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DepED
DEPARTMENT OF EDUCATION

Mathematics

Quarter 2-Module 4

Zero and Negative Integral Exponents

Week 3

Learning Code - M9AL-IId-1

ALTERNATIVE DELIVERY MODE
ADM

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

Development Team of the Module

Writers: **Rhoda P. Luis - TIII**
Cherry Lyn R. Solis – MTI

Editor: Andrea R. Intal - Head Teacher III
Juvy G. Delos Santos- Head Teacher III
Rolando A. Ibayan Jr. – Head Teacher VI

Validators: Remylinda T. Soriano, EPS, Math
Angelita Z. Modesto, PSDS
George B. Borromeo, PSDS

Illustrator: Writers

Layout Artist: Writers

Management Team: Malcolm S. Garma, Regional Director
Genia V. Santos, CLMD Chief
Dennis M. Mendoza, Regional EPS in Charge of LRMS and Regional ADM Coordinator
Maria Magdalena M. Lim, CESO V, Schools Division Superintendent
Aida H. Rondilla, Chief-CID
Lucky S. Carpio, Division EPS in Charge of LRMS and Division ADM Coordinator

MODULE 4

Zero and Negative Integral Exponents

In the previous grade level, you have learned about the different laws involving positive integral exponents. You were also taught the importance of this concept in our daily lives. In this module, you will learn how to apply the laws involving positive integral exponents to zero and negative integral exponents. With this, you will appreciate more the concepts of exponents.

LEARNING COMPETENCY

The learner

- applies the laws involving positive integral exponents to zero and negative integral exponents. **M9AL-IId-1**

WHAT I KNOW

Find out how much you already know about the module. Write the letter that you think is the best answer to each question on a sheet of paper. Answer all items. After taking and checking this short test, take note of the items that you were not able to answer correctly and look for the right answer as you go through this module.

1. Simplify $4x^0$.
   a. x b. 4 c. 1 d. 4x
2. 2^{-2} is equal to __.
   a. -4 b. $-\frac{1}{4}$ c. 4 d. $\frac{1}{4}$
3. What is the base in the expression $-(-6)^5$?
   a. 6 b. -6 c. -6 x 5 d. 5
4. What is the product of x^{-5} and $2x^7$?
   a. $2x^2$ b. $3x^{-2}$ c. $3x^2$ d. $2x^{12}$
5. Which of the following is true?
   a. $(x^3)^2 = x^5$ b. $5^3 \bullet 5^7 = 25^{10}$ c. $\frac{x^7}{x^{10}} = \frac{1}{x^3}$ d. $\frac{25x^4}{5x^4} = 5x$
6. Simplify the expression $3x^{-5}$.
   a. $\frac{1}{3x^5}$ b. $\frac{3}{x^5}$ c. $\frac{x}{3^5}$ d. $\frac{3^5}{x}$
7. Write the quotient of $\frac{3^4}{3^{-3}}$ as a single power.
   a. 3^7 b. 3 c. $\frac{1}{3}$ d. 3^{-1}
8. What rule/s should be applied to simplify the expression $(3x^3y^2)^{-3}$?
   i. Quotient Rule
   ii. Power Rule
   iii. Negative Rule
   iv. Product Rule
   a. i & iii b. ii & iv c. ii & iii d. iii & iv

9. Simplify the expressions $\frac{(3x^{-5}y^2)^0}{(4x^{-3}y^2)^{-2}}$

a. 1 b. $\frac{16y^4}{x^6}$ c. $\frac{3}{4}$ d. $\frac{3x^2}{4}$

10. When a caterpillar larvae hatches, it weighs only 10^{-2} grams. However, each day it can eat 10^4 times its initial body weight. How many grams of food can the larvae eat each day?

a. 10^2 b. 10^3 c. 10^4 d. 10^6

WHAT'S IN

Let us recall the different laws involving positive integral exponents, where a and b are not equal to zero, and m, n and x are nonnegative integers.

Product Rule	$a^m \cdot a^n = a^{m+n}$
Power Rule	$(a^m)^n = a^{mn}$
Power of a Product Rule	$(a^m b^n)^x = a^{mx} b^{nx}$
Quotient Rule	$\frac{a^m}{a^n} = a^{m-n}$
Power of a Quotient Rule	$(\frac{a}{b})^m = \frac{a^m}{b^m}$

Study the examples below.

1. $x^2 \cdot x^5 = x^{2+5} = x^7$
2. $(m^3)^4 = m^{3 \cdot 4} = m^{12}$
3. $(2x^2)^3 = 2^3 x^{2 \cdot 3} = 8x^6$
4. $(\frac{4}{y})^2 = \frac{4^2}{y^2} = \frac{16}{y^2}$
5. $\frac{5^6}{5^4} = 5^{6-4} = 5^2 = 25$

Try This!

Activity 1: Know Me More

Simplify the following expressions.

1. $3^2 \cdot 3^3$
2. $(-2)^3$
3. $(\frac{p^3}{q^2})^2$
4. $(x^4)^3$
5. $(2z)^4$
6. $\frac{15m^{11}}{3m^7}$
7. $(3x^2y^4)^2$
8. $\frac{x^8}{x^6}$
9. $(\frac{a^5}{a^4})^2$
10. $\left(\frac{24n^{12}}{3n^8}\right)^2$

WHAT'S NEW

Communication, Critical Thinking and Collaboration

CUTE BATS: DO THEY EXIST?

Last December 2019, reports showed that a coronavirus that specialists had never seen before in humans had started to spread in Wuhan, a large city in the Chinese province of Hubei. It is said that when humans contract a coronavirus, it normally happens due to contact with an infected animal. Some of the most common carriers are bats, though they do not typically transmit coronaviruses directly to humans. It is said that the transmission might occur via an intermediate animal, which will usually, though not always, be a domestic one. And maybe this is one of the reasons why most people now fear this mammal.

But did you know that the world's smallest bat is the kitti's hog-nosed bat or also known as bumblebee bat. It weighs only 7×10^{-2} ounces. It is an incredible tiny creature. The bumblebee bats are found in Thailand and Myanmar, where they occupy limestone caves along rivers. Bumblebee bats are vulnerable and endangered species because of the loss of habitat from human interference.

news.mongabav.com/Bat Conversation International

The weight of the bumblebee is represented in scientific notation where the exponent of the base 10 is negative. Exponents can be used in a variety of ways to represent length. Specifically, negative exponents are used to represent how small thing is. But what does it mean when a number is raised to a negative number? How are we going to evaluate a number with a negative exponent?

WHAT IS IT

Let us analyze what you have read.

1. What is the smallest bat in the world?
   _____
2. Where can you find these mammals?
   _____
3. How heavy is this mammal?
   _____
4. What do you think can you do to protect them?
   _____
5. Is there really a reason for us to be afraid of bats?
   _____
6. What does it mean when a number is raised to a negative number? How are we going to evaluate a number with a negative exponent?
   _____

In the previous grade level, quotient rule was discussed. The given exponent in the numerator is always greater than the exponent in the denominator. But what will happen when we will be asked to divide an expression where the base and exponent are the same? For instance, what if we are asked to simplify $\frac{10^7}{10^7}$.

If we apply the quotient rule to the fraction $\frac{10^7}{10^7}$, we obtain 10^0. But we also know that any nonzero number divided by itself is equal to 1.

That is,

$$\frac{10^7}{10^7} = 10^0 \quad \text{and} \quad \frac{10^7}{10^7} = \frac{\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}}{\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot\cancel{10}} = 1$$

These are the same.

Therefore, $10^0 = 1$.

In general, we define

Zero Exponent

$a^0 = 1$, where $a \neq 0$
Any number, excluding zero, with an exponent of zero is equal to 1.

Example 1: Evaluate each expression.
a. 6^0 b. $(-5)^0$ c. -924^0 d. $(100 + 200)^0$

Solution
a. $6^0 = 1$ b. $(-5)^0 = 1$ c. $-924^0 = -1$ d. $(100 + 200)^0 = 300^0 = 1$

Let us now consider the fraction $\frac{10^3}{10^5}$. In this case, the exponent of the numerator is less than the exponent of the denominator. If we will apply the quotient rule, we will obtain 10^{-2}. If we will divide the common factors of 10, we will get $\frac{1}{10^2}$.

That is,

$$\frac{10^3}{10^5} = 10^{-2} \quad \text{and} \quad \frac{10^3}{10^5} = \frac{\cancel{10}\cdot\cancel{10}\cdot\cancel{10}}{\cancel{10}\cdot\cancel{10}\cdot\cancel{10}\cdot 10\cdot 10} = \frac{1}{10^2}$$

These are the same.

Hence, $10^{-2} = \frac{1}{10^2}$

In general, we have

Negative Exponents

$a^{-n} = \frac{1}{a^n}$, where $a \neq 0$ and n is a counting number.

To show that $a^{-n} = \frac{1}{a^n}$, let us consider $a^n \cdot a^{-n}$

$a^n \cdot a^{-n} = a^{n + (-n)}$ Product Rule

$= a^0$

$= 1$ Zero Exponent

Therefore, a^{-n} is the *reciprocal* or the *multiplicative inverse* of a^n.

Example 2: Transform into expressions with positive exponents only and then evaluate.

a. 3^{-4} b. $(\frac{1}{6})^{-2}$ c. $\frac{1}{10^{-2}}$ d. $\frac{2}{3^{-2}}$

Solution:

a. $3^{-4} = \frac{1}{3^4} = \mathbf{\frac{1}{81}}$

b. $(\frac{1}{6})^{-2} = \frac{1}{\frac{1^2}{6}} = 6^2 = \mathbf{36}$

c. $\frac{1}{10^{-2}} = \frac{1}{\frac{1}{10^2}} = 10^2 = \mathbf{100}$

d. $\frac{2}{3^{-2}} = \frac{2}{\frac{1}{3^2}} = \frac{2}{\frac{1}{9}} = 2 \cdot 9 = \mathbf{18}$

Note: *The quotient rule can be simplified now that we have given meaning to zero and negative integral exponents.*

Example 3: Simplify the following and write your answers with positive exponents.

a. $9x^0$ c. $(3b)^{-3}$

b. $2x^7 \cdot 2x^{-3}$ d. $\frac{24x^5}{12x^{-5}}$

Solution:

a. $9x^0 = 9(1)$ Zero Exponent

$= \mathbf{9}$

b. $2x^7 \cdot 2x^{-3} = 4 \cdot x^{7 + (-3)}$ Product Rule

$= \mathbf{4x^4}$

c. $(3b)^{-3} = \frac{1}{(3b)^3}$ Negative Exponent

$= \frac{1}{3^3 b^3}$ Power of a Product Rule

$= \mathbf{\frac{1}{27b^3}}$

d. $\frac{24x^5}{12x^{-5}} = \frac{24}{12}(x^{5 - (-5)})$ Quotient Rule

$= \mathbf{2x^{10}}$

Example 4: Write each expression with positive exponents only.

a. $\frac{x^{-4}}{y^{-2}}$ b. $\frac{2x^{-3}}{3y^{-1}}$

Solution:

a. $\frac{x^{-4}}{y^{-2}} = \frac{\frac{1}{x^4}}{\frac{1}{y^2}}$ Negative Exponents

$= \frac{1}{x^4} \cdot \frac{y^2}{1}$ Get the reciprocal of the divisor and then multiply

$= \mathbf{\frac{y^2}{x^4}}$

b. $\frac{2x^{-3}}{3y^{-1}} = \frac{\frac{2}{x^3}}{\frac{3}{y}}$ Negative Exponents

$= \frac{2}{x^3} \cdot \frac{y}{3}$ Get the reciprocal of the divisor and then multiply

$= \mathbf{\frac{2y}{3x^3}}$

Timesaving Method

Any *factor* of an expression can be moved from the numerator to the denominator, or from the denominator to the numerator, *by changing the sign of its exponents*.

Note: *Only factors, not terms of the numerator and denominator can be handled this way*.

Let us answer again example 4a, solve $\frac{x^{-4}}{y^{-2}}$ using the timesaving method or commonly referred to as "shortcut".

Since the base x in the numerator has a negative exponent move it to the denominator then change the sign of its exponent. The base y in the denominator has a negative exponent so, move it to the numerator, and change the sign of its exponent.

In this case, $\frac{x^{-4}}{y^{-2}}$ will now become $\mathbf{\frac{y^2}{x^4}}$ when simplified without negative exponents.

Let us have more examples.

Example 5: Simplify and write each expression with positive exponents only.

a. $\frac{2x^{-4}}{3y}$ b. $\frac{5a^{-5}}{6b^{-2}}$ c. $\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4}$

Solution:

a. $\frac{2x^{-4}}{3y}$

$\frac{2x^{-4}}{3y} = \mathbf{\frac{2}{3x^4\,y}}$ Using the timesaving method, move the factor x^{-4} to the denominator and change the sign of its exponent.

b. $\frac{5a^{-5}}{6b^{-2}}$ Move the factor a^{-5} to the denominator and change the sign of its exponent. Also, move b^{-2} to the numerator and change the sign of its exponent.

Hence, we have $\frac{5a^{-5}}{6b^{-2}} = \mathbf{\frac{5b^2}{6a^5}}$

c. $\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4}$ Using the timesaving method, move the factor y^{-2} to the denominator and the factor x^{-2} to the numerator. Do not forget to change the signs of their exponents.

$\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4} = \frac{4x^3\,x^2}{8y^4y^2}$ Simplify and apply the Product Rule.

$= \frac{x^5}{2y^6}$

Therefore, $\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4} = \mathbf{\frac{x^5}{2y^6}}$.

To simplify the expression:

$\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4}$, Apply the Quotient Rule.

$\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4} = \frac{4}{8}x^{3-(-2)}y^{-2-4}$ Simplify

$= \frac{1}{2}\,x^5y^{-6}$ Negative Exponent

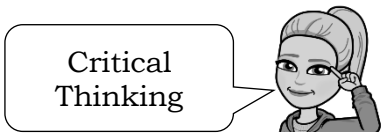
$\frac{4x^3\,y^{-2}}{8x^{-2}\,y^4} = \mathbf{\frac{x^5}{2y^6}}$

In simplifying exponential expressions using the rules, we can say that:

1. There is no recommended sequence to follow. You may use the properties in whatever sequence that is convenient.
2. All rules apply to products and quotients, not to sum and differences. For instance,
   $(3x)^2 = 3^2x^2$
   $(3 + x)^2$ is *not equal* to $3^2 + x^2$

WHAT'S MORE

It is now your turn. Try the following exercises!



Activity 2

Simplify each.

1. 8^{-2}
2. 6^0
3. $15a^0$
4. $\left(\frac{1}{3}\right)^0$
5. $100^0 + 200^0 + 300^0$
6. 22^{-1}
7. 4^{-3}
8. $\left(\frac{2}{3}\right)^{-2}$
9. $\frac{8^{-3}}{8^{-4}}$
10. $16 \cdot 4^{-2}$

Activity 3

Simplify each. Express your answers using positive exponents only. Assume that the variables are nonzero constants.

1. $(-4b^{-2})^0$
2. $\frac{5^4}{5^4}$
3. $x^{-8} \cdot x^5$
4. $4h^{-2}\,(-2h^{-4})$
5. $5x^0 - 10y^0$
6. $(ab^2)^{-1}$
7. a^6b^{-2}
8. $(2x^2y^{-3})^4$
9. $(9y^0)^2$
10. $(-7m^{-2}n^{-1})^{-2}$

Activity 4

Simplify each. Express your answers using positive exponents only. Assume that the variables and denominators are nonzero constants.

1. $\left(\frac{10^4}{10^{-5}}\right)^0$
2. $\frac{p^{-9}}{q^{-6}}$
3. $\left(\frac{g^4}{g^{-1}}\right)^5$
4. $\left(\frac{x^2}{y^3}\right)^{-1}$
5. $\frac{15n^{-4}\,p^5}{-3n^6p^{-7}}$
6. $\frac{c^{-2}\,d^4}{c^{-5}\,d^2}$

WHAT I HAVE LEARNED

Zero Exponent: $a^0 = 1$, where $a \neq 0$
Any number, excluding zero, with an exponent of zero is equal to 1.

Negative Exponent: $a \neq 0$ and n is a nonnegative integer
a^{-n} is the **reciprocal** or the **multiplicative inverse** of a^n.

Timesaving Method
Any factor of an expression can be moved from the numerator to the denominator, or from the denominator to the numerator, by changing the sign of its exponents.

In simplifying exponential expressions using the rules, we can say that:

1. There is no recommended sequence to follow. You may use the properties in whatever sequence that is convenient.
2. All rules apply to products and quotients, not to sum and differences.

WHAT I CAN DO

I. Simplify the following expressions with positive exponents only.

1. $\frac{1}{2^{-4}}$
2. $(2x^4y^{-4})(3x^2y^4)$
3. $(2p^3)^0(p^4)$
4. $\frac{-12x^5y^{-2}}{8\,x^{-3}y}$
5. $(-3x^7y^{-4}z^0)^3$
6. $(2r^{-5}s^9t^6)^{-3}$
7. $\frac{(x^{-2})\ y^4}{y^{-5}}$
8. $\frac{(10x^5)}{y^4z^{-7}}$
9. $(a + b)^{-2}$
10. $\frac{(x+y)^{-1}}{2z^{-6}}$

II. Answer the following problems.

1. A seed on a dandelion flower weighs 10^{-3} grams. A dandelion itself can weigh up to 10^3 grams. How many times heavier is a dandelion than its seeds? Express your answer in exponential form.
2. The weight of a newborn baby chicken weighs 3^{-2} pounds. If an adult chicken can weigh up to 3^4 times more than a newborn chicken, how much does an adult chicken weigh?

ASSESSMENT

Write the letter of the correct answer on your answer sheet. If your answer is not among the choices, write the correct answer.

1. Simplify $(2r^3)(2r^{-2})$

   a. 2r b. $2r^5$ c. 4r d. $2r^6$

2. $(x^{-2})^0$ is equal to

   a. -x b. x c. 1 d. x^0

3. A number with a negative exponent can be expressed as _____.

   a. a number base with a positive exponent in the denominator
   b. a negative base number with a positive exponent
   c. a negative base number with a negative exponent
   d. a base number with a negative exponent in the denominator

4. What is the product of $4x^5y^{-3}$ and $-3x^{-3}y^3$?

   a. x^2y b. $-12x^2$ c. $12x^2$ d. x^8y^6

5. Simplify: $(2x^{-2})^0 + (3x^2)^0$

   a. 2 b. 3 c. 4 d. 5

6. Simplify the expressions $(2b^4)^{-5}$ with positive exponents only.

   a. $\frac{2}{b^{20}}$ b. $\frac{32}{x}$ c. $\frac{1}{32b^{20}}$ d. $\frac{b^{20}}{32}$

7. Which of the following equations is true?

   a. $2^{-3} = -8$ b. $2^{-3} = \frac{1}{8}$ c. $2^{-3} = -\frac{1}{8}$ d. $2^{-3} = -6$

8. What rule/s are you going to apply in this expression, $(\frac{2x^3y^0}{-7x^5y^3})^{-3}$?

   i. Quotient Rule
   ii. Power Rule
   iii. Negative Rule
   iv. Factor Rule

   a. i & iii b. i, ii & iv c. i, ii & iii d. ii, iii & iv

9. Write the quotient of $\frac{12x^4y^7z^0}{-3x^3y^9z^{-5}}$ as a single power.

a. $-4x^7z^5$ b. $4xy^2$ c. $\frac{4x}{y^2z^5}$ d. $-\frac{4xz^5}{y^2}$

10. Simplify the expressions $\frac{(a^3b^{-4}c^0)^{-2}}{(a^2b^5c^3)^{-4}}$

a. $\frac{a^{14}}{b^{20}c^2}$ b. $a^6b^8c^9$ c$\frac{ab}{c^3}$. d. $a^2b^{28}c^{12}$

ADDITIONAL ACTIVITIES

Communication, Critical Thinking

I. Read, analyze and solve each problem.

1. Mr. Gonzales posted a problem in the class. The students were asked to find a number that could replace the question mark.

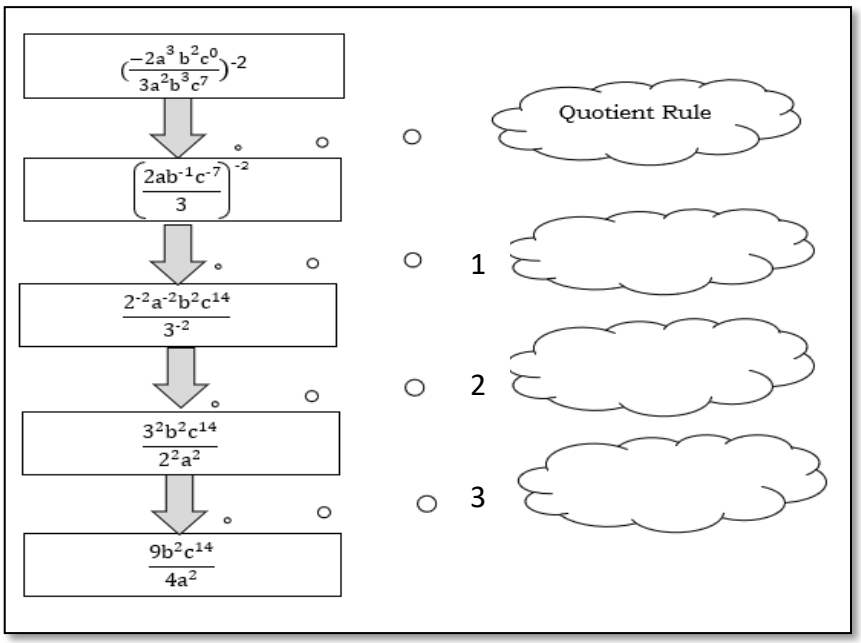
$(4x^2y^4)^0 = x^7 \bullet x^?$

Mica says that the question mark should be replaced by 0.
Richard says that the question mark should be 1.
Amy says that the question mark should be -7.
Leni says that the question is impossible to answer.

Who is correct and explain why?

2. Is $5^{-3} = -5^3$? Explain why or why not.

II. Complete the Math-Rule Map (MRM) by supplying the missing rules inside the clouds.



III. **REFLECT!**

Viruses like COVID-19 spread at an exponential rate causing epidemics affecting millions of people. How can you help stop the spread of this virus in your community?

E-Search

You may also check the following link for your reference and further learnings on representing quadratic function through table of values and graphs:

https://www.youtube.com/watch?v=j7N-vvjEKIQ
https://www.youtube.com/watch?v=tOuCdKqO6-s
https://www.youtube.com/watch?v=Zt2fdy3zrZU
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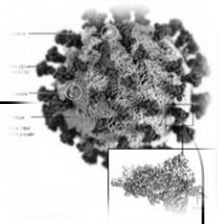
bitmoji application

Coronavirus: Here's how small the enemy is and how it attacks. Accessed June 2020. https://www.ocregister.com/2020/04/10/coronavirus-heres-how-small-the-enemy-is-and-how-it-attacks/

Coronavirus. University of Texas McLellan Lab.Posted Feb.19, 2020. https://news.utexas.edu/2020/02/19/breakthrough-in-coronavirus-research-results-in-new-map-to-support-vaccine-design/

PROBLEM-BASED LEARNING WORKSHEET



SMALL ENEMY

SARS-CoV-2 is the virus that causes the disease COVID-19. The name "coronavirus" is derived from Latin "corona," meaning crown or wreath. The spikes adorning the virus's outer surface gave its original images the look of a corona like that surrounding our sun. Coronaviruses have enveloped virions (virus particles) that measure approximately 120 nm (1 nm = 10^{-9} meter) in diameter.

Accessed from: Coronavirus: Here's how small the enemy is and how it attacks.
https://www.ocregister.com/2020/04/10/coronavirus-heres-how-small-the-enemy-is-and-how-it-attacks/

LET'S ANALYZE

1. What is 10^{-9} using positive exponent?

2. What is its value in fraction form and decimal form?

3. Express the approximate measure of the virus particles in scientific notation in meters.

ANSWER KEY

WHAT I KNOW

1. B
2. D
3. B
4. A
5. C
6. B
7. A
8. C
9. B
10. A

WHAT'S IN

Activity 1

1. 243
2. -8
3. $\frac{p^6}{q^4}$
4. x^{12}
5. 16z4
6. $5m^4$
7. $9x^4y^8$
8. x^2
9. a^2
10. $16n^8$

WHAT IS IT

1. kitti's hog-nosed or bumblebee bat
2. Thailand and Myanmar
3. 7×10^{-2} ounces

4-6. Answer may vary

WHAT'S MORE

Activity 2

1. $\frac{1}{64}$
2. 1
3. 15
4. 1
5. 3
6. $\frac{1}{22}$
7. $\frac{1}{64}$
8. $\frac{9}{4}$
9. 8
10. 1

Activity 3

1. 1
2. 1
3. $\frac{1}{x^3}$
4. $-\frac{8}{h^6}$
5. -5
6. $\frac{1}{ab^2}$
7. $\frac{a^6}{b^2}$
8. $\frac{16x^8}{y^{12}}$
9. 81
10. $\frac{m^4n^2}{49}$

Activity 4

1. 1
2. $\frac{q^6}{p^9}$
3. g^{25}
4. $\frac{y^3}{x^2}$
5. $-\frac{5p^{12}}{n^{10}}$
6. c^3d^2

WHAT I CAN DO

I.

1. 16
2. $6x^6$
3. p^4
4. $-\frac{3x^8}{2y^3}$
5. $-\frac{27x^{21}}{y^{12}}$
6. $\frac{r^{15}}{8s^{27}t^{18}}$
7. $\frac{y^9}{x^2}$
8. $\frac{10x^5z^7}{y^4}$
9. $\frac{1}{(a+b)^2}$ or $\frac{1}{a^2+2ab+b^2}$
10. $\frac{z^6}{2(x+y)}$ or $\frac{z^6}{2x+2y}$

II. 1. 10^6 2. 9 pounds

ASSESSMENT

1. c
2. c
3. a
4. b
5. a
6. c
7. b
8. c
9. d
10. d

ADDITIONAL ACTIVITIES

I. 1. Amy

2. No; $5^{-3} = \frac{1}{124}$ *while* $-5^3 = -125$

II. 1. Power Rule

2. Negative Exponent Rule
3. Definition of Exponents/Simplify

Problem-Based Worksheet

1. $\frac{1}{10^9}$
2. $\frac{1}{1000000000}$; 0.000000001
3. 1.2×10^{-9} meters

PROBLEM-BASED LEARNING WORKSHEET