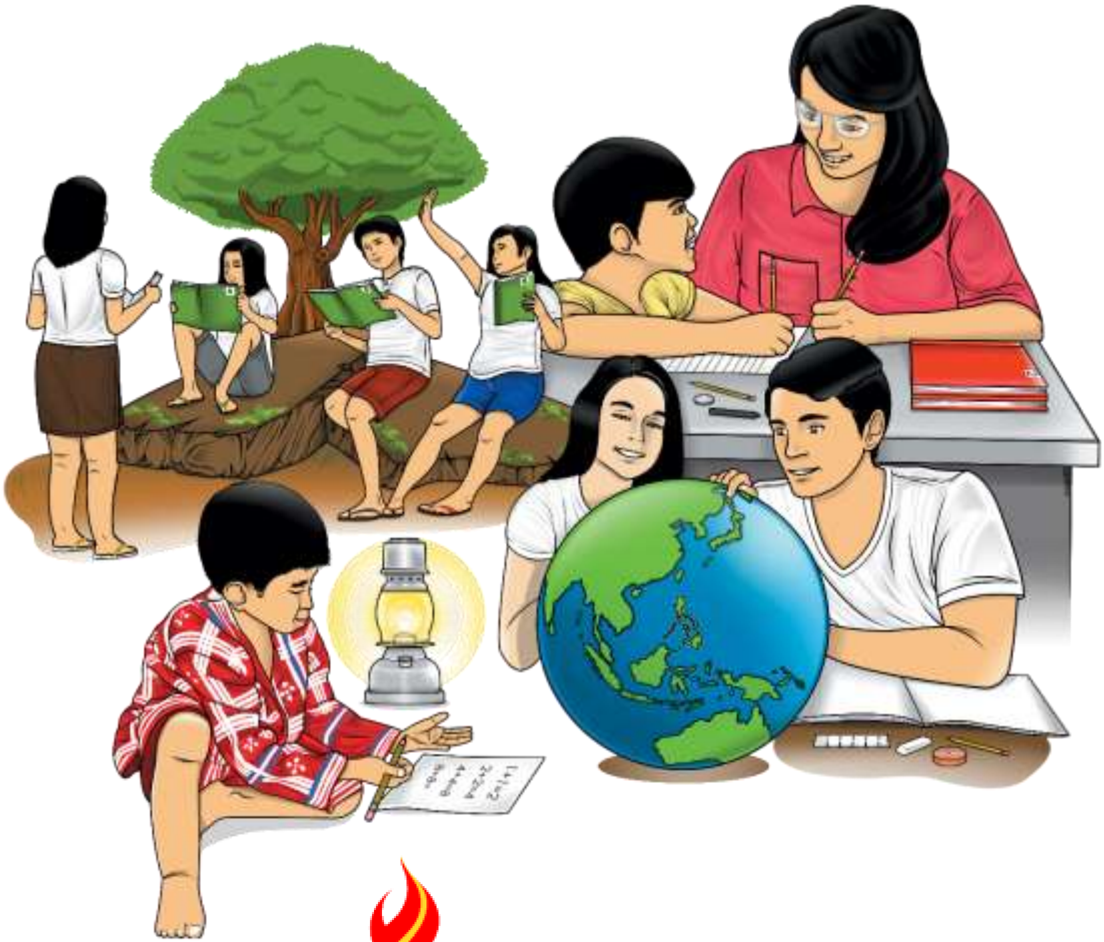
Senior High School

DepED DEPARTMENT OF EDUCATION

General Mathematics

Quarter 1 – Module 16:
Representing Real-life Situations Using Exponential Functions



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DEPARTMENT OF EDUCATION

Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

What I Need to Know

Population growth is believed to be continuous overtime and there is an increase in growth rate over time. This scenario illustrates the exponential function. Population growth of organisms, growth of money in the bank, as well as decay of a substance, are some of the occurrences where exponential functions are used. Exponential function belongs to the so-called transcendental functions because they cannot be expressed by a finite number of algebraic operations.

In this learning module, you will familiarize more about exponential function, and how the concept of an exponential function is utilized in our daily life. This module was designed and written with you in mind. It is here to help you master representing and solving real-life situations using exponential functions.

After going through this module, you are expected to:

1. Define exponential functions;
2. Show illustrations of exponential functions that represent real-life situations;
3. Represent real-life situations using the exponential functions; and
4. Solve problems involving real-life situations using the exponential functions.

What I Know

Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. In the exponential function $f(x) = b^x$, x is the ____.
   a. base
   b. dependent variable
   c. exponent
   d. independent variable

2. Which of the following is an exponential function?
   a. $f(x) = x^2 + 3x - 4$
   b. $f(x) = 2^x - 3x + 4$
   c. $f(x) = 2^{3x-4}$
   d. $f(x) = x^2 + 3^x - 4$

3. Which of the given situations illustrates an exponential function?
   a. The distance travelled varies directly as the speed.
   b. The area of a square is s^2 where s is the length of the side of a square.
   c. Radioactive material has a half-life of 1500 years.
   d. As x increases, the value of y increases.

4. Solve $f(x) = 2^x$, if $x = -4$.
   a. 1/16
   b. 1/8
   c. 1/4
   d. ½

5. Which of the following depict the increase in number or size at a constantly growing rate?
   a. Half-life
   b. Exponential growth
   c. Exponential decay
   d. Compound interest

6. What is the rate of change in the formula $y = y_0(2)^{\frac{t}{T}}$ every T units of time?
   a. doubles
   b. half
   c. triples
   d. multiples

7. In the formula $A = P(1 + r)^t$; what is P?
   a. principal compounds
   b. principal invested
   c. principal time
   d. principal year

8. Which of the following statements modeled an exponential growth?
   a. The cost of pencils as a function of the number of pencils.
   b. The distance when a stone is dropped as a function of time.
   c. The distance of a swinging pendulum bob from the center as a function of time.
   d. The compound interest of the principal amount as a function of time.

For nos. 9-10. Suppose a culture of 300 bacteria is put in a petri dish and the culture doubles every hour.

9. What is the exponential model on the given situation?
   a. $y = 2(300)^{\frac{1}{t}}$
   b. $y = 300(2)^{\frac{1}{t}}$
   c. $y = 2(300)^t$
   d. $y = 300(2)^t$

10. How many bacteria will be there after 9 hours?
   a. 93,660
   b. 153,600
   c. 653,100
   d. 393,660

For nos. 11-12. The half-life of a substance is 400 years. Initially there are 200 grams.

11. What is the exponential model for the given situation?
   a. $y = 200(\frac{1}{2})^{\frac{t}{400}}$
   b. $y = 400(\frac{1}{2})^{\frac{t}{200}}$
   c. $y = 200(\frac{1}{2})^{\frac{400}{t}}$
   d. $y = 400(\frac{1}{2})^{\frac{200}{t}}$

12. How much will remain after 800 years?

a. 100 g
b. 25 g
c. 50 g
d. 12.5g

For nos. 13-14. Lino invested ₱5,000.00 into an account which increases annually at the rate of 5.5%.

13. What equation best describes this investment after t years?

a. $A = 5000(0.055)^t$
b. $A = 5000(1.055)^t$
c. $A = 5000(1.55)^t$
d. $A = 5000\text{A}$

14. How much is his investment after 5 years?

a. ₱6,534.80
b. ₱7,843.20
c. ₱25,204.50
d. ₱45,354.80

15. A large slab of meat is taken from the refrigerator and placed in a pre-heated oven. The temperature T of the slab t minutes after being placed in the oven is given by $T = 170 - 165e^{-0.006t}$. What is the temperature rounded to the nearest integer after 30 minutes?

a. 32°C
b. 42°C
c. 52°C
d. 64°C

Lesson 1 Representing Real-Life Situations Using Exponential Functions

The beauty of Mathematics can be found everywhere. Sometimes, you are not aware that in front of you are situations which can be written as a Mathematics model. Some conditions in life increase and decrease tremendously such as the growth of bacteria, interest of an investment or an amount loaned, depreciation or appreciation of the market value of a certain product, and even the decay of microorganism. These real-life situations exhibit exponential patterns.

This lesson is about modeling real-life situations using exponential functions like population growth, population decay, growth of an epidemic, interest in banks and investments.

What's In

Before you proceed to the new lesson, study the following, and recall what you have learned from the previous lesson so that you will be ready for your next journey.

> Definition
>
> An exponential function with the base b is a function of the form $f(x) = b^x$ or, $y = b^x$ where($b > 0, b \neq 1$).
> Some examples are: $f(x) = 2^x$, $f(x) = 3^x$, and $f(x) = 4^x$

The following will help you to recall, how to evaluate functions.

Example 1. If $f(x) = 4^x$, evaluate $f(2)$, $f(-2)$, $f(1/2)$, and $f(\pi)$.

Solution:

$f(2) = 4^2 = 16$

$f(-2) = 4^{-2} = \frac{1}{4^2} = \frac{1}{16}$

$f(1/2) = 4^{1/2} = \sqrt{4} = 2$

$f(\pi) = 4^{\pi}$

Example 2. Complete the table of values for x = -3, -2, -1, 0, 1, 2, and 3 for the exponential functions $f(x) = 3^x$ and $f(x) = (1/3)^x$.

x	-3	-2	-1	0	1	2	3
$f(x) = 3^x$	1/27	1/9	1/3	1	3	9	27
$f(x) = (1/3)^x$	27	9	3	1	1/3	1/9	1/27

Let b a positive number not equal to 1. A transformation of an exponential function with base b is a function of the form:

$$f(x) = a * b^{x-c} + d \text{ } where \text{ } a, c, and \text{ } d \text{ } are \text{ } real \text{ } numbers$$

Notes to the Teacher

Since π is irrational, the rules for rational exponents are not applicable. We define using rational numbers: πcan be approximated by $4^{3.14}$. A better approximation is $4^{3.14159}$. Intuitively, one can obtain any level of accuracy for 4^{π} by considering sufficiently more decimal places of. Mathematically, it can be proved that these approximations approach a unique value, which we define to be.

What's New

Helping Hands!

Read and analyze the problem carefully to complete the table and to answer the questions that follow.

Ms. Love Reyes, a Mathematics teacher introduces a new project to teach her students the values of helpfulness and sharing through peer tutoring while learning Math. She believes that her students will be more comfortable and open when interacting with a peer. To teach a short cut technique in solving rational equations and inequalities, she demonstrates the strategy to one of her students and requires this student to do the same to two of his classmates, with a condition that each student who undergoes the peer tutorial will repeat the process until everyone in the class will be able to learn the short cut technique. Also, each student is required to submit a reflection paper of their experienced while doing the peer tutoring and learning with classmates, for her to assess if she is successful to attain her objectives.

a. Based on the situation above, complete the table below.

Tutorial Stage	0	1	2	3	4	5	6
Number of Students who undergo the tutorial	1						

(Hint: In 0 stage, only one student undergoes the tutorial, he is the first student chose by Ms. Reyes, stage 1 is the stage where the first students share his learning to his classmate and continue up to stage 6)

b. What pattern can be observed from the data?

c. Write a formula to determine the number of students who are already involved with the tutorial project in a particular stage?

d. If the project will be extended to other students within the school, in what stage will it reach 512 students?

e. Illustrate the situation above using a tree diagram.

f. What kind of teacher is Mrs. Reyes?

g. Given a chance, will you join the project? Why or Why not?

What is It

The problem in the previous activity is an example of real-life situations using exponential functions. Hence, exponential functions occur in various real-world situations. Exponential functions are used to model and illustrate real-life situations such as population growth, radioactive decay and carbon dating, growth of an epidemic, loan interest and investments.

In the previous activity, you need to complete the table for you to see the pattern. Have you seen the pattern? The pattern represents the exponential functions. You may observe that as the stage increases, the number of students involved also increases in the pattern which is equal to $f(x) = 2^x$. If you got it correctly, congratulations! You already representing the exponential function to a real-life situation and I am sure you can now answer the question, if the project will be extended to other students within the school, in what stage will it reach 512 students? So, the answer is stage 9.

Going back to the project, what can you say to Mrs. Reyes? What kind of teacher is she? Well, it's up to you to answer the question to yourself. What I believe is that, you will be lucky if you will be a student of Mrs. Reyes because she is not only teaching Mathematics but she is also infusing good values to her students. You may now reflect on the question, if given the chance, will you join the project? Why or why not?

Exponential Function

An exponential function with the base b is a function of the form $f(x) = b^x$ or $y = b^x$, where $(b > 0, b \neq 1)$.
Some of the most common applications in real-life of exponential functions and their transformations are population growth, exponential decay, and compound interest.

The following are examples of representing an exponential function in real-life situations.

Example 1

Suppose a culture of 300 bacteria at MJD Farm is put into a Petri dish and the culture doubles every 10 hours. Give an exponential model for the situation. How many bacteria will there be after 90 hours?

Solution:

a. Let y = number of bacteria
At $t = 0, y = 300$

$t = 10, \quad y = 300(2) = 600$
$t = 20, \quad y = 300(2)^2 = 1200$
$t = 30, \quad y = 300(2)^3 = 2400$
$t = 40, \quad y = 300(2)^4 = 4800$

An exponential model for this situation is $y = 300(2)^{t/10}$

b. If $t = 90$, then $y = 300(2)^{90/10}$, $y = 300(2)^9$, $y = 153{,}600$. There will be 153,600 bacteria after 90 hours.

> **Exponential Models and Population Growth**
> Suppose a quantity y doubles every T unit of time. If y_o is the initial amount, then the quantity after t units is given by $y = y_o (2)^{t/T}$

Example 2

A certain radioactive substance decays half of itself every 5 days. Initially, there are 50 grams. Determine the amount of substance left after 30 days, and give an exponential model for the amount of remaining substance.

Solution:

a. Let t= time in days
At t= 0 Amount of Substance = 50g
t= 5 Amount of Substance = 50 (1/2) = 25 g
t = 10 Amount of Substance = $50 (1/2)^2 = 12.5$ g
t = 15 Amount of Substance = $50 (1/2)^3 = 6.25$ g

An exponential model for this situation is $y = 50 (1/2)^{t/5}$

b. $y = 50(1/2)^{30/5} = 50(1/2)^6 = 0.78125$ g

> **Exponential Decay**
> The half-life of a radioactive substance is the time it takes for half of the substance to decay. The exponential decay formula is $y = y_o (1/2)^{t/T}$.

Example 3

Aling Dionisia deposits ₱10,000.00 in BDO that pays 3% compound interest annually. Define an exponential model for this situation. How much money will she have after 11 years without withdrawal?

Solution: Compound Interest means the interest earned at the end of the period is added to the principal and this new amount will earn interest in the nesting period.

a. At $t = 0$ ₱10,000
$t = 1$ ₱10,000+ ₱10,000(0.03) = ₱10,300.00
$t = 2$ ₱10,300+ ₱10,300(0.03) = ₱10,609.00
$t = 3$ ₱10,609 + ₱10,609(0.03) = ₱10,927.27

From the above, the principal amount together with the interest earned as computed is as follows:

At $t = 0$ ₱10,000
$t = 1$ ₱10, 000(1+0.03) = ₱10,000(1.03) = ₱10,300.00
$t = 2$ ₱10,000$(1+0.03)^2$ = ₱10,000$(1.03)^2$ = ₱10,609.00
$t = 3$ ₱10, 000$(1+0.03)^3$= ₱10,000$(1.03)^3$ =₱10,927.27

An exponential model for this situation is $A = 10{,}000(1.03)^t$

b. A = ₱10,000$(1.03)^{11}$

= ₱13,842.34

After 11 years without withdrawal there will be ₱13,842.34 in bank.

Compound Interest

If a principal P (*initial amount of money*) is invested at an annual rate of r; compounded annually, then the amount after t years is given by

$A = P(1+r)^t$.

Example 4

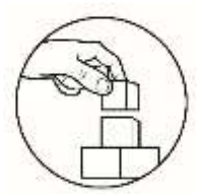
The Natural Exponential Function

While an exponential function may have various bases, a frequently used base is the irrational number ***e***, whose value is approximately 2.71828. Because ***e*** is a commonly used base, the natural exponential function is defined as having ***e*** as the base.
The predicted population of a certain city is given by P=200,000 $e^{(0.03y)}$ where y is the number of years after the year 2020. Predict the population for the year 2030.

Solution:

The number of years from 2020 to 2030 is 10, so y= 10.
P = $(200,000)(2.71828)^{(0.03)(10)}$
P = 269, 971.70
The predicted population for the year 2030 is 269, 971.

The **natural exponential function** is the function f(x) = e^x.



What's More

Activity 1.1

Solve the following:

1. A culture of 100 bacteria in a petri dish doubles every hour.
   a. Complete the table.

t	0	1	2	3	4
No. of bacteria					

   b. Write the exponential model for the number of bacteria inside the box.

   c. How many bacteria will be there after 6 hours?
   Solution:

   Answer: ____________

2. Half-life of a radioactive substance is 12 hours and there are 100 grams initially.

   a. Complete the table.

t	0	12	24	36	48
Amount					

   Write the exponential model for the amount of substance inside the box.

   b. Determine the amount of substance left after 3 days.
      Solution:

      Answer: ____________

3. Kim deposited ₱10,000.00 in a bank that pays a 3% compound interest annually.
   a. Identify the given: P = _______
      r = _______

   b. Write the exponential model for the amount of substance inside the box.

   c. How much money will he have after 2 years?
      Solution:

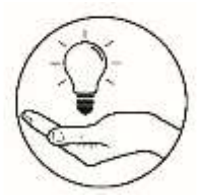
      Answer: ____________

Activity 1.2

1. Suppose the half-life of a certain radioactive substance is 20 days and there are 10g initially. Determine the exponential model and the amount of substance remaining after 75 days.
   Solution:

2. Danzel deposited an amount of ₱10,000.00 in a bank that pays 4% annual interest compounded annually. How much money will he have in the bank after 2 years.
   Solution:

3. The population of a certain country can be approximated by the function P(x) = 20,000,000 $e^{0.0251x}$ where x is the number of years. Use this model to get the approximate number of the population after 30 years.
   Solution:



What I Have Learned

A. Fill in the blanks with the correct term or phrase to complete the sentence.

1. A function of the form $f(x) = b^x$ or $y = b^x$, where $b > 0$ and $b \neq 1$ is called ______________.
2. Suppose a quantity y doubles every T units of time. If y_o is the initial amount, then the quantity y after t units is given by the formula __________________.
3. The time it takes for half of the substance to decay is called _____________.
4. The exponential decay formula is ________________.
5. If a principal P is invested at an annual rate of r; compounded annually, then the amount after t years is given by the formula ________________.

B. In your own words, what are the steps to represent exponential function to real-life situation?

C. Our population today increases exponentially which results to some economic problems. If you will become the president of the Philippines, what programs will you suggest to solve the problems? Explain.

What I Can Do

Read and understand the situation below, then answer the questions or perform the tasks that follow.

Wise Decision and Friendship Goal

Your 18-year old, senior high school best friend, is asking for your advice as to which between the two "25^{th} birthday gift options" posted by her parents she should choose for her 25^{th} birthday.

Option A: Her parents will give her ₱3,000.00 each year starting from her 19^{th} birthday until her 25^{th} birthday.

Option B: Her parents will give her ₱400.00 on her 19^{th} birthday, ₱800.00 on her 20^{th} birthday, ₱1,600.00 on her next birthday, and the amount will be doubled each year until she reaches 25.

Task:

You need to prepare a computation highlighting the amount of money (y) your best friend gets each year (x) starting from her 19^{th} birthday using options A and B in tabular form. Write equations that represent the two options with a complete set of solutions. At the end of your report, write a conclusion stating the option you will choose and explain your decision.

Written Report:

Conclusion:

____

____

____

____

____

____

____

Rubrics for rating the output:

Score	Descriptors
20	The situation is correctly modeled with an exponential function, appropriate mathematical concepts are fully used in the solution and the correct final answer is obtained.
15	The situation is correctly modeled with an exponential function, appropriate mathematical concepts are partially used in the solution and the correct final answer is obtained.
10	The situation is not modeled with an exponential function, other alternative mathematical concepts are used in the solution and the correct final answer is obtained.
5	The situation does not model an exponential function, a solution is presented but has an incorrect final answer.

The additional 5 points will be determined from the conclusion or justification made.
5-States a conclusion with complete and appropriate justification based on a reasonable interpretation of the data.
4-States a conclusion with enough justification, based on a reasonable interpretation of the data.
3-States a conclusion with some justification, based on a reasonable interpretation of the data.
2-States a conclusion on a reasonable interpretation of the data.
1-The conclusion is based on an unreasonable interpretation of the data.

Assessment

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. In the exponential function $f(x) = b^x$, b is called as the ___________.
   a. base
   b. dependent variable
   c. exponent
   d. independent variable

2. Which of the following defines an exponential function?
   a. $f(x) = 2x^2$
   b. $f(x) = 2x-1$
   c. $f(x) = 3^x$
   d. $f(x) = x^2+1$

3. Solve $f(x) = 2^{x+1}$, if $x = 2$.
   a. 2
   b. 4
   c. 8
   d. 16

4. Which of the given situations illustrate an exponential change?
   a. A store has 100 regular customers and each month 5 new customers come
   b. The number of organisms in a culture doubles every 5 hours
   c. The monthly wage of a laborer increases by 75 every year
   d. As x increases the value of y increases

5. What do you call a quantity that decreases at a rate proportional to its current value?
   a. Population growth
   b. Exponential growth
   c. Exponential decay
   d. Compound interest

6. Which of the following situations describe an exponential decay?
   a. The number of rabbits doubles every month.
   b. The population decreases every year by 100.
   c. The atmospheric pressure decreases as you go higher.
   d. The amount of money increases every year.

7. What is the approximate value of e in the equation $y = e^x$?
   a. 3.1416
   b. 31.416
   c. 2.71828
   d. 27.1828

8. Half-life is the time required for a quantity to reduce to half its initial value.
   Which of the following represents exponential function involving half-life?
   a. $y= y_o(2)^{t/T}$
   b. $y=y_o (1/2)^{t/T}$
   c. $A = P(1+r)^t$
   d. $y= e^x$.

For nos. 9-10. What if the 200 bacteria in a certain culture doubles every 3 hours?

9. What is the exponential model for the given situation?

a. $y= 2(200)^{t/3}$
b. $y= 200(2)^{t/3}$
c. $y= 2(200)^{3/t}$
d. $y= 200(2)^{3/t}$

10. How many bacteria are there after 9 hours?

a. 1600
b. 1800
c. 2000
d. 2100

For nos. 11-12. The half-life of a radioactive substance is 10 days and there are 10 grams initially.

11. What is the exponential model for the given situation?

a. $y= (1/2)(10)^{10/t}$
b. $y= 10(1/2)^{t/10}$
c. $y= 10(1/2)^{10/t}$
d. $y= (1/2)(10)^{t/10}$

12. What is the amount of substance left after 20 days?

a. 5 g
b. 2.5 g
c. 0.025 g
d. 1.25 g

For nos. 13-14. Alex deposited ₱1,000.00 in a bank at Lucena City that pays 5% compound interest annually.

13. What equation best describes this investment after t years?

a. $A= 1{,}000\ (1.5)^t$
b. $A= 1{,}000\ (1.05)^t$
c. $A= 1{,}000\ (15)^t$
d. $A= 1{,}000\ (1.005)^t$

14. How much money will he have after 2 years?

a. ₱1,100.50
b. ₱1,102.50
c. ₱1,201.50
d. ₱1,220.50

15. The predicted population of a certain city is given by $P=5{,}000e^{(0.15y)}$ where y is the number of years after 2020. What is the population in the year 2028?

a. 6,600
b. 16,600
c. 17,600
d. 18,000

Additional Activities

Now that you have gained skills in representing and solving real-life situations using exponential functions, try to sharpen your skill by working on the task below:

Your task is to study the exponential function of the Corona Virus. Look for the different exponential model for the virus.

Answer Key

What I Know	What's More	Assessment
1.C	1.a.	1. A
2. C	b. y= $10(2)^t$;	2. C
3. C	c. y= $10(2)^6$; 6400 bacteria	3. C
4. A	2. a.	4. B
5. B	y= $5(1/2)^{t/5}$;	5. C
6. A	y= $5(1/2)^{72/5}$; 0.625g	6. B
7. B		7. C
8. D	a. P=P10,000; r= 3%	8. B
9. D	A= $10,000(1.03)^t$;	9. D
10.B	A= $10,000(1.03)^t$; A= P10,609	10. A
11. A		11. B
12. C	a. P(x)= $20,000(e)^{(0.0251)(30)}$	12. C
13. B	b. 42,467	13. B
14. A		14. B
15. A		15. B

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