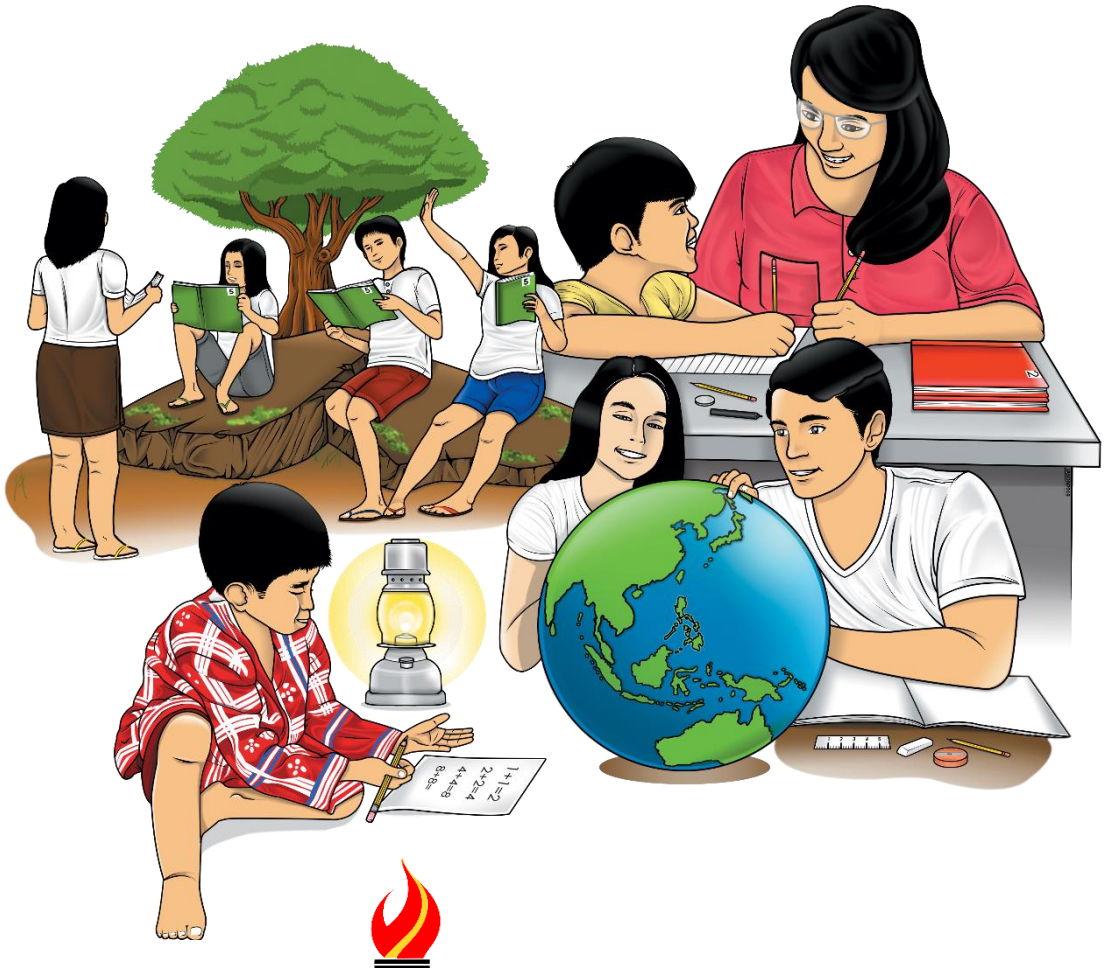
Senior High School

DepED
DEPARTMENT OF EDUCATION

General Mathematics

Quarter 1 – Module 28: Solving Real-Life Problems Involving Logarithmic Functions, Equations and Inequalities



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Secretary: Leonor Magtolis Briones
Undersecretary: Diosdado M. San Antonio

Development Team of the Module

Writers: Mary Grace D. Constantino

Editors: Elizabeth D. Lalunio, Anicia J. Villaruel and Roy O. Natividad

Reviewers: Jerry Punongbayan, Diosmar O. Fernandez, Dexter M. Valle, Jerome A. Chavez, Rizza Ann E. Lipardo, Jasmin Flores and Moahna Aura M. Mancenido

Illustrator: Hanna Lorraine Luna, Diane C. Jupiter and Meryll C. Calvendra

Layout Artist: Roy O. Natividad, Sayre M. Dialola and Glydel Eveth T. Enriquez

Management Team: Francis Cesar B. Bringas
Job S. Zape, Jr.
Ramonito Elumbaring
Reicon C. Condes
Elaine T. Balaogan
Fe M. Ong-ongowan
Hermogenes M. Panganiban
Philip B. Gallendez
Josephine T. Natividad
Anicia J. Villaruel
Dexter M. Valle

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Department of Education – Region 4A CALABARZON

Office Address: Gate 2 Karangalan Village, Brgy. San Isidro, Cainta, Rizal
Telefax: 02-8682-5773/8684-4914/8647-7487
E-mail Address: lrmd.calabarzon@deped.gov.ph

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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

Previously, you learned how to simplify and solve logarithmic functions, equations, and inequalities. Also, you already have the background of the properties, techniques, and steps in solving problems using logarithmic functions. You are now aware of the use of the Richter Scale to find the magnitude of an earthquake, determining for the acidity and pH level of a solution concentration, computing the population, and solving compound interest.

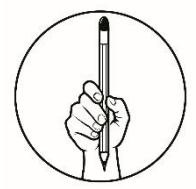
Can you still remember the formulas to solve those real-life applications of logarithmic functions? It is not enough that you know the formulas, what matters most is you know how to apply it in real-life situations. In this module, you will gain a deeper understanding of the application of a logarithmic function, equation, and inequalities to real-life situations.

You will realize that aside from the mentioned real-life problem above, there are still other real-life situations where you could use logarithm like computing for the decay rate, how bacteria and viruses multiply, and on how to get the age of a decomposed bone by knowing the carbon-14 content. You might also find it interesting to solve for your future savings account or how you could possibly get a higher amount if you will save earlier.

And now, are you ready for the new lesson? Fasten your seatbelt and focus on the world of solving numerous ways of using logarithm is a real-life situation.

After going through this module, you are expected to:

1. recall how to solve logarithmic equations and inequalities; and
2. solve problems involving logarithmic functions, equations, and inequalities.



What I Know

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

1. Which of the following situations show the application of the logarithmic function to the real-life situation?
   a. Getting the number of teachers in one division
   b. Looking for the missing value of a variable
   c. Computing the age of Maria given her sibling's true age
   d. Getting the pH level of water from an unknown water tunnel

2. The following situations show the application of the logarithmic functions to real-life situation **EXCEPT**:
   a. Determining the time your money may double in amount
   b. Measuring the size of human statistics
   c. Determining the vital statistics of a person
   d. Getting the total number of population in one particular region in a certain time frame

3. An earthquake is measured with a wave amplitude of 1012 times. What is the magnitude of this earthquake using the Richter scale to the nearest tenth? *(Hint:* $R = \frac{2}{3} log \frac{E}{10^{4.40}}$*)*
   a. 5.07
   b. 6.07
   c. 7.57
   d. 7.87

4. A particular running experiment is initially 100 bacteria cells. She expects that the number of cells is given by the function $c(t) = 100(2)^{\frac{t}{15}}$, where time t is the number of hours since the experiment started. After how many hours would the scientist expect to have 300 bacteria cells? Give your answer to the nearest hour.
   a. 2 hours
   b. 24 hours
   c. 104 hours
   d. 1, 048 hours

5. Which of the following logarithmic inequalities is correct? Round off your answer to 2 decimal places.
   a. log(x-1) + log(x+1) < 2logx if x = 2
   b. log(x-1) + log(x+1) < 2logx if x = 100
   c. log(x+1) > 2log(x) if x = 2
   d. log(x+5) > 5log(-x) if x = -2

6. Simplify $log_5 x \geq 3$.

a. x ≥ 125
c. x ≥ 15
b. x ≥ 85
d. x ≥ 225

7. The formula in the risk of having an increasing car accident as the concentration of alcohol in blood increases is $A = 6e^{12.75x}$ where x is the blood alcohol concentration and A is the given percentage of car accident risk. At which blood alcohol concentration level would correspond to a 50% risk of a car accident?

a. 0.20
c. 0.17
b. 0.25
d. 0.19

8. Evaluate the logarithmic form $\log_6 8$.

a. 1.16
c. 2.16
b. 2.25
d. 1.25

9. Determine the depreciated value of a teacher's table that was discounted 50% of its original value of ₱5000.00 using a decay factor.

a. ₱5000.00
c. ₱3000.00
b. ₱2500.00
d. ₱4500.00

10. Find the inverse of $f(x) = b^x$.

a. $f^{-1}(x) = \log_x b$
c. $f(x) = \log_b x$
b. $f^{-1}(x) = \log_b x$
d. $f^{-1}(b) = \log_b x$

11. The magnitude of an earthquake in Matanao, Davao Del Sur on December 15, 2019, is 6.8. And it is predicted that there will be another earthquake that will strike somewhere in the Philippines that is 4 times stronger than the mentioned earthquake. What could be the possible magnitude of the predicted earthquake? (Earthquake Magnitude on a Richter scale $R = \frac{2}{3} log \frac{E}{10^{4.40}}$)

a. 7
c. 8.40
b. 8
d. 7.20

12. Suppose that you are observing the behavior of bacteria duplication in a laboratory. You observe that the bacteria triple every hour. Write an equation with base 3 to determine the population of bacteria after one day.

a. 3.02×10^{11}
c. 2.90×10^{11}
b. 3.20 x 1011
d. 2.82 x 1011

13. Using item number 12, determine how long it would take for the population of bacteria to reach 300,000 bacteria.

a. 11.48 days
c. 12.5 days
b. 13 days
d. 14 days

For item numbers 14-15, refer to the following:
A Senior High School student plans to invest in a bank since he knew that his family struggles financially. He thought that if he will not prepare for the future it will be hard for him to continue to study at the university. This decision is very wise for a student like him. It suggests that even as early as Grade 7, students should have the urge and initiative to save for the future. His initial amount for his savings is ₱5,500.00. Help him to decide to save his money with the formula $A = P(1 + r)^n$ and by answering the questions that follow:

14. A bank offers 12% compounded annually, predict the balance after 5 years.
    a. ₱9,500.00
    b. ₱10,692.88
    c. ₱9,692.88
    d. ₱10,500.00

15. If he would like to have ₱20,000 in the future how long will it take him to save with the same amount of initial investment and the same interest rate?
    a. 8 years
    b. 10 years
    c. 12 years
    d. 13 years

Lesson 1 Solving Problems involving Logarithmic Functions, Equations and Inequalities

Learning new things like discovering the importance of learning logarithm and its significance in real-life situations is fun. You will notice that some of the problems here are somewhat the same with the problems you already solved involving exponential function. Yes! You already know about solving some problems here, but this time you will solve them using logarithmic functions, equations, and inequalities.

What's In

As the saying goes, "*A person who does not remember where he came from will never reach his destination*". Because of that here are some exercises to refresh your mind.

Activity 1

Determine whether each of the given expressions below is a logarithmic function, a logarithmic equation, a logarithmic inequality, or neither of the three. Enjoy working while recalling your previous lessons regarding logarithm. Have fun!

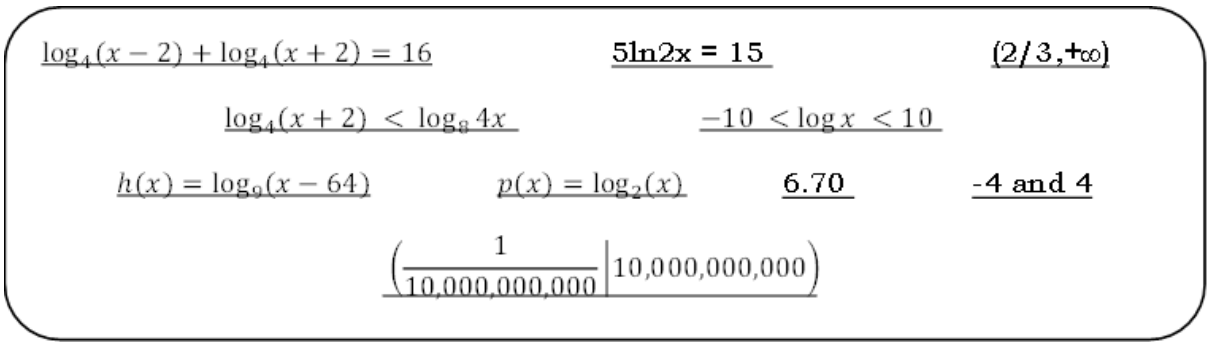
1. $g(x) = 2\log x$ — Logarithmic Function
2. $y = \log_4(2x-1)$ — Logarithmic Function
3. $x\log_8(2x) = -\log(3x-5)$ — Logarithmic Equation
4. $\log(4x - 1) > 0$ — Logarithmic Inequality
5. $g(x) = 2x-7$ — Neither of the three

How did you distinguish logarithmic functions, logarithmic equations and logarithmic inequalities from each other?

Activity 2

Pick, Pair and Solve

Complete the table below by selecting your answer inside the box and putting them in the column where they belong. In the columns, logarithmic equations and logarithmic inequalities, make sure you will **pick** and **pair it** with the correct solutions. Have fun!



Logarithmic Equations	Solutions to Logarithmic Equations	Logarithmic Functions	Logarithmic Inequalities	Solutions to Logarithmic Inequalities
$Log_4(x-2)+log_4(x+2)=16$	-4 and 4	$p(x)=log_2(x)$	$-10<logx<10$	1/10,000,000,000 | 10,000,000,000
5ln2x=15	6.70	$h(x)=log_9(x-64)$	$Log_4(x+2)<log_8 4x$	(2/3, +∞)

I know that you got the correct answer in this lesson review, this time we will go deeper as you enjoy solving logarithmic problems applying in real life situation.

What's New

Why oh Why?

In a far-flung area somewhere in Quezon Province, the school principal observed that the number of graduating students decreases every year. In the year 2018, the number of graduating students is 200, but in the year 2020, it becomes 150 only. Use the formula $A = Pe^{rt}$ and the information given to answer the following questions:

Questions:

1. What is the decay rate of the number of graduating students?
2. Using the decay rate that you get in item 1, about how many years will it take for the school to record less than 100 graduating students?
3. Do you think the way of living in a remote area affects the decreasing population of learners per year?
4. What could be the other reasons for the decreasing population of graduating learners per year?
5. Were you able to solve the problem with the given formula? Justify your answer.

What is It

You have noticed that you were given a formula on the problem above under ***What's New*** to solve for the decay rate. Sometimes, this formula is also used for problems involving exponential growth. Let us now try to solve the problem above. Using the formula $A = Pe^{rt}$ we can substitute the given value for the first question which is you were asked to look for the decay rate.
Given: A = 150 P = 200 t = 2 years r = ?
Using substitution in the formula $A = Pe^{rt}$, we have

$$150 = 200e^{r(2)}$$

To simplify: divide both sides by 200 that becomes

$$0.75 = e^{r(2)}$$

$$\ln 0.75 = 2r \ln e$$

from this equation divide both sides by 2 that makes the equation

$$0.1438 = r \ln e$$

Since ln e is equal to one then the final answer is r = 0.1438 or 14.38% decay rate.
To answer question number 2, do it with the same process but this time look for the time instead of rate and use the 0.1438 for the value of r. This will become inequality since we are looking for the time that a population decayed to less than 100 graduating students. Thus, $100 < 200e^{0.1438t}$

Using the same process, this will give us the answer 4.82 years < t or t > 4.82 years. Therefore, if the number of graduating students will continue to decrease following the decay rate of 14.38%, intuitively, in five years there will be less than 100 graduating students. This information will provide the school administration and teachers to look for a solution regarding the declining number of graduating students. This is the role of mathematics to real-life problems, it gives us the information we need to make wise decisions.
Word problems involving logarithmic functions, equations, and inequalities generally involve solving and evaluating exponential form. Exponential and logarithm cannot be separated from each other. If the given problem is in logarithmic form, it is necessary to transform them to exponential and solve for the unknown value which will satisfy the original equation or function.
This is just one of the applications of logarithmic inequality, function, and equation. Aside from this, you will be given other examples of the logarithm that will be applied in real life.

Example 1

COVID-19 pandemic according to news is spreading rapidly, transferring from human to human. It is a kind of virus that affects the human respiratory system and it is commonly associated with cough, pneumonia, SARS (Severe Acute Respiratory Syndrome), and other respiratory-related infections.

Let us assume that the virus has an initial population of 10,000 and grows to 25,000 after 50 minutes. Assume that its growth follows an exponential model $f(t) = Ae^{kt}$ representing the number of viruses after **t** minutes. The e is used in the model because the virus continuously grows over time.

a. Find **A and k.**

b. Use the model to determine the number of viruses after 6 hours.

Solution:

(a) Given: $f(0) = 10{,}000$

$f(50) = 25{,}000$

Thus, $f(0) = Ae^{k(0)}$

$A = 10{,}000$

$F(50) = 25{,}000e^{k(50)}$

$= 25{,}000$

$e^{50k} = \frac{5}{2}$

$\ln e^{50k} = ln\frac{5}{2}$

Take the ln of both sides

$50k = ln\frac{5}{2}$

$= 0.01832$

Therefore, A = 10,000 and k=0.01832.

Also, the exponential model is $f(t) = 10{,}000e^{0.01832t}$

(b) 6 hours = 360 minutes;

$f(360) = 10{,}000e^{.01832(360)}$

$= 7{,}315{,}752$

Therefore, the number of viruses after 6 hours is 7,315,752.

Example 2

Under certain circumstances, a virus spreads according to the equation $p(t) = \frac{1}{1+15e^{-0.3t}}$ where p(t) is the proportion of the population of the virus spread at time t days. How long will it take the virus to spread at 75% of the population?

Solution:

$$0.75 = \frac{1}{1+15e^{-0.3t}}$$

$$0.75 + 11.25e^{-0.3t} = 1$$

$$11.25e^{-0.3t} = 0.25$$

$$e^{-0.3t} = \frac{0.25}{11.25}$$

$$-0.3t \ln e = ln\frac{0.25}{11.25}$$

$$t = 12.69$$

Therefore, it will take approximately 13 days for the virus to spread to 75% of the population.

Example 3

When an organism dies, the amount of carbon-14 in its system starts to decrease. The Carbon-14 is about 7,200 years. An archaeologist found a bone in Mountain Province of Cordillera Region that contains ¼ of the carbon-14 it originally had, how long ago did the human die?

Solution:

The mathematical model of the situation is $y = (\frac{1}{2})^{t/7,200}$ where y is the amount of carbon-14 in the organism after t years and y_0 initial amount of carbon-14.

Since the bone is only ¼ of the carbon-14 it originally had, we have

$$¼\ y_o = y_o\ (\frac{1}{2})^{t/7,200}$$

Taking the ln of both sides, $\ln ¼ = (\frac{t}{7,200})\ ln\frac{1}{2}$

$$\ln ¼ \div \ln ½ = \frac{t}{7,200}$$

$$t = 14,400$$

Therefore, the human died 14,400 years ago and this must be a big contribution to our history.

Example 4

Mr. Boy a fisherman from Mulanay Quezon Province initially invested ₱500,000.00 in a local cooperative and wanted a double amount form its initial investment. Using the formula from the previous lesson on exponential function $A = P(1+r)^n$ where: A is the future value; P is the present value; r is the interest rate and n is the number of years, how many years will it take an investment to triple if the annual interest rate is 6%?

Solution:

Triple of the initial investment means that three (3) times ₱500,000.00 which is equal to ₱1,500,000.00

Given: A = ₱1,500,000.00, P = ₱500,000.00, r = 6% or .06, n = ?

$A = P(1+r)^n$

$₱1,500,000.00 = ₱500,000.00(1+.06)^n$

$3 = (1.06)^n$

$\log 3 = \log(1.06)^n$

$\log 3 = n\log(1.06)$

$n = \frac{log3}{log1.06}$

$n = 18.85$ years

Therefore the money will triple approximately after 19 years.

What's More

Read each problem carefully and answer each question to solve the problem. Have Fun!

Activity 1.1

One of the remote areas in Manila which happens to be the capital of the Philippines has recorded an increasing case of diarrhea. It is found out that a certain bacteria has been discovered which causes this disease. This culture starts at 5,000 bacteria, and doubles every 100 minutes. How long will it take a number of bacteria to reach 20,000.

1. What could be the mathematical model for this situation? _____
2. Identify the given. _____
3. Substitute the given to the mathematical model _____
4. How long will it take for the number of bacteria to reach 20,000?_____

Activity 1.2

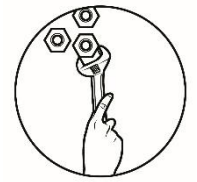
1. Using the world population formula P = 6.9(1.011)t, where t is the number of years after 2010 and P is the world population in billions of people, estimate:
   a) the population in the year 2030 to the nearest hundred million, and
   b) by what year will the population be doubled from 2010?
2. An earthquake occurred on October 2019 at Tulunan Cotabato was recorded to have a magnitude of 6.3. Another earthquake somewhere in Davao was recorded to have a 7.1 magnitude on December 2018. How much more energy was released by the 2018 earthquake compared to that of 2019 recorded earthquake? You can refer to the discussion in the introduction to logarithm for computation.
3. How much money should be invested at 5% compounded annually for 30 years so that you have ₱25,000.00 at the end of 30 years? Round your answer to the nearest two decimal places.

What I Have Learned

A. Please read the sentences carefully and fill in the missing word/s by writing your answer on the line/s provided.

1. Logarithmic equation is a _____.
2. Logarithmic inequality is a _____.
3. Logarithmic function is a _____.
4. Logarithmic function is the _____ of exponential function.

B. Give at least three examples of real-life situations which can be modelled by a logarithmic functions, equations or inequalities.



What I Can Do

Read and analyze the situation below then answer the question given.
Exponential function cannot be separated in solving problems involving logarithmic function. Most of the time, professionals like chemists, engineers, and scientists encounter problems that require the application of exponential and logarithmic functions.

Chemists define the acidity or alkalinity of a substance according to the formula "pH = –log[H+]" where [H+] is the hydrogen ion concentration, measured in moles per liter. Solutions with a pH value of less than 7 are considered acidic while solutions with a pH value of greater than 7 are basic. On the other hand, solutions with a pH of 7 (such as pure water) are neutral. Suppose that you test apple juice and find that the hydrogen ion concentration is [H+] = 0.0003. Find the pH value and determine whether the juice is basic or acidic.
Here are the steps to solve the problem and the rubric that will guide you in giving the correct solution to the problem.

Steps in Problem Solving	Possible Highest Points	Your Score
1. Give the appropriate model or equation to find the pH Level.	2 points	
2. Identify the given	2 points	
3. Substitute the given and show the solution	3 points	
4. Give the final answer	3 points	
Total	10 points	

Assessment

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

1. Which of the following situations show the application of the logarithmic function?
   a. Determining the level of acid in a solution
   b. Determining the time your money may double in amount
   c. Measuring the size of human statistics
   d. Getting the ion component of a chemical

2. Compute for the value of x in a given logarithmic inequalities $\log_2(x+1) > \log_4(x2)$.
   a. $x > ½$
   b. $x > ¾$
   c. $x > ½\ x \neq 0$
   d. $x > ¾\ x \neq 1$

3. An earthquake is measured with wave amplitude of 1015 times. What is the magnitude of this earthquake using the Richter scale $R = 2/3 \log (E/10^{4.40})$ to the nearest tenth?
   a. 6.07
   b. 7.07
   c. 7.57
   d. 8.00

4. A particular bacterial colony doubles its population every 15 hours. A scientist running an experiment is starting with 100 bacteria cells. She expects the number of cells to be given by the function $c(t) = 100(2)^{\frac{t}{15}}$, where t is the number of hours since the experiment started. After how many hours would the scientist expect to have 500 bacteria cells? Give your answer to the nearest hour.
   a. 5 hours
   b. 15 hours
   c. 25 hours
   d. 35 hours

5. If $\log_{0.3}(x-1) < \log_{0.09}(x-1)$, then x lies in the interval _____.
   a. $2 < x < \infty$
   b. $-\infty < x < 2$
   c. $-2 < x < -1$
   d. $1 < x < 2$

6. What is the depreciated value of a smartphone discounted 35% of its original price of ₱36,000.00?
   a. ₱23,400.00
   b. ₱12,600.00
   c. ₱12,000.00
   d. ₱23,000.00

7. Solve the logarithmic inequality $\log_2 x \leq 4$.
   a. $0 \geq x \leq 16$
   b. $0 \leq x \leq 8$
   c. $x \leq 16$
   d. $0 \leq x \leq 16$

8. The formula in the risk of having an increasing car accident as the concentration of alcohol in blood increases is $A = 6e^{12.75x}$ where x is the blood alcohol concentration and A is the given percentage of car accident risk. At which blood alcohol concentration level would correspond to a 75% risk of a car accident?
   a. 0.20
   b. 0.25
   c. 0.17
   d. 0.19

9. You observed that the behavior of bacteria laboratory tripled every minute. Write an equation with base 3 to determine the population of bacteria after one hour.
   a. 3.23×10^{28}
   b. 4.23×10^{28}
   c. 2.23×10^{28}
   d. 1.23×10^{28}

10. Using item number 9, determine how long it would take for the population of bacteria to reach 1,000,000 bacteria.
   a. 12 days
   b. 12.58 days
   c. 13.58 days
   d. 14.68 days

11. Find the value of x in the equation $\log_4(2x - 1) = 2$
   a. 8.5
   b. 8
   c. 9.5
   d. 9

12. The magnitude of an earthquake in San Luis Aurora Province in May 2020 is 5.4. And it is predicted that there will be another earthquake that will strike somewhere in the Philippines that is 5 times stronger than the mentioned earthquake. What could be the possible magnitude of the predicted earthquake? (Use Earthquake Magnitude on a Ritcher scale $R = \frac{2}{3} log \frac{E}{10^{4.40}}$)

a. 7
b. 8
c. 6.13
d. 7.10

For item numbers 13-15, refer to the following:

Mr. Juan Bayan thought of investing or saving some of his money after all the leisures that he enjoyed. He believes in the saying "*early comer is better than hard worker*". With ₱10,000.00 remaining cash on hand he plans to save it in a bank, but he is still in doubt where to invest the money. Using the formula $A = P(1 + r)^n$ help him to solve his problem by answering the questions that follow.

13. A bank offers him a time deposit of 36% compounded annually, how much will his money be after 10 years?

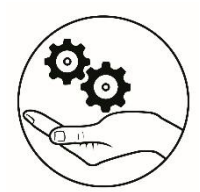
a. ₱216,000.00
b. ₱116,000.00
c. ₱116,465.70
d. ₱216,465.70

14. If he would like to have ₱500,000 in the future, how long will it take him to save with the same amount of initial investment and the same interest rate?

a. 19 years
b. 20 years
c. 25 years
d. 30 years

15. He's been thinking that if only he save at an early age he could have gotten a lot bigger. Based on question no. 14 if he starts to invest at the age of 24 how old is he to get the ₱500,000.00?

a. 44 years old
b. 32 years old
c. 52 years old
d. 60 years old



Additional Activities

Solve the following:

1. You find a skull in a nearby tribe ancient burial site and with the help of a spectrometer, you discovered that the skull contains 9% of the C-14 found in a modern skull. Assuming that the half-life of C-14 (radiocarbon) is 5,730 years, how old is the skull?

2. Suppose that the population of a colony of bacteria increases exponentially. At the start of an experiment, there are 10,000 bacteria, and one hour later, the population has increased to 10,500. How long will it take for the population to reach 25,000? Round off your answer to the nearest hour.

Answer Key

What I Know

1. D
2. B
3. A
4. B
5. A
6. A
7. C
8. A
9. B
10. B
11. D
12. D
13. A
14. C
15. C

What's More

Activity 1.1

$Y = 5{,}000(2)^{t/100}$

$20{,}000 = 5{,}000(2)^{t/100}$

$t = 200$

Activity 1.2

1. a. 8.6 billon people
   b. 2074
2. The earthquake recorded during 2018 of December released 15.85 times more energy than that released on October 2019.
3. The initial amount should be ₱5, 784.44.

Assessment

1. C
2. C
3. B
4. D
5. C
6. A
7. D
8. A
9. B
10. B
11. A
12. C
13. D
14. B
15. A

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For inquiries or feedback, please write or call:

Department of Education - Bureau of Learning Resources (DepEd-BLR)

Ground Floor, Bonifacio Bldg., DepEd Complex
Meralco Avenue, Pasig City, Philippines 1600

Telefax: (632) 8634-1072; 8634-1054; 8631-4985

Email Address: blr.lrqad@deped.gov.ph * blr.lrpd@deped.gov.ph