on the compounding period. Therefore, if the bank compounds the interest every 66 months, it credits half of the year’s interest to the account after 66 months. During the second half of the year, the account earns interest not only on the initial $1000,$1000, but also on the interest earned during the first half of the year. Mathematically speaking, at the end of the year, we have 1000(1+0.022)2=$1020.10.1000(1+0.022)2=$1020.10. Similarly, if the interest is compounded every 44 months, we have 1000(1+0.023)3=$1020.13,1000(1+0.023)3=$1020.13, and if the interest is compounded daily (365(365 times per year), we have $1020.20.$1020.20. If we extend this concept, so that the interest is compounded continuously, after tt years we have 1000limn→∞(1+0.02n)nt.1000limn→∞(1+0.02n)nt. Now let’s manipulate this expression so that we have an exponential growth function. Recall that the number ee can be expressed as a limit: e=limm→∞(1+1m)m.e=limm→∞(1+1m)m. Based on this, we want the expression inside the parentheses to have the form (1+1/m).(1+1/m). Let n=0.02m.n=0.02m. Note that as n→∞,n→∞, m→∞m→∞ as well. Then we get 1000limn→∞(1+0.02n)nt=1000limm→∞(1+0.020.02m)0.02mt=1000[limm→∞(1+1m)m]0.02t.1000limn→∞(1+0.02n)nt=1000limm→∞(1+0.020.02m)0.02mt=1000[limm→∞(1+1m)m]0.02t. We recognize the limit inside the brackets as the number e.e. So, the balance in our bank account after tt years is given by 1000e0.02t.1000e0.02t. Generalizing this concept, we see that if a bank account with an initial balance of PP earns interest at a rate of r%,r%, compounded continuously, then the balance of the account after tt years is Balance=Pert.Balance=Pert. A 25-year-old student is offered an opportunity to invest some money in a retirement account that pays 5%5% annual interest compounded continuously. How much does the student need to invest today to have $1$1 million when she retires at age 65?65? What if she could earn 6%6% annual interest compounded continuously instead? We have 1,000,000 = P e 0.05 (40) P = 135,335.28. 1,000,000 = P e 0.05 (40) P = 135,335.28. She must invest $135,335.28$135,335.28 at 5%5% interest. If, instead, she is able to earn 6%,6%, then the equation becomes 1,000,000 = P e 0.06 (40) P = 90,717.95. 1,000,000 = P e 0.06 (40) P = 90,717.95. In this case, she needs to invest only $90,717.95.$90,717.95. This is roughly two-thirds the amount she needs to invest at 5%.5%. The fact that the interest is compounded continuously greatly magnifies the effect of the 1%1% increase in interest rate. Suppose instead of investing at age 2525, the student waits until age 35.35. How much would she have to invest at 5%?5%? At 6%?6%? If a quantity grows exponentially, the time it takes for the quantity to double remains constant. In other words, it takes the same amount of time for a population of bacteria to grow from 100100 to 200200 bacteria as it does to grow from 10,00010,000 to 20,00020,000 bacteria. This time is called the doubling time. To calculate the doubling time, we want to know when the quantity reaches twice its original size. So we have 2y0=y0ekt2=ektln2=ktt=ln2k.2y0=y0ekt2=ektln2=ktt=ln2k. If a quantity grows exponentially, the doubling time is the amount of time it takes the quantity to double. It is given by Doubling time=ln2k.Doubling time=ln2k. Assume a population of fish grows exponentially. A pond is stocked initially with 500500 fish. After 66 months, there are 10001000 fish in the pond. The owner will allow his friends and neighbors to fish on his pond after the fish population reaches 10,000.10,000. When will the owner’s friends be allowed to fish? We know it takes the population of fish 66 months to double in size. So, if t represents time in months, by the doubling-time formula, we have 6=(ln2)/k.6=(ln2)/k. Then, k=(ln2)/6.k=(ln2)/6. Thus, the population is given by y=500e((ln2)/6)t.y=500e((ln2)/6)t. To figure out when the population reaches 10,00010,000 fish, we must solve the following equation: 10,000 = 500 e (ln 2 / 6) t 20 = e (ln 2 / 6) t ln 20 = (ln 2 6) t t = 6 (ln 20) ln 2 ≈ 25.93. 10,000 = 500 e (ln 2 / 6) t 20 = e (ln 2 / 6) t ln 20 = (ln 2 6) t t = 6 (ln 20) ln 2 ≈ 25.93. The owner’s friends have to wait 25.9325.93 months (a little more than 22 years) to fish in the pond. Suppose it takes 99 months for the fish population in Example 6.44 to reach 10001000 fish. Under these circumstances, how long do the owner’s friends have to wait? Exponential functions can also be used to model populations that shrink (from disease, for example), or chemical compounds that break down over time. We say that such systems exhibit exponential decay, rather than exponential growth. The model is nearly the same, except there is a negative sign in the exponent. Thus, for some positive constant k,k, we have y=y0e−kt.y=y0e−kt. As with exponential growth, there is a differential equation associated with exponential decay. We have y′=−ky0e−kt=−ky.y′=−ky0e−kt=−ky. Systems that exhibit exponential decay behave according to the model where y0y0 represents the initial state of the system and k>0k>0 is a constant, called the decay constant. The following figure shows a graph of a representative exponential decay function. Figure 6.80 An example of exponential decay. Let’s look at a physical application of exponential decay. Newton’s law of cooling says that an object cools at a rate proportional to the difference between the temperature of the object and the temperature of the surroundings. In other words, if TT represents the temperature of the object and TaTa represents the ambient temperature in a room, then T′=−k(T−Ta).T′=−k(T−Ta). Note that this is not quite the right model for exponential decay. We want the derivative to be proportional to the function, and this expression has the additional TaTa term. Fortunately, we can make a change of variables that resolves this issue. Let y(t)=T(t)−Ta.y(t)=T(t)−Ta. Then y′(t)=T′(t)−0=T′(t),y′(t)=T′(t)−0=T′(t), and our equation becomes y′=−ky.y′=−ky. From our previous work, we know this relationship between y and its derivative leads to exponential decay. Thus, y=y0e−kt,y=y0e−kt, and we see that T−Ta=(T0−Ta)e−ktT=(T0−Ta)e−kt+TaT−Ta=(T0−Ta)e−ktT=(T0−Ta)e−kt+Ta where T0T0 represents the initial temperature. Let’s apply this formula in the following example. According to experienced baristas, the optimal temperature to serve coffee is between 155°F155°F and 175°F.175°F. Suppose coffee is poured at a temperature of 200°F,200°F, and after 22 minutes in a 70°F70°F room it has cooled to 180°F.180°F. When is the coffee first cool enough to serve? When is the coffee too cold to serve? Round answers to the nearest half minute. We have T = (T 0 − T a) e − k t + T a 180 = (200 − 70) e − k (2) + 70 110 = 130 e −2 k 11 13 = e −2 k ln 11 13 = −2 k ln 11 − ln 13 = −2 k k = ln 13 − ln 11 2 . T = (T 0 − T a) e − k t + T a 180 = (200 − 70) e − k (2) + 70 110 = 130 e −2 k 11 13 = e −2 k ln 11 13 = −2 k ln 11 − ln 13 = −2 k k = ln 13 − ln 11 2 . Then, the model is T=130e(ln11−ln132)t+70.T=130e(ln11−ln132)t+70. The coffee reaches 175°F175°F when 175 = 130 e (ln 11 − ln 13 2) t + 70 105 = 130 e (ln 11 − ln 13 2) t 21 26 = e (ln 11 − ln 13 2) t ln 21 26 = ln 11 − ln 13 2 t ln 21 − ln 26 = ln 11 − ln 13 2 t t = 2 (ln 21 − ln 26) ln 11 − ln 13 ≈ 2.56. 175 = 130 e (ln 11 − ln 13 2) t + 70 105 = 130 e (ln 11 − ln 13 2) t 21 26 = e (ln 11 − ln 13 2) t ln 21 26 = ln 11 − ln 13 2 t ln 21 − ln 26 = ln 11 − ln 13 2 t t = 2 (ln 21 − ln 26) ln 11 − ln 13 ≈ 2.56. The coffee can be served about 2.52.5 minutes after it is poured. The coffee reaches 155°F155°F at 155 = 130 e (ln 11 − ln 13 2) t + 70 85 = 130 e (ln 11 − ln 13 2) t 17 26 = e (ln 11 − ln 13 2) t ln 17 − ln 26 = (ln 11 − ln 13 2) t t = 2 (ln 17 − ln 26) ln 11 − ln 13 ≈ 5.09. 155 = 130 e (ln 11 − ln 13 2) t + 70 85 = 130 e (ln 11 − ln 13 2) t 17 26 = e (ln 11 − ln 13 2) t ln 17 − ln 26 = (ln 11 − ln 13 2) t t = 2 (ln 17 − ln 26) ln 11 − ln 13 ≈ 5.09. The coffee is too cold to be served about 55 minutes after it is poured. Suppose the room is warmer (75°F)(75°F) and, after 22 minutes, the coffee has cooled only to 185°F.185°F. When is the coffee first cool enough to serve? When is the coffee be too cold to serve? Round answers to the nearest half minute. Just as systems exhibiting exponential growth have a constant doubling time, systems exhibiting exponential decay have a constant half-life. To calculate the half-life, we want to know when the quantity reaches half its original size. Therefore, we have y02=y0e−kt12=e−kt−ln2=−ktt=ln2k.y02=y0e−kt12=e−kt−ln2=−ktt=ln2k. Note: This is the same expression we came up with for doubling time. If a quantity decays exponentially, the half-life is the amount of time it takes the quantity to be reduced by half. It is given by Half-life=ln2k.Half-life=ln2k. One of the most common applications of an exponential decay model is carbon dating. Carbon-14Carbon-14 decays (emits a radioactive particle) at a regular and consistent exponential rate. Therefore, if we know how much carbon was originally present in an object and how much carbon remains, we can determine the age of the object. The half-life of carbon-14carbon-14 is approximately 57305730 years—meaning, after that many years, half the material has converted from the original carbon-14carbon-14 to the new nonradioactive nitrogen-14.nitrogen-14. If we have 100100 g carbon-14carbon-14 today, how much is left in 5050 years? If an artifact that originally contained 100100 g of carbon, how old is it? Round the answer to the nearest hundred years. We have 5730 = ln 2 k k = ln 2 5730 . 5730 = ln 2 k k = ln 2 5730 . So, the model says y = 100 e − (ln 2 / 5730) t . y = 100 e − (ln 2 / 5730) t . In 5050 years, we have y = 100 e − (ln 2 / 5730) (50) ≈ 99.40 . y = 100 e − (ln 2 / 5730) (50) ≈ 99.40 . Therefore, in 5050 years, 99.4099.40 g of carbon-14carbon-14 remains. To determine the age of the artifact, we must solve 10 = 100 e − (ln 2 / 5730) t 1 10 = e − (ln 2 / 5730) t t ≈ 19035. 10 = 100 e − (ln 2 / 5730) t 1 10 = e − (ln 2 / 5730) t t ≈ 19035. The artifact is about 19,00019,000 years old. If we have 100100 g of carbon-14,carbon-14, how much is left after 500500 years? If an artifact that originally contained 100100 g of carbon now contains 20g20g of carbon, how old is it? Round the answer to the nearest hundred years. True or False? If true, prove it. If false, find the true answer. 348. The doubling time for y=ecty=ect is (ln(2))/(ln(c)).(ln(2))/(ln(c)). 349. If you invest $500,$500, an annual rate of interest of 3%3% yields more money in the first year than a 2.5%2.5% continuous rate of interest. 350. If you leave a 100°C100°C pot of tea at room temperature (25°C)(25°C) and an identical pot in the refrigerator (5°C),(5°C), with k=0.02,k=0.02, the tea in the refrigerator reaches a drinkable temperature (70°C)(70°C) more than 55 minutes before the tea at room temperature. 351. If given a half-life of t years, the constant kk for y=ekty=ekt is calculated by k=ln(1/2)/t.k=ln(1/2)/t. For the following exercises, use y=y0ekt.y=y0ekt. 352. If a culture of bacteria doubles in 33 hours, how many hours does it take to multiply by 10?10? 353. If bacteria increase by a factor of 1010 in 1010 hours, how many hours does it take to increase by 100?100? 354. How old is a skull that contains one-fifth as much radiocarbon as a modern skull? Note that the half-life of radiocarbon is 57305730 years. 355. If a relic contains 90%90% as much radiocarbon as new material, can it have come from the time of Christ (approximately 20002000 years ago)? Note that the half-life of radiocarbon is 57305730 years. 356. The population of Cairo grew from 55 million to 1010 million in 2020 years. Use an exponential model to find when the population was 88 million. 357. The populations of New York and Los Angeles are growing at 1%1% and 1.4%1.4% a year, respectively. Starting from 88 million (New York) and 66 million (Los Angeles), when are the populations equal? 358. Suppose the value of $1$1 in Japanese yen decreases at 2%2% per year. Starting from $1=¥250,$1=¥250, when will $1=¥1?$1=¥1? 359. The effect of advertising decays exponentially. If 40%40% of the population remembers a new product after 33 days, how long will 20%20% remember it? 360. If y=1000y=1000 at t=3t=3 and y=3000y=3000 at t=4,t=4, what was y0y0 at t=0?t=0? 361. If y=100y=100 at t=4t=4 and y=10y=10 at t=8,t=8, when does y=1?y=1? 362. If a bank offers annual interest of 7.5%7.5% or continuous interest of 7.25%,7.25%, which has a better annual yield? 363. What continuous interest rate has the same yield as an annual rate of 9%?9%? 364. If you deposit $5000$5000 at 8%8% annual interest, how many years can you withdraw $500$500 (starting after the first year) without running out of money? 365. You are trying to save $50,000$50,000 in 2020 years for college tuition for your child. If interest is a continuous 10%,10%, how much do you need to invest initially? 366. You are cooling a turkey that was taken out of the oven with an internal temperature of 165°F.165°F. After 1010 minutes of resting the turkey in a 70°F70°F apartment, the temperature has reached 155°F.155°F. What is the temperature of the turkey 2020 minutes after taking it out of the oven? 367. You are trying to thaw some vegetables that are at a temperature of 1°F.1°F. To thaw vegetables safely, you must put them in the refrigerator, which has an ambient temperature of 44°F.44°F. You check on your vegetables 22 hours after putting them in the refrigerator to find that they are now 12°F.12°F. Plot the resulting temperature curve and use it to determine when the vegetables reach 33°F.33°F. 368. You are an archaeologist and are given a bone that is claimed to be from a Tyrannosaurus Rex. You know these dinosaurs lived during the Cretaceous Era (146(146 million years to 6565 million years ago), and you find by radiocarbon dating that there is 0.000001%0.000001% the amount of radiocarbon. Is this bone from the Cretaceous? 369. The spent fuel of a nuclear reactor contains plutonium-239, which has a half-life of 24,00024,000 years. If 11 barrel containing 10kg10kg of plutonium-239 is sealed, how many years must pass until only 10g10g of plutonium-239 is left? For the next set of exercises, use the following table, which features the world population by decade. Years since 1950 Population (millions) 00 2,5562,556 1010 3,0393,039 2020 3,7063,706 3030 4,4534,453 4040 5,2795,279 5050 6,0836,083 6060 6,8496,849 Source: . 370. [T] The best-fit exponential curve to the data of the form P(t)=aebtP(t)=aebt is given by P(t)=2686e0.01604t.P(t)=2686e0.01604t. Use a graphing calculator to graph the data and the exponential curve together. 371. [T] Find and graph the derivative y′y′ of your equation. Where is it increasing and what is the meaning of this increase? 372. [T] Find and graph the second derivative of your equation. Where is it increasing and what is the meaning of this increase? 373. [T] Find the predicted date when the population reaches 1010 billion. Using your previous answers about the first and second derivatives, explain why exponential growth is unsuccessful in predicting the future. For the next set of exercises, use the following table, which shows the population of San Francisco during the 19th century. Years since 1850 Population (thousands) 00 21.0021.00 1010 56.8056.80 2020 149.5149.5 3030 234.0234.0 Source: . 374. [T] The best-fit exponential curve to the data of the form P(t)=aebtP(t)=aebt is given by P(t)=35.26e0.06407t.P(t)=35.26e0.06407t. Use a graphing calculator to graph the data and the exponential curve together. 375. [T] Find and graph the derivative y′y′ of your equation. Where is it increasing? What is the meaning of this increase? Is there a value where the increase is maximal? 376. [T] Find and graph the second derivative of your equation. Where is it increasing? What is the meaning of this increase? El crecimiento exponencial es un patrón de datos que muestra incrementos más grandes a medida que pasa el tiempo, creando la curva de una función exponencial. Por ejemplo, si es que una población de bacteria empieza con dos en el primer mes, luego con cuatro en el segundo mes, 16 en el tercer mes, 256 en el cuarto mes y así, significa que la población crece exponencialmente con una potencia de 2 cada año. La siguiente fórmula es usada para modelar el crecimiento exponencial. Si es que una cantidad crece por un porcentaje fijo en intervalos regulares, el patrón puede ser descrito por esta función: Crecimiento Exponencial$latex y=a{{(1+r)}^x}$ Recordamos que la función exponencial original tiene la forma $latex y=a{{b}^x}$. En la fórmula del crecimiento original, hemos reemplazado a b con $latex 1+r$. Entonces, en esta fórmula tenemos: $latex a=$ valor inicial. Esta es la cantidad inicial antes del crecimiento. $latex r=$ tasa de crecimiento. Esto es representado como un decimal. $latex x=$ intervalo de tiempo. Esto es el tiempo que ha pasado. La mayoría de eventos que ocurren naturalmente crecen continuamente. Por ejemplo, las bacterias siguen creciendo a lo largo de un periodo de 24 horas. Las bacterias no esperan hasta el final de las 24 horas para reproducirse todas al mismo tiempo. Para modelar el crecimiento continuo que ocurre naturalmente como las poblaciones, bacteria, etc., usamos el exponencial e. e puede ser pensada como una constante universal que representa las posibilidades de crecimiento usando un proceso continuo. Además, usando e también podemos representar al crecimiento medido periodicamente a lo largo del tiempo. Entonces, si es que una cantidad crece continuamente con un porcentaje fijo, podemos usar la siguiente fórmula para modelar este patrón: Crecimiento Exponencial Continuo$latex A=A_{0}{{e}^{kt}}$ En esta fórmula tenemos: $latex A=$ valor final. Esta es la cantidad después del crecimiento. $latex A_{0}=$ valor inicial. Esta es la cantidad antes del crecimiento. $latex e=$ exponencial. e es aproximadamente igual a 2.718... $latex k=$ tasa de crecimiento continuo. También es denominada la constante de proporcionalidad. $latex t=$ tiempo transcurrido. Los siguientes ejercicios usan las fórmulas detalladas arriba y alguna variación para encontrar la solución. Es recomendable que intentes resolver los ejercicios tú mismo antes de mirar la respuesta. Una población de bacteria crece de acuerdo con la función $latex f(x)=100{{e}^{0.02t}}$, en donde t es medido en minutos. ¿Cuántas bacterias habrá después de 4 horas (240 minutos)? Este es un crecimiento continuo, por lo que tenemos la fórmula $latex A=A_{0}{{e}^{kt}}$. Podemos reconocer los siguientes datos: $latex A_{0}=100$ $latex k=0.02$ $latex t=240$ Entonces, tenemos: $latex f(240)=100{{e}^{0.02(240)}}\approx 12151$ Entonces, habrá 12 151 bacterias después de 4 horas. Una población de bacteria crece de acuerdo con la función $latex f(x)=100{{e}^{0.02t}}$, en donde t es medido en minutos. ¿Cuándo llegará la población a 50 000? Aquí, tenemos misma fórmula que el anterior ejercicio, pero ahora tenemos que encontrar el tiempo conociendo la cantidad final. Podemos reconocer los siguientes datos: $latex A_{0}=100$ $latex k=0.02$ $latex A=50000$ Entonces, tenemos: $latex 50 000=100{{e}^{0.02t}}$ $latex 500={{e}^{0.02t}}$ $latex \ln(500)=0.02t$ $latex t=\frac{\ln(500)}{0.02}$ $latex t\approx 310.73$ Entonces, la población de bacterias llegará a ser 50 000 después de 310.73 minutos. Podemos modelar a la población de una comunidad con la fórmula $latex A=10000({{e}^{0.005t}})$. Aquí, A representa a la población y t representa el tiempo en años. ¿Cuál es la población después de 10 años? Ya tenemos una fórmula dada: $latex A=10000({{e}^{0.005t}})$. Tenemos que calcular la población usando el tiempo $latex t=10$. Entonces, reemplazamos $latex t=10$ para obtener: $latex A=10000({{e}^{0.005(10)}})$ $latex =10000({{e}^{0.05}})$ $latex =10000(1.0513)$ $latex =10513$ Por lo tanto, la población en la comunidad después de 10 años será 10 513. La población de cierta comunidad era 10 000 en el año 1980. En el año 2000, se encontró había crecido y era 20 000. Forma una función exponencial para modelar a la población de la comunidad P que cambia a través del tiempo t. Cuando tenemos crecimiento poblacional continuo, podemos modelar a la población con la fórmula general $latex P=P_{0}({{e}^{\lambda t}})$, en donde $latex P_{0}$ representa a la población inicial, λ es la constante de crecimiento exponencial y t es el tiempo. Usando la información dada, tenemos que encontrar la constante λ para completar la fórmula. Entonces, tenemos: $latex P=P_{0}({{e}^{\lambda t}})$ $latex 20000=10000({{e}^{20 \lambda}})$ $latex \frac{20000}{10000}={{e}^{20 \lambda}}$ $latex 2={{e}^{20 \lambda}}$ $latex \ln(2)=20 \lambda$ $latex \frac{\ln(2)}{20}=\lambda$ $latex 0.0347=\lambda$ Entonces, podemos modelar al crecimiento poblacional de la comunidad con la fórmula $latex P=10000({{e}^{0.0347 t}})$. El crecimiento poblacional de una ciudad pequeña es modelado con la función $latex P=P_{0}({{e}^{0.1234t}})$. ¿Cuándo llegó la población a 37 500 si es que en 1980 la población fue 12500? Podemos reemplazar los valores en la fórmula con la información dada: $latex P=P_{0}({{e}^{0.1234t}})$ $latex 37500=12500({{e}^{0.1234t}})$ Ahora, tenemos que despejar para el tiempo: $latex 37500=12500({{e}^{0.1234t}})$ $latex \frac{37500}{12500}=({{e}^{0.1234t}})$ $latex 3=({{e}^{0.1234t}})$ $latex \ln(3)=0.1234t$ $latex \frac{\ln(3)}{0.1234}=t$ $latex 8.9=t$ Por lo tanto, la población de la ciudad llegó a 37 500 en 1989. Un tipo de bacteria se duplica cada 5 minutos. Asumiendo que empezamos con una bacteria, ¿cuántas bacterias tendremos al final de 96 minutos? Sabemos que la bacteria crece continuamente, por lo que tenemos que usar la fórmula: $latex A=A_{0}({{e}^{kt}})$ La bacteria se duplica cada 5 minutos, entonces después de 5 minutos, tendremos 2. Usamos esto para encontrar el valor de k: $latex 2=1({{e}^{5k}})$ $latex \ln(2)=\ln({{e}^{5k}})$ $latex \ln(2)=5k$ $latex k=\frac{\ln(2)}{5}$ $latex k=0.13863$ Ahora, formamos la ecuación usando este valor de k y resolvemos usando el tiempo de 96 minutos: $latex A=A_{0}({{e}^{0.13863t}})$ $latex A=1({{e}^{0.13863(96)}})$ $latex A\approx602 248$ → Calculadora de Ecuaciones Exponenciales Practica el uso de las fórmulas de crecimiento exponencial con los siguientes ejercicios. Resuelve los ejercicios y selecciona una respuesta. Verifica tu respuesta para comprobar que seleccionaste la correcta. ¿Interesado en aprender más sobre funciones exponenciales? 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