

Chapter 16

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**Chapter
16**

Exponents and Scientific Notation

Dear Family,

People shop on the Internet, talk to one another using email, and keep digital photo and video albums. Computers represent all this information using numbers.

The number system that computers use is based on powers of 2 and is called the *binary system*. For example, the number 45 is represented as $32 + 8 + 4 + 1 = 2^5 + 2^3 + 2^2 + 2^0$. Try this with your student.

- Find the first eight powers of two, starting with $2^0 = 1$. Write these values on the blanks under the powers of two in the table.

| | | | | | | | | |
|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--------------|
| Power | $2^7 =$ _____ | $2^6 =$ _____ | $2^5 =$ _____ | $2^4 =$ _____ | $2^3 =$ _____ | $2^2 =$ _____ | $2^1 =$ _____ | $2^0 =$ 1 |
| Digit (0 or 1) | | | | | | | | |

- Pick any number from 0 to 255. Find the sum of the powers of two that equal your number.
- Put a 1 in the "Digit" row if the power of two is in your number; put a 0 in the "Digit" row if the power of two is not in your number. For example, the digits for 45 are shown below because $45 = 2^5 + 2^3 + 2^2 + 2^0$.

| | | | | | | | | |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Power | 2^7 | 2^6 | 2^5 | 2^4 | 2^3 | 2^2 | 2^1 | 2^0 |
| Digit | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |

- Write your number as a binary number. For example, 45 is 00101101.

Computer storage and file sizes are often recorded in kilobytes. A kilobyte is equal to 2^{10} bytes = 1024 bytes. People often round this to 1000 bytes. Ask your student to research what powers of two correspond to megabyte, gigabyte, and terabyte. Find the following information on the Internet or in the library.

- How many kilobytes does a typical page of text use?
- How many megabytes does a typical digital photo use?
- How many gigabytes does one minute of video typically use? How does video compare to audio?

Understanding powers helps make computer terms a *bit* more familiar!

**Capítulo
16**

Exponentes y Notación Científica

Estimada Familia:

Las personas compran por Internet, conversan entre sí usando el correo electrónico y tienen álbumes de videos y fotos digitales. Las computadoras representan toda esta información usando números.

El sistema numérico que las computadoras usan se basa en potencias de 2 y se llama *sistema binario*. Por ejemplo, el número 45 se representa como

$32 + 8 + 4 + 1 = 2^5 + 2^3 + 2^2 + 2^0$. Intente hacer esto con su estudiante.

- Encuentren las primeras ocho potencias de dos, empezando con $2^0 = 1$. Escriban estos valores en los espacios en blanco bajo las potencias de dos en la tabla

| | | | | | | | | |
|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|--------------|
| Potencia | $2^7 =$ _____ | $2^6 =$ _____ | $2^5 =$ _____ | $2^4 =$ _____ | $2^3 =$ _____ | $2^2 =$ _____ | $2^1 =$ _____ | $2^0 =$ 1 |
| Dígito (0 ó 1) | | | | | | | | |

- Escojan cualquier número entre 0 y 255. Encuentren la suma de las potencias de dos que equivalen a su número.
- Coloquen un 1 en la fila de "Dígito" si la potencia de dos se encuentra en su número; coloquen un 0 en la fila de "Dígito" si la potencia de dos no se encuentra en su número. Por ejemplo, los dígitos de 45 se muestran a continuación porque $45 = 2^5 + 2^3 + 2^2 + 2^0$.

| | | | | | | | | |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Potencia | 2^7 | 2^6 | 2^5 | 2^4 | 2^3 | 2^2 | 2^1 | 2^0 |
| Dígito | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |

- Escriban su número como número binario. Por ejemplo, 45 es 00101101.

La capacidad de almacenamiento de una computadora y los tamaños de los archivos a menudo se registran en kilobytes. Un kilobyte equivale a 2^{10} bytes = 1024 bytes. A menudo, la gente redondea esto a 1000 bytes. Pida a su estudiante que investigue qué potencias de dos corresponden a megabyte, gigabyte y terabyte. Encuentren la siguiente información en la Internet o en la biblioteca.

- ¿Cuántos kilobytes usa una hoja de texto común?
- ¿Cuántos megabytes usa una fotografía digital común?
- ¿Cuántos gigabytes usa un minuto de video común? ¿Cómo se puede comparar el video con el audio?

¡Comprender las potencias permitirá que se familiaricen un *poco* más con los términos de computación!

**Activity
16.1****Start Thinking!**

For use before Activity 16.1

When have you used exponents before?

What is another way to say “ x to the second power?” Why do you think it is called that?

What is another way to say “ x to the third power?” Why do you think it is called that?

**Activity
16.1****Warm Up**

For use before Activity 16.1

Find the product.

1. $5 \times 5 \times 5$

2. $10 \times 10 \times 10$

3. $(-3) \times (-3) \times (-3)$

4. $10 \times 10 \times 10 \times 10 \times 10$

5. $4 \times 4 \times 4 \times 4$

6. $(-2) \times (-2) \times (-2) \times (-2)$

**Lesson
16.1****Start Thinking!**

For use before Lesson 16.1

Use the nursery rhyme on page 411 of your textbook to guide you in writing your own “power poem.”

**Lesson
16.1****Warm Up**

For use before Lesson 16.1

Write the product using exponents.

1. $2 \cdot 2 \cdot 2$

2. $(-7) \cdot (-7)$

3. $\frac{2}{3} \cdot \frac{2}{3} \cdot \frac{2}{3} \cdot \frac{2}{3} \cdot \frac{2}{3}$

4. $\left(-\frac{1}{6}\right) \cdot \left(-\frac{1}{6}\right) \cdot \left(-\frac{1}{6}\right)$

5. $11 \cdot 11 \cdot 11 \cdot 11 \cdot 11 \cdot 11 \cdot 11$

6. $\left(-\frac{1}{4}\right) \cdot \left(-\frac{1}{4}\right) \cdot \left(-\frac{1}{4}\right) \cdot \left(-\frac{1}{4}\right)$

16.1 Practice A

Write the product using exponents.

1. $6 \cdot 6 \cdot 6 \cdot 6 \cdot 6$

2. $(-2) \cdot (-2) \cdot (-2)$

3. $\frac{2}{3} \cdot \frac{2}{3} \cdot \frac{2}{3} \cdot \frac{2}{3}$

4. $(-1.2) \cdot (-1.2) \cdot (-1.2)$

5. $\frac{1}{5} \cdot \frac{1}{5} \cdot x \cdot x \cdot x$

6. $10 \cdot 10 \cdot (-n) \cdot (-n) \cdot (-n)$

7. $(-5) \cdot (-5) \cdot (-5) \cdot (-5) \cdot y \cdot y \cdot y \cdot y \cdot y$

Evaluate the expression.

8. 9^2

9. -5^4

10. $(-3)^4$

11. $\left(\frac{1}{4}\right)^3$

12. Write the prime factorization of 500 using exponents.

Evaluate the expression.

13. $7 + (-2) \cdot 3^2$

14. $(15^2 - 5 \cdot 4^2) \div 5$

15. $\left| \frac{1}{3} \left(2^3 - \frac{10^2}{5} \right) \right|$

16. $\frac{3}{2} (4^3 - 2^2 \cdot 3^2)$

17. There are 5 posts supporting the guard rail for the steps to your home. The tallest post is 3 feet tall. The height of each of the other posts is $\frac{5}{6}$ the height of the next larger post.

a. Write an expression for the height of the shortest post.

b. What is the height of the shortest post?

18. You ran 4 miles. Rob ran half as far as you. Tim ran half as far as Rob. Nicole ran half as far as Tim.

a. Write an expression for how far Nicole ran.

b. How far did Nicole run?

16.1 Practice B

Write the product using exponents.

1. $4 \cdot 4 \cdot 4 \cdot 4 \cdot 4 \cdot 4$

2. $(-12) \cdot (-12) \cdot (-12) \cdot (-12) \cdot (-12)$

3. $-\frac{3}{7} \cdot \frac{3}{7} \cdot \frac{3}{7}$

4. $\left(-\frac{3}{7}\right) \cdot \left(-\frac{3}{7}\right) \cdot \left(-\frac{3}{7}\right)$

5. $(-9) \cdot (-9) \cdot (-9) \cdot (-9) \cdot x \cdot x \cdot x$

6. $25 \cdot 25 \cdot 25 \cdot 25 \cdot (-p) \cdot (-p) \cdot (-p) \cdot (-p) \cdot (-p)$

7. $(-2) \cdot (-2) \cdot x \cdot x \cdot x \cdot y \cdot y \cdot y \cdot y$

Evaluate the expression.

8. 7^3

9. -4^4

10. $(-4)^4$

11. $\left(\frac{2}{5}\right)^3$

12. Write the prime factorization of 1323 using exponents.

Evaluate the expression.

13. $280 - (-3) \cdot (-5)^3$

14. $(20^2 - 3^3 \cdot 8^2) \div 16$

15. $\frac{2}{3}(16^2 - 17^2)$

16. $\left|\frac{1}{5}\left(\frac{6^3}{3^3} - 2^3\right)\right|$

17. Bed A is 7 feet long. Bed B is $\frac{7}{8}$ as long as bed A. Bed C is $\frac{7}{8}$ as long as bed B. Bed D is $\frac{7}{8}$ as long as bed C.

a. Write an expression for the length of bed D.

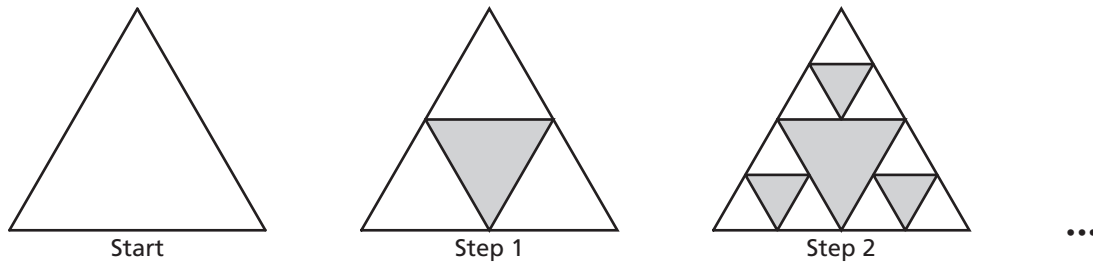
b. What is the length of bed D?

16.1 Enrichment and Extension

The Sierpinski Triangle

A geometric pattern is formed by multiplying by the same number at each step. For example, the numbers 1, 2, 4, 8, 16, ... form a geometric pattern because each number is twice the previous number.

The Sierpinski Triangle is constructed using the pattern below.



1. Describe the pattern between steps.
2. Draw the next step in the pattern.
3. Complete the table.

| Step | White Triangles | Gray Triangles |
|------|-----------------|----------------|
| 0 | 1 | 0 |
| 1 | 3 | 1 |
| 2 | | |
| 3 | | |
| 4 | | |

4. Describe the pattern in the number of white triangles at each step.
5. Describe the pattern in the number of gray triangles at each step.
6. How many white triangles will there be at the ninth step? Write your answer using exponents.

16.1 Puzzle Time

How Does A Bee Part His Hair?

Write the letter of each answer in the box containing the exercise number.

Evaluate the expression.

1. 3^3
2. -4^5
3. $(-2)^5$
4. $(-7)^4$
5. $\left(\frac{1}{5}\right)^3$
6. $\left(-\frac{1}{3}\right)^5$
7. $-\left(\frac{1}{4}\right)^3$
8. $\left|-\left(\frac{1}{6}\right)^3\right|$
9. $7^3 - 5^4$
10. $4 \bullet 3^4 + 6$
11. $2(11^3 - 10^3)$
12. $\frac{1}{8}(4^6 - 4^3)$
13. $|6^3 - 7^3|$
14. $|9^2 + (-9)^3|$
15. You are sending a package in the mail. The box is a cube measuring 14 inches on all sides. How many cubic inches is the package?
16. You sent an email to 8 friends. They each forwarded the email to 8 friends. And those friends each forwarded the email to 8 friends. The chain of emails is represented by the expression $8 + 8^2 + 8^3$. How many people were sent your email?

Answers

- S. $-\frac{1}{243}$
- T. -282
- C. 584
- I. -1024
- E. 662
- O. $\frac{1}{125}$
- I. 27
- O. 504
- H. 330
- B. 2744
- W. $\frac{1}{216}$
- H. 2401
- H. 127
- Y. 648
- M. $-\frac{1}{64}$
- N. -32

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|--|----|---|---|--|----|---|---|----|----|----|----|---|----|
| 8 | 2 | 9 | 4 | | 10 | 1 | 6 | | 13 | 5 | 3 | 11 | 14 | 16 | 12 | 7 | 15 |
|---|---|---|---|--|----|---|---|--|----|---|---|----|----|----|----|---|----|

**Activity
16.2****Start Thinking!**

For use before Activity 16.2

Explain why exponents are a useful convention.

Give an example of a variable expression that is much easier to write using exponents than not using them.

**Activity
16.2****Warm Up**

For use before Activity 16.2

Evaluate the expression.

1. 3^5

2. 5^4

3. 10^6

4. $(-4)^3$

5. $(-3)^2$

6. $(-2)^5$

**Lesson
16.2****Start Thinking!**

For use before Lesson 16.2

In Activity 10.2, you found the rule for finding the product of powers: $a^m \cdot a^n = a^{m+n}$.

Which of the following expressions can be simplified using the product of powers rule?

$$2^6 \cdot 2^7 \quad 3^2 \cdot 4^2 \quad (-2)^2 \cdot (-2)^{12}$$

$$c^3 \cdot c^4 \quad x^3 \cdot y^1 \quad a^2 \cdot 4^2$$

**Lesson
16.2****Warm Up**

For use before Lesson 16.2

Simplify the expression. Write your answer as a power.

1. $2^4 \cdot 2^3$

2. $7^5 \cdot 7^7$

3. $\left(\frac{1}{2}\right)^2 \cdot \left(\frac{1}{2}\right)^5$

4. $\left(-\frac{3}{5}\right)^3 \cdot \left(-\frac{3}{5}\right)^3$

5. $x^5 \cdot x^{11}$

6. $y^3 \cdot y$

16.2 Practice A

Simplify the expression. Write your answer as a power.

1. $2^3 \cdot 2^2$

2. $9^6 \cdot 9^8$

3. $(-7)^3 \cdot (-7)^5$

4. $\left(\frac{5}{8}\right)^{10} \cdot \left(\frac{5}{8}\right)^2$

5. $c \cdot c^5$

6. $q^4 \cdot q^4$

7. $\left(-\frac{4}{9}\right)^2 \cdot \left(-\frac{4}{9}\right)^5$

8. $(4.7)^3 \cdot (4.7)^2$

9. $(3^2)^3$

10. $(k^5)^{10}$

11. $\left(\left(\frac{1}{2}\right)^4\right)^3$

12. $\left((9.2)^3\right)^6$

Simplify the expression.

13. $(4n)^2$

14. $(-2w)^5$

15. $\left(\frac{1}{3}p\right)^4$

16. $(2.5j)^3$

17. $(ab)^{18}$

18. $3^2(3 \cdot 3^4)$

19. Is $3^2 \cdot 4^2 = 12^4$? Evaluate each side of the equation to explain your answer.

20. The volume of a sphere is $V = \frac{4}{3}\pi r^3$ and the relationship between the radius r and the diameter d is $r = \frac{d}{2}$.

a. Find the volume of the sphere in terms of the diameter d and simplify the expressions.

b. What is the volume of the sphere when the diameter is $\frac{2}{3}$ centimeter?

16.2 Practice B

Simplify the expression. Write your answer as a power.

1. $8^3 \cdot 8^7$

2. $(-16)^5 \cdot (-16)^{21}$

3. $\left(-\frac{5}{9}\right)^5 \cdot \left(-\frac{5}{9}\right)^5$

4. $\left(\frac{1}{15}\right)^{12} \cdot \left(\frac{1}{15}\right)$

5. $q^7 \cdot q^9$

6. $(13.2)^6 \cdot (13.2)^2$

7. $(-7.4)^9 \cdot (-7.4)^{12}$

8. $(9^3)^3$

9. $(d^2)^6$

10. $(2.9^3)^6$

11. $\left(\left(\frac{5}{8}\right)^2\right)^3$

12. $\left(\left(-\frac{2}{9}\right)^3\right)^5$

Simplify the expression.

13. $(-2p)^4$

14. $\left(\frac{1}{5}k\right)^3$

15. $(1.4c)^3$

16. $(mn)^8$

17. $(3^2)^4 - 3^5 \cdot 3$

18. $10\left(\frac{1}{5}v\right)^3$

19. The volume of a right circular cylinder is $V = \pi r^2 h$. The relationship between the height h of a given right circular cylinder and the radius r is

$$r = \frac{2}{3}h.$$

- a. Find the volume of the right circular cylinder in terms of the height h and simplify the expression.

- b. What is the volume of the right circular cylinder when the height is $\frac{3}{4}$ inch?

Find the value of x in the equation without evaluating the power.

20. $3^2 \cdot 3^x = 3^{12}$

21. $(5^x)^4 = 5^{24}$

16.2 Enrichment and Extension

Compound Exponents

Compound exponents have the form a^{m^n} . They are evaluated from the top down.

Example: Simplify 4^{3^2} .

$$\begin{aligned} 4^{3^2} &= 4^{(3^2)} && \text{Rewrite.} \\ &= 4^9 && \text{Simplify.} \\ &= 262,144 && \text{Evaluate.} \end{aligned}$$

Simplify the expression.

1. x^{4^3} 2. y^{3^4} 3. a^{11^2} 4. b^{9^3}

Compound exponents are used in Fermat numbers. Fermat numbers have the form $2^{2^n} + 1$ and are used in number theory and computational algorithms.

5. Complete the table.

| n | 2^n | 2^{2^n} | Fermat number |
|-----|-------|-----------|---------------|
| 1 | 2 | 4 | 5 |
| 2 | | | |
| 3 | | | |
| 4 | | | |

6. What pattern do you notice in the 2^{2^n} column?
7. Would 3^{2^n} have the same pattern? Explain.
8. Which do you think would grow faster, 2^{2^n} or 2^{n^2} ?

16.2 Puzzle Time

Did You Hear About...

| | | | | | |
|---|---|---|---|---|---|
| A | B | C | D | E | F |
| G | H | I | J | K | L |
| M | N | | | | |

Complete each exercise. Find the answer in the answer column. Write the word under the answer in the box containing the exercise letter.

| | | |
|-------------------------------------|--|--|
| $-4c^5$ NOTES | <p>Simplify the expression. Write your answer as a power.</p> <p>A. $4 \cdot 4^5$ B. $6^3 \cdot 6^7$</p> | $2.25r^2$ ONE |
| 2058 KEYS | | $(-3)^{11}$ TEACHER |
| $-1024c^5$ BECAUSE | <p>C. $(-3)^8 \cdot (-3)^3$ D. $\left(\frac{4}{5}\right)^2 \cdot \left(\frac{4}{5}\right)^6$</p> <p>E. $(7^3)^5$ F. $((-8)^{10})^3$</p> | $1.5r^2$ CLASS |
| 3^{24} HOW | | 7^{15} CALLED |
| 6^{10} PIANO | <p>Simplify the expression.</p> <p>G. $(8a)^3$ H. $(-4c)^5$</p> <p>I. $(1.5r)^2$ J. $\left(\frac{2}{3}m\right)^4$</p> | 6561 GOT |
| $8a^3$ DOOR | | $512a^3$ LOCKSMITH |
| $\left(\frac{4}{5}\right)^8$ WHO | <p>K. $3^2 \cdot 3^4 - 4^4$ L. $7 \cdot (7^3 - 7^2)$</p> <p>M. $\left(\frac{1}{3}\right)^4 \cdot (9^3)^2$</p> | $\frac{2}{3}m^4$ SHE |
| $\frac{16}{81}m^4$ OF | | $\left(\frac{4}{5}\right)^{12}$ ARE |
| $6 \cdot 10^7$ STUCK | <p>N. The budget for a remake of a movie is 100 times the budget of the original movie. The original movie's budget was $6 \cdot 10^5$ dollars. What is the budget of the remake? Express your answer as a power.</p> | 4^6 THE |
| $(-8)^{30}$ THE | | 473 HER |

**Activity
16.3****Start Thinking!**

For use before Activity 16.3

You have learned about the Product of Powers Property. What does the property state?

There is a related property called the Quotient of Powers Property. What do you think it might state?

**Activity
16.3****Warm Up**

For use before Activity 16.3

Write the power as repeated multiplication.

1. 5^4

2. 7^3

3. 6^7

4. $(-4)^3$

5. $(-3)^5$

6. $(-1)^3$

**Lesson
16.3****Start Thinking!**

For use before Lesson 16.3

Scott learned about the Quotient of Powers Property in math class, but he is not convinced that it is helpful. For example, he thinks that it is just as easy to simplify $\frac{2^5}{2^2}$ by calculating

$2^5 = 32$ and dividing by $2^2 = 4$ to get 8. Do you agree or disagree with Scott? Give reasons to support your answer.

**Lesson
16.3****Warm Up**

For use before Lesson 16.3

Simplify the expression. Write your answer as a power.

1. $\frac{5^9}{5^6}$

2. $\frac{4^8}{4^4}$

3. $\frac{2.5^5}{2.5^2}$

4. $\frac{10.1^7}{10.1^3}$

5. $\frac{(-5)^{12}}{(-5)^{10}}$

6. $\frac{(-2)^7}{(-2)^6}$

16.3 Practice A

Simplify the expression. Write your answer as a power.

1. $\frac{3^8}{3^6}$

2. $\frac{10^{11}}{10^3}$

3. $\frac{(-4)^5}{(-4)^4}$

4. $\frac{(5.6)^{15}}{(5.6)^9}$

5. $\frac{p^{13}}{p^{11}}$

6. $\frac{(-0.7)^{25}}{(-0.7)^{12}}$

7. $\frac{s^{28}}{s^7}$

8. $\frac{\pi^6}{\pi}$

9. A personal computer developed in the 1980s had approximately 2^{18} bytes of memory. Today a laptop has 1 gigabyte = 2^{30} bytes of memory. How many times more memory does today's laptop have than the personal computer from the 1980s?

Simplify the expression. Write your answer as a power.

10. $\frac{6^3 \cdot 6^7}{6^4}$

11. $\frac{3^4 \cdot 3^5}{3 \cdot 3^2}$

12. $\frac{(-0.5)^8 \cdot (-0.5)^5}{(-0.5)^6 \cdot (-0.5)^2}$

13. $\frac{m^{14}}{m^{10}} \cdot \frac{m^5}{m^2}$

Simplify the expression.

14. $\frac{5^4 \cdot n^4}{5^2}$

15. $\frac{x^5 \cdot z^4}{x^2 \cdot z^2}$

16. $\frac{c^6 \cdot d^{10} \cdot 2^6}{d^5 \cdot 2^3}$

17. $\frac{a^{12}b^8}{a^{10}b^5}$

Find the value of x in the equation without evaluating the power.

18. $\frac{5^9}{5^x} = 625$

19. $\frac{3^7 \cdot 3^x}{3^6} = 9$

16.3 Practice B

Simplify the expression. Write your answer as a power.

1. $\frac{12^{20}}{12^9}$

2. $\frac{7.6^{13}}{7.6^3}$

3. $\frac{(-9)^{15}}{(-9)^3}$

4. $\frac{(-8.5)^{11}}{(-8.5)^{10}}$

5. $\frac{u^{33}}{u^{11}}$

6. $\frac{\pi^9}{\pi^4}$

7. $\frac{(-1000)^{13}}{(-1000)^8}$

8. $\frac{t^{21}}{t^{19}}$

9. One kilometer equals 10^3 meters. One terameter equals 10^{12} meters. How many times larger is a terameter than a kilometer?

Simplify the expression. Write your answer as a power.

10. $\frac{11^7 \cdot 11^{10}}{11^4 \cdot 11^2}$

11. $\frac{2.5^8 \cdot 2.5^3}{2.5 \cdot 2.5^4}$

12. $\frac{(-7.9)^{15} \cdot (-7.9)^9}{(-7.9)^{12} \cdot (-7.9)^7}$

13. $\frac{b^{35}}{b^{20}} \cdot \frac{b^{15}}{b^{10}}$

Simplify the expression.

14. $\frac{4^8 \cdot m^7 \cdot n^4}{4^5 \cdot m^2}$

15. $\frac{r^{12} \cdot s^7 \cdot t^9}{r^9 \cdot s^3}$

16. $\frac{p^{18}q^{11}}{p^{10}q^8}$

17. $\frac{3^5a^{17}b^{21}}{3^4a^{15}b^{12}}$

Find the value of x in the equation without evaluating the power.

18. $\frac{9^7}{9^x} = 729$

19. $\frac{2^{12} \cdot 2^x}{2^{10}} = 32$

16.3 Enrichment and Extension

Number Search

Émile Borel was a French mathematician who studied probability theory and randomness. He developed a theory that if monkeys randomly hit the keys of typewriters, over a long period of time, one would eventually by chance type the play *Hamlet* by William Shakespeare.

Evaluate each expression. Circle the corresponding answer in the grid. Answers may read vertically, horizontally, diagonally, backwards, or forwards, but always in a straight line. When you have finished, put the unused numbers in the blanks in order, reading left to right and top to bottom.

Question: What is the probability of one monkey randomly typing *Hamlet* on the first try?

Answer: About ___ in (___)-----

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 7 | 8 | 1 | 9 | 4 | 3 |
| 3 | 2 | 6 | 0 | 7 | 6 | 2 |
| 1 | 4 | 5 | 3 | 5 | 8 | 1 |
| 5 | 0 | 6 | 2 | 9 | 0 | 4 |
| 2 | 7 | 7 | 0 | 4 | 8 | 1 |
| 8 | 0 | 4 | 3 | 6 | 7 | 9 |
| 7 | 9 | 1 | 2 | 4 | 0 | 5 |

1. $2^3 + 3^2 + 753$

2. $(2^2)^2 \cdot 5^2 + 6^2$

3. $95^2 + 10^2 - 1^2$

4. $31^2 - 3^2 \cdot 2$

5. $26^2 + 27^2 + 3^2 - 2$

6. $3^4 + 2^2$

7. $7^3 + 3$

8. $5(5)^3 + 2(5^3)$

9. $\frac{9^4 + 19 - (-7)^3}{7}$

10. $\frac{1}{2}(6^4 - 9^2 - 1)$

11. $(7 \cdot 2^2)^2 \cdot 10 - 15$

12. $\frac{10^5 + 10^4}{2} + 2 \cdot 10^3 + 21^2 - 3 \cdot 2^2 - 2^2$

16.3 Puzzle Time

What Do You Give A Dog That Loves Computers?

Write the letter of each answer in the box containing the exercise number.

Simplify the expression. Write the answer as a power.

1. $\frac{8^{12}}{8^6}$

2. $\frac{3^{24}}{3^{15}}$

3. $\frac{(-7)^{14}}{(-7)^4}$

4. $\frac{2.8^7}{2.8^4}$

5. $\frac{\pi^{12}}{\pi^5}$

6. $\frac{x^8}{x^3}$

7. $\frac{3^4 \cdot 3^5}{3^2 \cdot 3^2}$

8. $\frac{8^{15}}{8^7 \cdot 8}$

9. $\frac{\pi^5 \cdot \pi^9}{\pi^3 \cdot \pi^3}$

10. $\frac{x^{14} \cdot x^5}{x^7}$

11. $\frac{(-7)^3 \cdot (-7)^9}{(-7)^2 \cdot (-7)}$

12. $\frac{2.8^{15} \cdot 2.8^8}{2.8^9 \cdot 2.8^6}$

13. There are about $4 \cdot 10^5$ known species of beetles. The number of known species of caddis flies is about 10^4 . How many times more species of beetles are there than caddis flies?
14. The area of the Pacific Ocean is approximately $6.4 \cdot 10^7$ square miles. The area of the Gulf of Mexico is approximately 10^5 square miles. How many times greater is the area of the Pacific Ocean than the area of the Gulf of Mexico?

| Answers | |
|---------|-------------|
| Y. | 2.8^3 |
| D. | x^{12} |
| I. | π^7 |
| D. | $(-7)^9$ |
| E. | x^5 |
| E. | 3^9 |
| T. | 40 |
| G. | 8^7 |
| O. | $(-7)^{10}$ |
| S. | π^8 |
| S. | 8^6 |
| K. | 640 |
| T. | 3^5 |
| G. | 2.8^8 |

| | | | | | | | | | | | | | | |
|----|---|---|----|---|--|----|---|---|----|---|---|----|---|---|
| 11 | 3 | 8 | 12 | 4 | | 10 | 5 | 9 | 14 | 6 | 7 | 13 | 2 | 1 |
|----|---|---|----|---|--|----|---|---|----|---|---|----|---|---|

Activity
16.4**Start Thinking!**

For use before Activity 16.4

What do you think it means for a number to be raised to the **zero power**?

Use your calculator to see if you are right.

Activity
16.4**Warm Up**

For use before Activity 16.4

Simplify the expression. Write your answer as a power.

1. $\frac{5^4 \cdot 5^2}{5^3}$

2. $\frac{2^{11} \cdot 2^5}{2^{13}}$

3. $\frac{4^5 \cdot 4^3}{4^2}$

4. $\frac{a^{13} \cdot a^{11}}{a^{12}}$

5. $\frac{c^9 \cdot c^5}{c^{10}}$

6. $\frac{n^7 \cdot n^{14}}{n^{11}}$

**Lesson
16.4****Start Thinking!**

For use before Lesson 16.4

Can a number raised to a negative power ever be greater than 1? If so, give an example. If not, explain why not.

Can a number raised to a negative power ever be less than 0? If so, give an example. If not, explain why not.

**Lesson
16.4****Warm Up**

For use before Lesson 16.4

Evaluate the expression.

1. $\frac{3^6}{3^6}$

2. $7^0 \cdot 7^2$

3. $\frac{-2^6}{-2^6}$

4. $5^3 \cdot 5^{-3}$

5. $9^0 \cdot 9^3$

6. $(-3)^3 \cdot (-3)^{-3}$

16.4 Practice A**Evaluate the expression.**

1. 3^{-4}

2. 32^0

3. $\frac{8^3}{8^5}$

4. $\frac{(-9)^4}{(-9)^7}$

5. $5^{-12} \cdot 5^{12}$

6. $\frac{1}{4^{-5}} \cdot \frac{1}{4^8}$

7. $6^{-1} \cdot 6^{-2}$

8. $\frac{2^6}{2^{-8} \cdot 2^{10}}$

9. One terameter equals 10^{12} meters. One micrometer equals 10^{-6} meter. One nanometer equals 10^{-9} meter.

- Find the product of one terameter and one micrometer, using only positive exponents.
- Find the quotient of one terameter and one micrometer, using only positive exponents.
- Find the product of one terameter and one nanometer, using only positive exponents.
- Find the quotient of one terameter and one nanometer, using only positive exponents.
- Find the quotient of one nanometer and one terameter, using only positive exponents.
- Find the quotient of one nanometer and one micrometer, using only positive exponents.
- Find the product of one nanometer and one micrometer, using only positive exponents.

Simplify. Write the expression using only positive exponents.

10. $8x^{-3}$

11. $5^{-3} \cdot m^6$

12. $\frac{7p^5}{p^{-1}}$

13. $\frac{10t^{-5}}{t^{-2}}$

14. $\frac{15d^4}{3d^9}$

15. $6w^{-2} \cdot 4w^2$

16.4 Practice B**Evaluate the expression.**

1. 5^{-3}

2. $(-8)^0$

3. $\frac{6^{-3}}{6^{-5}}$

4. $\frac{15^{-4}}{15^{-4}}$

5. $10^{-1} \cdot 10^{-2}$

6. $\frac{1}{3^{-4}} \cdot \frac{1}{3^6}$

7. $27^{-18} \cdot 27^{18}$

8. $\frac{4^{-7}}{4^2 \cdot 4^{-5}}$

9. One millimeter equals 10^{-3} meter. One picometer equals 10^{-12} meter. One femtometer equals 10^{-15} meter.

- Find the product of one millimeter and one picometer, using only positive exponents.
- Find the quotient of one picometer and one millimeter, using only positive exponents.
- Find the product of one millimeter and one femtometer, using only positive exponents.
- Find the quotient of one femtometer and one picometer, using only positive exponents.
- Find the quotient of one picometer and one femtometer, using only positive exponents.
- Find the quotient of one millimeter and one femtometer, using only positive exponents.
- Find the product of one picometer and one femtometer, using only positive exponents.

Simplify. Write the expression using only positive exponents.

10. $\frac{14u^{-4}}{7u^8}$

11. $\frac{18w^{-8}}{w^{-5}}$

12. $y^5 \cdot z^{-3}$

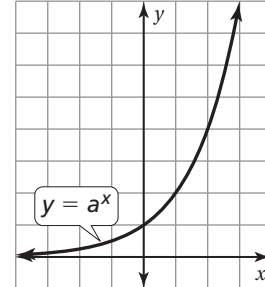
13. $\frac{2^{-3} \cdot a^0 \cdot b^5}{b^{-4}}$

16.4 Enrichment and Extension

Exponential Graphs

An exponential equation has the form $y = a^x$, where a is a positive number. For example,

$y = 2^x$ and $y = \left(\frac{3}{4}\right)^x$ are exponential equations.



1. Is the graph of $y = 2^x$ linear? Explain your reasoning.
2. What is the y -intercept of $y = 2^x$?
3. Does $y = 2^x$ have an x -intercept?

4. Copy and complete the table for $y = \left(\frac{1}{2}\right)^x$ and plot the points to graph it.

Describe how the graph of $y = \left(\frac{1}{2}\right)^x$ compares to the graph of $y = 2^x$.

5. What is the y -intercept of $y = \left(\frac{1}{2}\right)^x$?
6. Will all exponential equations have the same y -intercept? Explain your reasoning.
7. What value of a will make the graph linear?

| x | y |
|-----|-----|
| -3 | |
| -2 | |
| -1 | |
| 0 | |
| 1 | |
| 2 | |
| 3 | |

16.4 Puzzle Time

What Happened When The Tree Saw The Ghost?

Circle the letter of each correct answer in the boxes below. The circled letters will spell out the answer to the riddle.

Evaluate the expression.

1. $7^{-5} \cdot 7^3$

2. $5^2 \cdot 5^{-6}$

3. $\frac{2^7}{2^{10}}$

4. $\frac{6^0}{6^3}$

5. $\frac{(-8)^3}{(-8)^5}$

6. $\frac{(2.2)^7}{(2.2)^9}$

7. $\frac{4^5}{4^4} \cdot \frac{4^8}{4^{13}}$

8. $\frac{(-9)^3}{(-9)^7 \cdot (-9)^{-2}}$

Simplify the expression using only positive exponents.

9. $3^{-2}a^4$

10. $12^{-1}t^{-3}$

11. $\frac{b^4}{5^{-2}b^8}$

12. $\frac{14r^8}{2r^{15}}$

13. $\frac{x^5 \cdot y^6}{2^{-2} \cdot x^0 \cdot y^9}$

14. $\frac{6 \cdot f^{-4} \cdot g^2}{2 \cdot f^{-4} \cdot g^{-1}}$

| | | | | | | | | | | | | | | | | |
|------------------|--------------------|-------------------|----------------|----------------|------------------|----------------|--------|------------------|---------|--------------------|----------------|-----------------|--------------------|------------------|------------------|-----------------|
| H | A | I | S | T | R | M | E | W | L | A | N | S | U | V | D | Y |
| 8 | $\frac{4x^4}{y^2}$ | $\frac{1}{12t^3}$ | $\frac{1}{16}$ | $\frac{1}{49}$ | $\frac{1}{9a^4}$ | $\frac{1}{36}$ | $7r^7$ | $\frac{1}{4.84}$ | $3fg^3$ | $\frac{1}{216}$ | 81 | $\frac{1}{625}$ | $\frac{x^5}{4y^3}$ | $\frac{25}{b^2}$ | 49 | $-\frac{1}{64}$ |
| I | P | T | E | G | T | R | O | I | S | F | Q | I | K | E | B | D |
| $\frac{12}{t^3}$ | $3g^3$ | $\frac{1}{125}$ | $\frac{1}{8}$ | 4.84 | $\frac{25}{b^4}$ | $\frac{1}{81}$ | -8 | $\frac{a^4}{9}$ | 64 | $\frac{4x^5}{y^3}$ | $\frac{3}{fg}$ | $\frac{1}{64}$ | -16 | $\frac{1}{256}$ | $\frac{t^3}{12}$ | $\frac{7}{r^7}$ |

Activity
16.5**Start Thinking!**

For use before Activity 16.5

Explain how a scientist might use negative exponents.

Activity
16.5**Warm Up**

For use before Activity 16.5

Evaluate the expression.

1. 10^3

2. 10^{-4}

3. 10^5

4. 10^{-2}

5. 10^{10}

6. 10^{-5}

Lesson
16.5

Start Thinking!

For use before Lesson 16.5

Use the Internet to find the mass of an electron and the mass of Earth.

Before you begin your research, do you expect that the masses will be given in scientific notation? Why or why not?

Were you correct?

Lesson
16.5

Warm Up

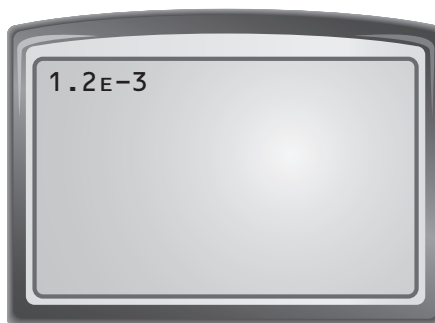
For use before Lesson 16.5

Write the number shown on the calculator display in standard form.

1.



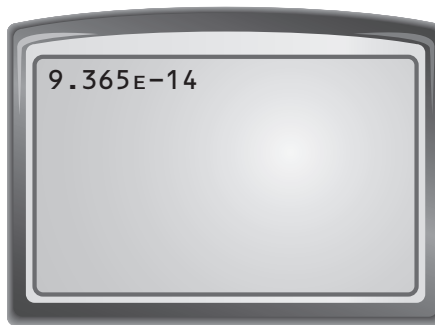
2.



3.



4.



16.5 Practice A

Write the number shown on the calculator display in standard form.

1.



2.



Tell whether the number is written in scientific notation. Explain.

3. 4.375×10^{-8}

4. 62.9×10^{14}

5. 9.897×10^{-15}

6. 0.451×10^{-12}

7. 25×10^{18}

8. 5.1786×10^{-25}

Write the number in standard form.

9. 8×10^6

10. 9×10^{-2}

11. 2×10^3

12. 5.3×10^{-4}

13. 1.2×10^8

14. 7.86×10^5

15. The average distance from Earth to the Sun is about 1.5×10^{11} meters.
The average distance from Earth to the Moon is about 3.84×10^8 meters.

- Write the distance from Earth to the Sun in standard form.
- Write the distance from Earth to the Moon in standard form.
- Which is closer to Earth, the *Sun* or the *Moon*?

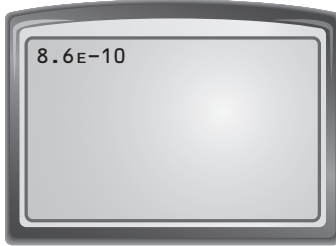
16. A day is about 8.64×10^4 seconds.

- How many seconds are in 5 days? Write your answer in standard form.
- How many seconds are in 1 month (30 days)? Write your answer in standard form.
- How many seconds are in 1 year (365 days)? Write your answer in standard form.
- How many seconds are in 1 leap year (366 days)? Write your answer in standard form.
- What is the difference (in seconds) between 1 year and 1 leap year? Write your answer in both standard form and scientific notation.

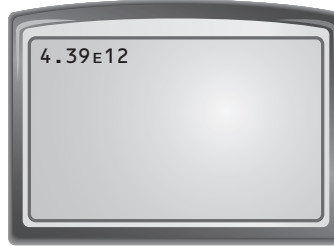
16.5 Practice B

Write the number shown on the calculator display in standard form.

1.



2.



Tell whether the number is written in scientific notation. Explain.

3. 17×10^{15}

4. 3.712×10^{-8}

5. 7.54×10^{21}

6. 0.999×10^{-15}

7. 125.42×10^{-12}

8. 7.65×10^{25}

Write the number in standard form.

9. 5×10^{-4}

10. 1.54×10^5

11. 1.78×10^{-6}

12. 9.876×10^{-4}

13. 2.08×10^7

14. 3.555×10^8

15. The radius of Earth is about 6.38×10^6 meters. The radius of the Moon is about 1.74×10^6 meters. The radius of the Sun is about 7×10^8 meters.

- Which is the largest, *Earth*, the *Moon*, or the *Sun*?
- Which is the smallest, *Earth*, the *Moon*, or the *Sun*?
- Write the radius of Earth in standard form.
- Write the radius of the Moon in standard form.
- Write the radius of the Sun in standard form.

16. A year is about 3.156×10^7 seconds.

- How many seconds are in 5 years? Write your answer in standard form.
- How many seconds are in half a year? Write your answer in standard form.
- How many seconds are in 1 month? Write your answer in standard form.

16.5 Enrichment and Extension

Different Bases

The decimal system is a base 10 system. Each place value represents 10 to a power. Computers often use a binary or base 2 system, where each place value represents a power of 2. Some systems use a base 8 or a base 16 system.

To convert a number from a given base into base 10, write the number as a sum of powers of the base and evaluate the expression.

1. Write 30,275 as a sum of powers of 10.

$$\underline{\quad} \cdot 10^4 + \underline{\quad} \cdot 10^3 + \underline{\quad} \cdot 10^2 + \underline{\quad} \cdot 10^1 + \underline{\quad} \cdot 10^0$$

2. The number 1001010 is in base 2. Write the number as a sum of powers of 2.

$$\underline{\quad} \cdot 2^6 + \underline{\quad} \cdot 2^5 + \underline{\quad} \cdot 2^4 + \underline{\quad} \cdot 2^3 + \underline{\quad} \cdot 2^2 + \underline{\quad} \cdot 2^1 + \underline{\quad} \cdot 2^0$$

3. Evaluate the expression in Exercise 2 to convert 1001010 from base 2 to base 10.
4. The number 331 is in base 4.
- Powers of what number should appear in your sum?
 - How many terms will there be in your sum?
 - Write and evaluate an expression to convert 331 from base 4 into base 10.
5. Use powers of the given base to write each number as a sum of powers of the base. Then evaluate the expression to convert the number to base 10.
- The number 22012 is in base 3.
 - The number 3004 is in base 8.
 - The number 501 is in base 6.
 - The number 312 is in base 16.
6. Write 41 in base 2. (A base 2 system uses the digits 0 and 1.)

 **16.5 Puzzle Time****What Position Did The Ghost Play On The Hockey Team?**

Write the letter of each answer in the box containing the exercise number.

1. Which number is written in scientific notation?

H. 1.8×8^{-5}

I. 4.2×10^{-8}

J. 6.5×9^7

2. Which number is
- not*
- written in scientific notation?

S. 5.3×10^{-6}

T. 6×10^{-6}

U. 45×10^8

3. Which number is
- not*
- written in scientific notation?

E. 0.9×10^{12}

F. -8.2×10^{10}

G. 1×10^{-13}

4. Write
- 3.54×10^6
- in standard form.

N. 0.00000354

O. 3,540,000

P. 354,000,000

5. Write
- -1.92×10^{-4}
- in standard form.

H. -0.000192

I. -19,200

J. -0.0000192

6. The distance to the Sun is about
- 9.3×10^7
- miles. What is the distance to the Sun in standard form?

K. 9,300,000 mi

L. 93,000,000 mi

M. 930,000,000 mi

7. The population of a country is about
- 1.32×10^9
- . What is the population of the country in standard form?

E. 13,200,000,000 people

F. 132,000,000 people

G. 1,320,000,000 people

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | 5 | 4 | 2 | 6 | 1 | 3 |
|---|---|---|---|---|---|---|

Activity
16.6**Start Thinking!**
For use before Activity 16.6

Choose a number greater than 1,000,000.
Write it in standard form.

Write a list of steps that describe how you
would write the number in scientific notation.

Repeat the process for a number less than
0.0009.

Activity
16.6**Warm Up**
For use before Activity 16.6

Write the number in standard form.

1. 6×10^3

2. 4×10^{-4}

3. 2×10^5

4. 2.6×10^{-2}

5. 5.25×10^{10}

6. 8.52×10^{-5}

Lesson
16.6

Start Thinking!

For use before Lesson 16.6

Estimate the population of the world.

Go to *www.census.gov* to find the actual world population.

Write the population in scientific notation. How did you choose to round the number and why?

Lesson
16.6

Warm Up

For use before Lesson 16.6

Write the number in scientific notation.

1. 0.00034

2. 6,750,000

3. 0.00000007

4. 125,000

5. 15,200,000,000

6. 0.000000000917

16.6 Practice A

Write the number in scientific notation.

1. 350,000
2. 0.0004
3. 0.0000000000000527
4. 12,500,000
5. 1,900,000,000
6. 0.0000001
7. 5,000,000,000,000
8. 0.00006524

Order the numbers from least to greatest.

9. 3.6×10^8 , 6.3×10^8 , 3.26×10^8
10. 9.8×10^{-12} , 1.23×10^{-11} , 5.05×10^{-13}
11. 6.18×10^7 , 5.6×10^{-7} , 6.8×10^7
12. 4.81×10^{-5} , 4.27×10^{-5} , 4.7×10^{-5}
13. The number of stars in the Milky Way Galaxy has been approximated to be between 200 billion and 400 billion. Write these numbers in scientific notation.
14. The ångström is a unit of length defined to be 0.1 nanometer or 0.0000000001 meter. Write this number in scientific notation.
15. In 2013, the net worth of a businessman was \$59,000,000,000.
 - a. Write \$59,000,000,000 in scientific notation.
 - b. As of 2012, the businessman had given over \$28,000,000,000 to charity. Write \$28,000,000,000 in scientific notation.
 - c. In 2002, the businessman's wealth briefly surpassed \$101,000,000,000. Write \$101,000,000,000 in scientific notation.
16. A pipette is a laboratory instrument that is used to transport a measured volume of liquid. A pipette that dispenses between 1 and 1000 microliters is called a micropipette.
 - a. A microliter is equivalent to 0.000001 liter. Write 0.000001 in scientific notation.
 - b. One thousand microliters is equivalent to 0.001 liter. Write 0.001 in scientific notation.

Order the numbers from least to greatest.

17. $\frac{16}{5}$, 322, 3.2×10^2 , 3.2%
18. 5.89×10^3 , $\frac{589}{1000}$, 0.58

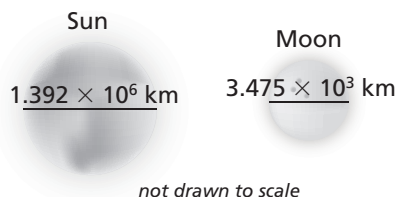
16.6 Practice B**Write the number in scientific notation.**

1. 0.000085
2. 410,000,000
3. 0.0143
4. 134,750,000,000
5. 7,000,000,000,000,000
6. 0.00000000000199
7. 52,400,000,000,000
8. 0.00000006133

Order the numbers from least to greatest.

9. 4.15×10^{14} , 5.4×10^{14} , 4.5×10^{14}
 10. 2.8×10^{-20} , 7.22×10^{-22} , 3.11×10^{-19}
 11. 4.118×10^{-3} , 4.1×10^{-5} , 4.181×10^{-5}
 12. 6.7×10^{-32} , 3.72×10^{32} , 6.17×10^{-32}
13. The atomic mass of carbon-12 is 0.000000000000000000001992 kilogram. Write this number in scientific notation.

14. Approximately how many moons would be needed side-by-side to span across the Sun?



15. Most golf balls have about 250 to 450 dimples. The record holder is a ball with 1070 dimples.
- a. Write 1070 in scientific notation.
 - b. In a recent year, it was estimated that 540,000,000 golf balls were sold. Using an average of 350 dimples, how many dimples were on the golf balls sold in that year? Write your answer in scientific notation.
16. The population of a country is about 6,940,000.
- a. Write 6,940,000 in scientific notation.
 - b. There are about 17,251 people per square mile in the country. What is the area of the country (in square miles)? Round your answer to the nearest whole number.

Order the numbers from least to greatest.

17. $5\frac{3}{8}$, 0.00538, 0.53%, $\frac{538}{1000}$
18. 8.19×10^{-2} , $\frac{270}{330}$, 0.0082

16.6 Enrichment and Extension**Avogadro's Number**

The mass of an atom is too small to measure with grams or milligrams. Scientists use *atomic mass units* (amu) to describe the mass of an atom. The number of atomic mass units in one gram is a constant known as Avogadro's number.

$$1 \text{ g} \approx 6.022 \times 10^{23} \text{ amu}$$
$$1.661 \times 10^{-24} \text{ g} \approx 1 \text{ amu}$$

1. Copy and complete the table.

| Element | Chemical Symbol | Mass (amu) | Mass (g) |
|----------|-----------------|-----------------------|----------|
| Silver | Ag | 1.26×10^{25} | |
| Oxygen | O | | 28 |
| Platinum | Pt | 9.64×10^{24} | |
| Helium | He | 3.01×10^{22} | |
| Nitrogen | N | | 34 |

2. Arrange the chemical symbols in order of increasing mass. What word do the symbols spell?



Puzzle Time

If A Man Wears Pajamas What Does A Woman Wear?

Write the letter of each answer in the box containing the exercise number.

1. Write 102,800,000 in scientific notation.

A. 1.028×10^8

B. 1028×10^5

C. 1×10^8

2. Write 0.0000522 in scientific notation.

Q. 5.22×10^5

R. 5.22×10^{-4}

S. 5.22×10^{-5}

3. Write -0.32 in scientific notation.

A. -3.2×10^{-1}

B. -3.2×10^0

C. -32×10^{-2}

4. Write 420,000,000,000 in scientific notation.

L. 42×10^{10}

M. 4.2×10^{11}

N. 4.2×10^{12}

5. Write 0.000006 in scientific notation.

A. 6×10^{-6}

B. 6×10^{-7}

C. 6×10^{-8}

6. A movie earned \$1,845,000,000 at the box office. What is the dollar amount written in scientific notation?

J. 1.845×10^9

K. 18.45×10^8

L. 1.845×10^6

7. The volume of a cylinder with radius $r = 1.5 \times 10^{-4}$ inch and height $h = 2.4 \times 10^{-3}$ inch is 0.00000000017 cubic inch. Write the volume of the cylinder in scientific notation.

L. 1.7×10^{-9} cubic inch

M. 1.7×10^{-10} cubic inch

N. 1.7×10^{-11} cubic inch

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | 5 | 6 | 3 | 4 | 1 | 2 |
|---|---|---|---|---|---|---|

**Activity
16.7****Start Thinking!**

For use before Activity 16.7

Copy the following two numbers.

0.00000001492

1.492×10^{-8}

Which number is easier to copy?

The second number is written in scientific notation. What are some benefits of using scientific notation to write very large or very small numbers?

**Activity
16.7****Warm Up**

For use before Activity 16.7

Tell whether the number is written in scientific notation. Explain.

1. 4.64×10^9

2. 0.12×10^{-4}

3. $1.06 \times 10^{0.2}$

4. 12.94×10^1

**Lesson
16.7****Start Thinking!**

For use before Lesson 16.7

Explain how to write a number in scientific notation. Why is scientific notation used to write numbers?

**Lesson
16.7****Warm Up**

For use before Lesson 16.7

Evaluate the expression using two different methods. Write your answer in scientific notation.

1. $(3.1 \times 10^4) + (2.3 \times 10^4)$

2. $(4 \times 10^6) + (1.7 \times 10^5)$

3. $(7.5 \times 10^7) \times (4 \times 10^7)$

4. $(6.6 \times 10^4) \times (5 \times 10^3)$

16.7 Practice A

Find the sum or difference. Write your answer in scientific notation.

1. $(2 \times 10^4) + (5 \times 10^4)$

2. $(3.5 \times 10^{-3}) + (1 \times 10^{-3})$

3. $(8.3 \times 10^{-5}) - (4.4 \times 10^{-5})$

4. $(7.2 \times 10^9) - (5.8 \times 10^9)$

5. $(7.4 \times 10^{-6}) + (5 \times 10^{-6})$

6. $(7.13 \times 10^{12}) + (8.04 \times 10^{12})$

Find the product or quotient. Write your answer in scientific notation.

7. $(1 \times 10^5) \times (4 \times 10^2)$

8. $(8 \times 10^5) \div (4 \times 10^5)$

9. $(2 \times 10^{-4}) \times (3 \times 10^7)$

10. $(9 \times 10^7) \div (3 \times 10^2)$

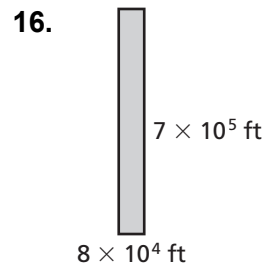
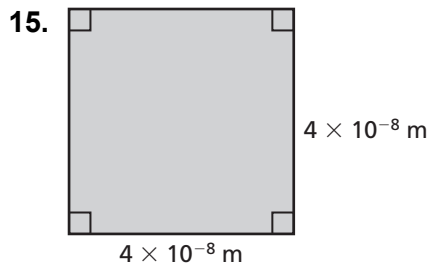
11. $(6 \times 10^{-12}) \times (7 \times 10^{-9})$

12. $(8 \times 10^5) \times (8 \times 10^5)$

13. $(2 \times 10^{-3}) \times (1.1 \times 10^2)$

14. $(9 \times 10^{-7}) \times (2.5 \times 10^3)$

Find the area of the figure. Write your answer in scientific notation.



17. The table shows the volumes of the three largest giant sequoia trees. Which tree has the greatest volume? How much greater is its volume than each of the other two trees?

| Tree Name | Volume (cubic feet) |
|-----------------|---------------------|
| General Grant | 4.66×10^4 |
| General Sherman | 5.25×10^4 |
| Washington | 4.785×10^4 |

16.7 Practice B

Find the sum or difference. Write your answer in scientific notation.

1. $(1.4 \times 10^2) - (1.1 \times 10^2)$

2. $(5.2 \times 10^{-4}) - (4.58 \times 10^{-4})$

3. $(6.4 \times 10^{-2}) + (4.7 \times 10^{-3})$

4. $(5.92 \times 10^{14}) - (3 \times 10^{12})$

Find the product or quotient. Write your answer in scientific notation.

5. $(6 \times 10^{-4}) \times (4 \times 10^7)$

6. $(8.4 \times 10^{-4}) \div (2.1 \times 10^{-6})$

7. $(7.5 \times 10^{-5}) \div (3 \times 10^{-3})$

8. $(9 \times 10^8) \times (3 \times 10^3)$

9. $(5 \times 10^{-3}) \times (1.3 \times 10^6)$

10. $(2.3 \times 10^6) \div (4.6 \times 10^{-9})$

11. $(6.8 \times 10^{-14}) \div (8.5 \times 10^{10})$

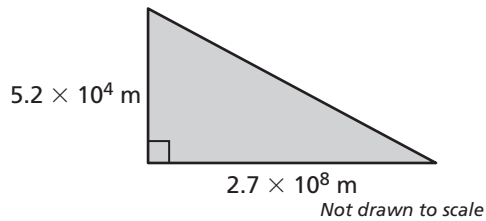
12. $(6.1 \times 10^{-6}) \times (3 \times 10^{-1})$

13. $(6 \times 10^{-8}) \times (3.1 \times 10^{12})$

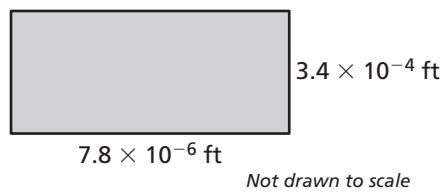
14. $(4 \times 10^{10}) \times (2.5 \times 10^3)$

Find the area of the figure. Write your answer in scientific notation.

15.



16.



17. How many times greater is the total area of Russia than the total area of Finland?



16.7 Enrichment and Extension

Engineering Notation

Engineering notation is similar to scientific notation except the power of ten can only be a multiple of three. As a result, the factor must be greater than or equal to 1 and less than 1000.

Example: $650,000,000 = 650 \times 10^6$

Example: $0.00000001 = 10 \times 10^{-9}$

You can use the same rules to perform arithmetic operations on numbers written in engineering notation as you did with scientific notation.

Example: $(5.5 \times 10^{-3}) - (4.8 \times 10^{-3}) = (5.5 - 4.8) \times 10^{-3}$
 $= 0.7 \times 10^{-3}$
 $= 700 \times 10^{-6}$

Example: $(4.3 \times 10^3) \times (6.0 \times 10^4) = 25.8 \times 10^7 = 258 \times 10^6$

Write the number in engineering notation.

1. 20,500,000
2. 0.000000048
3. 3.41×10^5
4. 8.15×10^{-7}

Evaluate the expression. Write your answer in engineering notation.

5. $(17 \times 10^{12}) + (255 \times 10^{12})$
6. $(7.545 \times 10^8) + (4.55 \times 10^7)$
7. $(340 \times 10^{-6}) - (285 \times 10^{-6})$
8. $(8.7 \times 10^7) - (5.5 \times 10^6)$
9. $(4.8 \times 10^2) \times (6.9 \times 10^5)$
10. $(9.2 \times 10^{-4}) \times (5.7 \times 10^{12})$
11. $(4.8 \times 10^4) \div (2.5 \times 10^7)$
12. $(7.2 \times 10^8) \div (1.6 \times 10^{-3})$
13. What is one advantage of expressing numbers in engineering notation?
14. What is one disadvantage of expressing numbers in engineering notation?



16.7 Puzzle Time

What Happened When The Rubber Duckie Fell Into The Bathtub?

Write the letter of each answer in the box containing the exercise number.

Find the sum or difference. Write your answer in scientific notation.

1. $(4 \times 10^7) + (6.1 \times 10^7)$
2. $(3.12 \times 10^{-5}) - (1.79 \times 10^{-5})$
3. $(5.8 \times 10^{-9}) + (2.67 \times 10^{-9})$
4. $(2.3 \times 10^4) - (1.1 \times 10^4)$
5. $(7 \times 10^{-8}) + (3.48 \times 10^{-5})$
6. $(9.6 \times 10^{-3}) - (7.7 \times 10^{-4})$

Find the product or quotient. Write your answer in scientific notation

7. $(6.3 \times 10^{-3}) \times (2 \times 10^2)$
8. $(4.1 \times 10^8) \div (8.2 \times 10^8)$
9. $(5.7 \times 10^{-6}) \times (3 \times 10^{-4})$
10. $(9.2 \times 10^5) \div (1.6 \times 10^7)$
11. A rectangular table located in the lobby of a middle school has a length of 2.24×10^3 millimeters and a width of 1.54×10^2 millimeters. Find the area of the rectangular table top.

Answers

- K.** 5.75×10^{-2}
- I.** 1.33×10^{-5}
- P.** 5×10^{-1}
- E.** 8.47×10^{-9}
- U.** 1.01×10^8
- Q.** 3.4496×10^5
- D.** 1.26×10^0
- A.** 3.487×10^{-5}
- U.** 1.71×10^{-9}
- T.** 1.2×10^4
- C.** 8.83×10^{-3}

| | | | | | | | | | | | | |
|---|---|--|----|---|---|---|----|---|---|--|---|---|
| 2 | 4 | | 11 | 9 | 5 | 6 | 10 | 3 | 7 | | 1 | 8 |
|---|---|--|----|---|---|---|----|---|---|--|---|---|

**Chapter
16**
Technology Connection

For use after Section 16.7

Operations with Scientific Notation

You can use your calculator and scientific notation to perform operations on large or small numbers.

EXAMPLE Multiply: $63,000,000,000 \times 204$

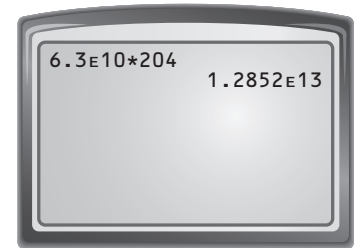
SOLUTION

Step 1 Rewrite the first number using scientific notation.

$$63,000,000,000 = 6.3 \times 10^{10}$$

Step 2 Enter the product. Press 6.3 $\boxed{2\text{nd}}$ [EE] 10 $\boxed{\times}$ 204.

Step 3 Press $\boxed{\text{ENTER}}$. The product is equal to 1.2852×10^{13} or 12,852,000,000,000.



Find the sum, difference, product, or quotient.

1. $310,000,000 \times 56,000$
2. $0.00000009 \div 0.0005$
3. $(5.6 \times 10^7) + (6.6 \times 10^4)$
4. $(1.3 \times 10^{-4}) - (5.1 \times 10^{-5})$
5. $0.0000075 \times 230,000$
6. $44,600,000,000 + 5,600,000,000$
7. $0.00000000558 - 0.0000000026$
8. $(9.8 \times 10^{12}) \div (3.2 \times 10^3)$
9. When does your calculator display answers using standard notation? When does it display answers using scientific notation? Give examples to support your answers.