Unit Overview
In this unit you will explore multiplicative patterns and representations of nonlinear data. Exponential growth and decay will be the basis for studying exponential functions. You will investigate the properties of powers and radical expressions. You will also perform operations with radical and rational expressions.

Unit 4 Vocabulary
Add these words and others you encounter in this unit to your vocabulary notebook.
- coefficient
- degree of a polynomial
- difference of two squares
- factor
- polynomial
- radical expression
- rational expression
- term

Essential Questions
- How do multiplicative patterns model the physical world?
- How are adding and multiplying polynomial expressions different from each other?

Embedded Assessments
This unit has two embedded assessments, following Activities 4.3 and 4.8. They will give you an opportunity to demonstrate what you have learned.

Embedded Assessment 1
Exponential Functions p. 229

Embedded Assessment 2
Polynomial Operations and Factoring p. 273
Write your answers on notebook paper or grid paper. Show your work.

1. Find the greatest common factor of 36 and 54.
2. Give the prime factorization of 90.
3. Which of the following is equivalent to $39 \cdot 26 + 39 \cdot 13$?
   - a. $13^9$
   - b. $13^4 \cdot 14$
   - c. $13^2 \cdot 3^2 \cdot 2$
   - d. $13^2 \cdot 3^2$
4. Explain 2 ways to evaluate $15(90 - 3)$.
5. Identify the coefficient, base and exponent of $4x^5$.
6. Complete the following table to create a linear relationship.

<table>
<thead>
<tr>
<th>x</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Graph the function described in the table in question 6.
8. Use ratios to model the following:
   - a. 7.5
   - b. Caleb receives 341 of the 436 votes cast for class president.
   - c. Students in Mr. Bulluck’s Class

<table>
<thead>
<tr>
<th>Girls</th>
<th>Boys</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>19</td>
</tr>
</tbody>
</table>
1. girls to boys
2. boys to total class members
9. For each of the following, tell which describes the number:
   - I. An integer
   - II. A rational number
   - III. An irrational number
   - a. $\sqrt{25}$
   - b. $\frac{4}{3}$
   - c. 2.16
   - d. $\pi$
10. Calculate.
   - a. $\frac{1}{2} + \frac{3}{8}$
   - b. $\frac{5}{12} - \frac{1}{3}$
   - c. $\frac{3}{4} \cdot \frac{2}{5}$
   - d. $\frac{5}{8} \div \frac{3}{4}$
Exponent Rules
Icebergs and Exponents

SUGGESTED LEARNING STRATEGIES: Marking the Text, Group Discussion, Create Representations, Predict and Confirm

An iceberg is a large piece of freshwater ice that has broken off from a glacier or ice shelf and is floating in open sea water. Icebergs are classified by size. The smallest sized iceberg is called a “growler”.

A growler was found floating in the ocean just off the shore of Greenland. Its volume above water was approximately 27 cubic meters.

1. Two icebergs float near this growler. One iceberg’s volume is \(3^4\) times greater than the growler. The second iceberg’s volume is \(2^8\) times greater than the growler. Which iceberg has the larger volume? Explain below.

2. What is the meaning of \(3^4\) and \(2^8\)? Why do you think exponents are used when writing numbers?

3. Suppose the original growler’s volume under the water is 9 times the volume above. How much of its ice is below the surface?

4. Write your solution to Item 3 using powers. Complete the equation below. Write the missing terms as a power of 3.

   \[
   \text{volume above water} \cdot 3^2 = \text{volume below the surface} \cdot 3^3 = \square
   \]

5. Look at the equation you completed for Item 4. What relationship do you notice between the exponents on the left side of the equation and the exponent on the right?

CONNECT TO GEOLOGY

Because ice is not as dense as sea water, about one-tenth of the volume of an iceberg is visible above water. It is difficult to tell what an iceberg looks like underwater simply by looking at the visible part. Growlers got their name because the sound they make when they are melting sounds like a growling animal.
6. Use the table below to help verify the pattern you noticed in Item 5. First write each product in the table in expanded form. Then express the product as a single power of the given base. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Product</th>
<th>Expanded Form</th>
<th>Single Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2^2 \cdot 2^4$</td>
<td>$2 \cdot 2 \cdot 2 \cdot 2 \cdot 2$</td>
<td>$2^6$</td>
</tr>
<tr>
<td>$5^3 \cdot 5^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^4 \cdot x^7$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a^6 \cdot a^2$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Based on the pattern you observed in the table in Item 6, write the missing exponent in the box below to complete the **Product of Powers Property** for exponents.

$$a^m \cdot a^n = a^\Box$$

8. The density of an iceberg is determined by dividing its mass by its volume. Suppose a growler had a mass of 59,049 kg and a volume of 81 cubic meters. Compute the density of the iceberg.

9. Write your solution to Item 8 using powers of 9.

$$\frac{\text{Mass}}{\text{Volume}} = \text{Density}$$

10. What pattern do you notice in the equation you completed for Item 9?
11. Use the table to help verify the patterns you noticed in Item 9. First write each quotient in the table below in expanded form. Then express the quotient as a single power of the given base. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Product</th>
<th>Expanded Form</th>
<th>Single Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{2^5}{2^3} )</td>
<td>( \frac{2 \cdot 2 \cdot 2 \cdot 2 \cdot 2}{2 \cdot 2} = \frac{2 \cdot 2 \cdot 2 \cdot 2}{2 \cdot 2} )</td>
<td>( 2^3 )</td>
</tr>
<tr>
<td>( \frac{5^4}{5^6} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \frac{a^3}{a^1} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \frac{x^7}{x^3} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. Based on the pattern you observed in Item 11, write the missing exponent in the box below to complete the Quotient of Powers Property for exponents.

\[
\frac{a^m}{a^n} = a^{\Box}, \text{ where } a \neq 0
\]

The product and quotient properties of exponents can be used to simplify expressions.

**EXAMPLE 1**

Simplify: \( 2x^5 \cdot 5x^4 \)

**Step 1:** Group powers with the same base. \( 2x^5 \cdot 5x^4 = 2 \cdot 5 \cdot x^5 \cdot x^4 \)

**Step 2:** Product of Powers Property

\( = 10x^{5+4} = 10x^9 \)

**Step 3:** Simplify the exponent.

**Solution:** \( 2x^5 \cdot 5x^4 = 10x^9 \)
EXAMPLE 2
Simplify \( \frac{2x^5y^4}{xy^2} \).

**Step 1:** Group powers with the same base.

\[
\frac{2x^5y^4}{xy^2} = 2 \cdot \frac{x^5}{x} \cdot \frac{y^4}{y^2}
\]

**Step 2:** Quotient of Powers Property

\[
= 2x^{5-1} \cdot y^{4-2}
\]

**Step 3:** Simplify the exponent.

\[
= 2x^4y^2
\]

**Solution:**

\[
\frac{2x^5y^4}{xy^2} = 2x^4y^2
\]

**TRY THESE A**

Simplify each expression.

\[
\begin{align*}
\text{a.} & \quad (4xy^4)(-2x^3y^5) \\
\text{b.} & \quad \frac{2a^2b^2c}{4ab^2c} \\
\text{c.} & \quad \frac{6y^3}{18x} \cdot 2xy
\end{align*}
\]

13. Write each quotient in expanded form and simplify it. Then apply the quotient property of exponents. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Quotient</th>
<th>Expanded Form</th>
<th>Single Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{a^3}{a^8} )</td>
<td>( \frac{1}{2} )</td>
<td>( 2^{5-8} = 2^{-3} )</td>
</tr>
<tr>
<td>( \frac{5^3}{5^6} )</td>
<td>( \frac{1}{2} )</td>
<td>( 2^{5-8} = 2^{-3} )</td>
</tr>
<tr>
<td>( \frac{x^4}{x^{10}} )</td>
<td>( \frac{1}{2} )</td>
<td>( 2^{5-8} = 2^{-3} )</td>
</tr>
</tbody>
</table>

**SUGGESTED LEARNING STRATEGIES:** Note Taking, Look for a Pattern
14. Based on the pattern you observed in Item 13, write the missing exponent in the box below to complete the **Negative Power Property** for exponents.

\[
\frac{1}{a^n} = a^{\color{red}{\phantom{-}n}}, \text{ where } a \neq 0
\]

15. Write each quotient in expanded form and simplify it. Then apply the quotient property of exponents. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Quotient</th>
<th>Expanded Form</th>
<th>Single Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{2^4}{2^4} )</td>
<td>( \frac{2 \cdot 2 \cdot 2 \cdot 2}{2 \cdot 2 \cdot 2 \cdot 2} = \frac{2^4}{2^4} )</td>
<td>( 2^{4-4} = 2^0 )</td>
</tr>
<tr>
<td>( \frac{5^6}{5^6} )</td>
<td>( \frac{5 \cdot 5 \cdot 5 \cdot 5 \cdot 5 \cdot 5}{5 \cdot 5 \cdot 5 \cdot 5 \cdot 5 \cdot 5} = \frac{5^6}{5^6} )</td>
<td>( 5^{6-6} = 5^0 )</td>
</tr>
<tr>
<td>( \frac{a^3}{a^3} )</td>
<td>( \frac{a \cdot a \cdot a}{a \cdot a \cdot a} = \frac{a^3}{a^3} )</td>
<td>( a^{3-3} = a^0 )</td>
</tr>
</tbody>
</table>

16. Based on the pattern you observed in Item 15, fill in the box below to complete the **Zero Power Property** of exponents.

\[
a^0 = a^{\color{red}{\phantom{-}0}}, \text{ where } a \neq 0
\]

You can use the negative power property and the zero power property of exponents to evaluate and simplify expressions.

**TRY THESE B**

Simplify each expression.

a. \( 2^{-3} \)  

b. \( \frac{10^2}{10^{-2}} \)  

c. \( 3^{-2} \cdot 5^0 \)  

d. \( (-3.75)^0 \)
When evaluating and simplifying expressions, you can apply the properties of exponents and then write the answer without negative or zero powers.

**EXAMPLE 3**

Simplify $5x^{-2}y z^0 \cdot \frac{3x^4}{y^4}$ and write without negative powers.

**Step 1:** Commutative Property

$$5x^{-2}y z^0 \cdot \frac{3x^4}{y^4} = 5 \cdot 3 \cdot x^{-2} \cdot x^4 \cdot y^1 \cdot y^{-4} \cdot z^0$$

**Step 2:** Apply the exponent rules.

$$= 5 \cdot 3 \cdot x^{-2+4} \cdot y^{1-4} \cdot z^0$$

**Step 3:** Simplify the exponents.

$$= 15 \cdot x^2 \cdot y^{-3} \cdot 1$$

**Step 4:** Write without negative exponents.

$$= \frac{15x^2}{y^3}$$

**Solution:**

$$5x^{-2}y z^0 \cdot \frac{3x^4}{y^4} = \frac{15x^2}{y^3}$$

**TRY THESE C**

Simplify and write without negative powers.

a. $2a^2b^{-3} \cdot 5ab$

b. $\frac{10x^2y^{-4}}{5x^{-3}y^{-1}}$

c. $(-3xy^{-5})^0$

**17.** Write each expression in expanded form. Then write the expression using a single exponent with the given base. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Expression</th>
<th>Expanded Form</th>
<th>Single Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(2^2)^4$</td>
<td>$2^2 \cdot 2^2 \cdot 2^2 \cdot 2^2 = 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2$</td>
<td>$2^8$</td>
</tr>
<tr>
<td>$(5^3)^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(x^3)^4$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
18. Based on the pattern you observed in Item 17, write the missing exponent in the box below to complete the **Power of a Power Property** for exponents.

\[(a^m)^n = a^{\square}\]

19. Write each expression in expanded form and group like terms. Then write the expression as a product of powers. The first one has been done for you.

<table>
<thead>
<tr>
<th>Original Expression</th>
<th>Expanded Form</th>
<th>Product of Powers</th>
</tr>
</thead>
<tbody>
<tr>
<td>((2x)^4)</td>
<td>(2x \cdot 2x \cdot 2x \cdot 2x = 2 \cdot 2 \cdot 2 \cdot 2 \cdot x \cdot x \cdot x \cdot x)</td>
<td>(2^4 x^4)</td>
</tr>
<tr>
<td>((-4a)^3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>((x^3y^2)^4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. Based on the pattern you observed in Item 19, write the missing exponents in the boxes below to complete the **Power of a Product Property** for exponents.

\[(ab)^m = a^{\square} \cdot b^{\square}\]

21. Use the patterns you have seen. Predict and write the missing exponents in the boxes below to complete the **Power of a Quotient Property** for exponents.

\[\left(\frac{a}{b}\right)^m = a^{\square} \cdot \frac{1}{b^{\square}}, \text{ where } b \neq 0\]
You can apply these power properties and the exponent rules you have already learned to simplify expressions.

**EXAMPLE 4**

Simplify \((2x^2y^5)^3(3x^3)^{-2}\) and write without negative powers.

**Step 1:** Power of a Power Property

\[
(2x^2y^5)^3(3x^3)^{-2} = 2^3x^{2\cdot3}y^{5\cdot3} \cdot 3^{-2} \cdot x^2 \cdot -2
\]

**Step 2:** Simplify the exponents and the numerical terms.

\[
= 8 \cdot x^6y^{15} \cdot \frac{1}{3^2} \cdot x^{-4}
\]

**Step 3:** Commutative Property

\[
= 8 \cdot \frac{1}{9} x^6 \cdot x^{-4} y^{15}
\]

**Step 4:** Product of Powers Property

\[
= \frac{8}{9} x^{6-4} y^{15}
\]

**Step 5:** Simplify the exponents.

\[
= \frac{8}{9} x^2 y^{15}
\]

**Solution:**

\[
(2x^2y^5)^3(3x^3)^{-2} = \frac{8}{9} x^2 y^{15}
\]

**EXAMPLE 5**

Simplify \(\left(\frac{x^2y^{-3}}{z}\right)^2\).

**Step 1:** Power of a Quotient Property

\[
\left(\frac{x^2y^{-3}}{z}\right)^2 = \frac{x^{2\cdot2}y^{-3\cdot2}}{z^2}
\]

**Step 2:** Simplify the exponents.

\[
= \frac{x^4y^{-6}}{z^2}
\]

**Step 3:** Negative Exponents Property

\[
= \frac{x^4}{y^6z^2}
\]

**Solution:**

\[
\left(\frac{x^2y^{-3}}{z}\right)^2 = \frac{x^4}{y^6z^2}
\]
TRY THESE

Simplify and write without negative powers.

a. \((2x^2y)^3 (-3xy^3)^2\)

b. \(-2ab(5b^2c)^3\)

c. \(\left(\frac{4x}{y^3}\right)^{-2}\)

d. \(\left(\frac{5x^3}{y}\right)^2 \left(\frac{y^3}{10x^2}\right)\)

e. \((3xy^{-2})^3(2x^3yz)(6yz^2)^{-1}\)

22. The tallest known iceberg in the North Atlantic was measured to be 168 m above sea level, making it the height of a 55-story building. It had an estimated volume of \(8.01 \times 10^5\) m\(^3\), and had an estimated mass of \(7.37 \times 10^8\) kg. Change these two numbers from scientific notation to standard form.

The properties of exponents can be used to multiply and divide numbers expressed in scientific notation.

EXAMPLE 6

Simplify \((1.3 \times 10^5)(4 \times 10^{-8})\).

\[\text{Step 1: Group terms and use the Product of Powers Property.} \quad (1.3 \times 10^5)(4 \times 10^{-8}) = 1.3 \times 4 \times 10^{5+(-8)}\]

\[\text{Step 2: Multiply numbers and simplify the exponent.} \quad = 5.2 \times 10^{-3}\]

\[\text{Solution:} \quad (1.3 \times 10^5)(4 \times 10^{-8}) = 5.2 \times 10^{-3}\]
EXAMPLE 7

Write in \( \frac{2.4 \times 10^5}{6 \times 10^7} \) scientific notation.

Step 1: Group terms and use the Quotient of Powers Property.

Step 2: Divide the numbers and simplify the exponent.

Step 3: Write 0.4 in scientific notation.

Step 4: Product of Powers Property.

Solution: \( \frac{2.4 \times 10^5}{6 \times 10^7} = 4.0 \times 10^{-3} \)

TRY THESE E

Express the product or quotient using scientific notation.

a. \((2.5 \times 10^{-3})(1.5 \times 10^6)\)

b. \(\frac{6.4 \times 10^{23}}{1.6 \times 10^{10}}\)

c. Compute the density of the iceberg described in Item 22.

CHECK YOUR UNDERSTANDING

Write your answers on notebook paper. Show your work.

Simplify and write each expression without negative exponents.

1. \(x^8 \cdot x^7\)

2. \(\frac{6a^{10}b^{6}}{3ab^3}\)

3. \((6a^2b)(-3ab^3)\)

4. \(\frac{7x^2y^5}{14xy^4}\)

5. \((-2z)^{-3}\)

6. \(\frac{6^{-4}}{6^{-2}}\)

7. \(\frac{4x^{-2}}{x^3}\)

8. \((5x^3y^{-8}z^2)^0\)

9. \((4x^3y^{-1})^2\)

10. \(\frac{5x^3}{y^2}\)

11. \((-2a^2b^{-2}c^3)(3ab^4c^5)(xyz)^0\)

12. \(\frac{2xy^2}{x^3y^3} \cdot \frac{5xy^3}{-30y^{-2}}\)

13. \((2.5 \times 10^5)(5 \times 10^{-3})\)

14. \(\frac{6.31 \times 10^7}{2 \times 10^2}\)

15. MATHEMATICAL REFLECTION: What have you learned about simplifying expressions with exponents as a result of this activity?
ACTIVITY

4.2

Exponential Functions

Protecting Your Investment

SUGGESTED LEARNING STRATEGIES: Marking the Text, Create Representations

The National Association of Realtors estimates that, on average, the price of a house doubles every ten years. Tony’s grandparents bought a house in 1960 for $10,000. Assume that the trend identified by the National Association of Realtors applies to Tony’s grandparents’ house.

1. What was the value of Tony’s grandparents’ house in 1970 and in 1980?

2. Compute the difference in value from 1960 to 1970.

3. Compute the ratio of the 1970 value to the 1960 value.

4. Complete the table of values for the years 1960 to 2010.

<table>
<thead>
<tr>
<th>Year</th>
<th>Decades since 1960</th>
<th>Value of house</th>
<th>Difference between values of consecutive decades</th>
<th>Ratio of values of consecutive decades</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>0</td>
<td>$10,000</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. What patterns do you recognize in the table in Item 4?

6. Using the data from the table, graph the ordered pairs (decades since 1960, house value) on the coordinate grid below.

7. Is the data comparing the number of decades since 1960 and value of the house linear? Explain using the table and explain using the graph.
8. Using the information that you have regarding the house value, predict the value of the house in the year 2020. Explain how you made your prediction.

9. Tony would like to know what the value of the house was in 2005. Using the same data, predict the house value in 2005. Explain how you made your prediction.

The increase in house value for Tony’s grandparents’ house is an example of exponential growth. Exponential growth can be modeled using an exponential function.

### Exponential Function

A function of the form \( f(x) = a \cdot b^x \), where \( x \) is the domain, \( f(x) \) is the range, \( a \neq 0 \), \( b > 0 \), and \( b \neq 1 \).

A function that can be used to model the house value is \( h(t) = 10,000 \cdot (2)^t \). Use this function for Items 10–12.

10. Identify the meaning of \( h(t) \) and \( t \). Which is the domain? Which is the range?
11. Use the function to find the value of the house in the year 2020. How does the value compare with your prediction in Item 8?

12. Use the function to find the value of the house in the year 2005. How does the value compare with your prediction in Item 9?

Radon, a naturally occurring radioactive gas, was identified as a health hazard in some homes in the mid 1980s. Since radon is colorless and odorless, it is important to be aware of the concentration of the gas. Radon has a half-life of approximately four days.

Tony’s grandparents’ house was discovered to have a radon concentration of 400 pCi/L. Renee, a chemist, isolated and eliminated the source of the gas. She then wanted to know the quantity of radon in the house in the days following so that she could determine when the house would be safe.

13. What is the amount of the radon in the house four days after the source was eliminated? Explain your reasoning.

14. Compute the difference of the amount of radon from Day 0 to Day 4.
15. Find the ratio of the amount of radon from Day 4 to Day 0.

16. Complete the table for the radon concentration.

<table>
<thead>
<tr>
<th>Half-Lives</th>
<th>Days after radon source was eliminated</th>
<th>Concentration of radon in pCi/L</th>
<th>Difference between concentration of consecutive half-lives</th>
<th>Ratio of concentrations of consecutive half-lives</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>400</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17. What patterns do you recognize in the table in Item 16?
18. Graph the data in Item 16 as ordered pairs in the form (half lives, concentration).

19. Is the data that compares the number of half-lives and the concentration of radon linear? Explain using the table of values and the graph.

20. Renee needs to know the concentration of radon in the house after 20 days. How many radon half-lives are in 20 days? What is the concentration after 20 days?
21. How many radon half-lives are in 22 days? Predict the concentration after 22 days.

The decrease in radon concentration in Tony’s grandparents’ house is an example of exponential decay. Exponential decay can also be modeled using an exponential function.

A function that can be used to model the radon concentration is \( r(t) = 400 \cdot \left(\frac{1}{2}\right)^t \). Use the function to answer Items 22–24.

22. Identify the meaning of \( r(t) \) and \( t \). Which is the domain? Which is the range?

23. Use the function to find the concentration of radon after 20 days. How does the concentration compare with your prediction in Item 20?
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Exponential Functions
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My Notes

24. Use the function to find the concentration of radon after
22 days. How does the concentration compare with your
prediction in Items 21?

25. For the following question, choose always, sometimes, or
never. Will the concentration of radon ever be 0? Why or
why not?

SUGGESTED LEARNING STRATEGIES: Predict and Confirm,
Summarize/Paraphrase/Retell, Group Discussion, Visualization

CHECK YOUR UNDERSTANDING

Write your answers on notebook paper.
Show your work.

1. Make a table of values and graph each
function.
   a. \( h(x) = 2^x \)
   b. \( l(x) = 3^x \)
   c. \( m(x) = \left(\frac{1}{2}\right)^x \)
   d. \( p(x) = \left(\frac{1}{3}\right)^x \)

2. Which of the functions in Item 1 represent
exponential growth? Explain using your
table of values and graph.

3. Which of the functions in Item 1 represent
exponential decay? Explain using your
table of values and graph.

4. How can you identify which of the
functions represent growth or decay
by looking at the function?

5. Mold can represent a health hazard in
homes. Imagine you are investigating
the growth of mold in your science class
and are cultivating mold spores in a
sample. The table below represents your
experimental findings

<table>
<thead>
<tr>
<th>Number of days</th>
<th>Number of mold spores</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>320</td>
</tr>
<tr>
<td>3</td>
<td>1280</td>
</tr>
</tbody>
</table>

Write an exponential function \( m(t) \) that
models the growth of the mold spores,
then use the function to predict the
number of mold spores on the fifth day
and on the eighth day.

6. Why can’t an exponential
function be equal to
zero? Why can’t an exponential function
have a base of one?
Before flying the first airplane in 1903 the Wright Brothers used kites and gliders to study the concepts of aerodynamic forces. The surfaces of a kite generate the forces necessary for flight, and its rigid structures support the surfaces. The frame of a box kite has four “legs” of equal length and four pairs of crossbars, all of equal length, used for bracing the kite. The legs of the kite form a square base around which fabric is wrapped. The crossbars are attached to the legs so that each cross bar is positioned as a diagonal of the square base.

1. a. Label the legs of the kite pictured to the right. How many legs are in a kite? How many cross bars?

b. Label the points on the top view where the ends of the cross bars are attached to the legs A, B, C, and D. Begin at the bottom left and go clockwise.

c. Use one color to show the sides of the square and another color to show crossbar AC. What two figures are formed by two sides of the square and one diagonal?

Members of the Windy Hill Science Club are building kites to explore aerodynamic forces. Club members will provide paper, plastic or light weight cloth for the covering of their kite. The club will provide the balsa wood for the frames.

2. The science club advisor has created the chart below to help determine how much balsa wood he needs to buy.

   a. For each kite, calculate the exact length of one crossbar that will be needed to stabilize the kite. Use your drawing from Question 1c as a guide for the rectangular base of these box kites.

   

<table>
<thead>
<tr>
<th>Kite</th>
<th>Dimensions of base (in feet)</th>
<th>Exact length of one crossbar (in feet)</th>
<th>Dimensions of base (in feet)</th>
<th>Exact length of one crossbar (in feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 by 1</td>
<td></td>
<td>D</td>
<td>1 by 2</td>
</tr>
<tr>
<td>B</td>
<td>2 by 2</td>
<td></td>
<td>E</td>
<td>2 by 4</td>
</tr>
<tr>
<td>C</td>
<td>3 by 3</td>
<td></td>
<td>F</td>
<td>3 by 6</td>
</tr>
</tbody>
</table>

   b. How much wood would you recommend buying for the cross bars of Kite A? Explain your reasoning.

   Math Tip: Pythagorean Theorem
   
   $a^2 + b^2 = c^2$

   Math Tip: If you take the square root of a number that is not a perfect square, the result is a decimal number that does not terminate or repeat and is called an irrational number.

   The exact value of an irrational number must be written using a radical sign.
To determine how much wood to buy, the club sponsor adds the amounts of wood needed for the kites. Each amount is written as a radical expression. Simplifying the expressions will make it easier to add.

### Radical Expression

an expression of the form \( \sqrt[n]{a} \), where \( a \) is the radicand, \( \sqrt{\,} \) is the radical symbol and \( n \) is the root index.

\[
\sqrt[n]{a} = b, \text{ if } b^n = a \quad \text{ and } \quad b \text{ is the } n\text{th root of } a.
\]

Finding the square root of a number or expression is the inverse operation of squaring a number or expression.

\[
\sqrt{25} = 5, \text{ because } (5)(5) = 25 \\
\sqrt{81} = 9, \text{ because } (9)(9) = 81 \\
\sqrt{x^2} = x, \text{ because } (x)(x) = x^2, x \geq 0
\]

Notice also that \((-5)(-5) = (-5)^2 = 25\). The principal square root of a number is the positive square root value. The expression \(\sqrt{25}\) simplifies to 5, the principal square root. The negative square root is the negative root value, so \(-\sqrt{25}\) simplifies to \(-5\).

To simplify square roots in which the radicand is not a perfect square:

**Step 1:** Write the radicand as a product of numbers, one of which is a perfect square.

**Step 2:** Find the square root of the perfect square.

### EXAMPLE 1

Simplify each expression.

a. \( \sqrt{75} = \sqrt{25 \cdot 3} = 5\sqrt{3} \)

b. \( \sqrt{72} = \sqrt{36 \cdot 2} = 6\sqrt{2} \) or

\[
\sqrt{72} = \sqrt{9 \cdot 4 \cdot 2} = (3 \cdot 2)\sqrt{2} = 6\sqrt{2}
\]

c. \( 7\sqrt{12} = 7\sqrt{4 \cdot 3} = 7(2\sqrt{3}) = 14\sqrt{3} \)

d. \( \sqrt{c^3} = \sqrt{c^2 \cdot c} = c\sqrt{c}, c \geq 0 \)

### TRY THESE A

Simplify each expression.

a. \( \sqrt{18} \)  
   b. \( 5\sqrt{48} \)  
   c. \( \sqrt{126} \)  
   d. \( \sqrt{24y^2} \)  
   e. \( \sqrt{45b^3} \)
3. Copy the lengths of the crossbars from the chart in Item 1. Then express the lengths of the crossbars in simplified form.

<table>
<thead>
<tr>
<th>Kite</th>
<th>Dimensions of base (feet)</th>
<th>Exact length of one cross bar (feet)</th>
<th>Simplified form of length of crossbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 by 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2 by 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3 by 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1 by 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>2 by 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3 by 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The club advisor wants to find the total length of the balsa wood needed. To do so, he will need to add radicals.

**Addition Property of Radicals**

\[ a\sqrt{b} \pm c\sqrt{b} = (a \pm c)\sqrt{b}, \]

where \( b \geq 0 \).

To add or subtract radicals, the index and radicand must be the same.

**EXAMPLE 2**

Add or subtract each expression and simplify.

a. \[ 3\sqrt{5} + 7\sqrt{5} \]
   \[ = (3 + 7)\sqrt{5} \quad \text{Add or subtract}\]
   \[ = 10\sqrt{5} \]

b. \[ 10\sqrt{3} - 4\sqrt{3} \]
   \[ = (10 - 4)\sqrt{3} \]
   \[ = 6\sqrt{3} \]

c. \[ 2\sqrt{5} + 8\sqrt{3} + 6\sqrt{5} - 3\sqrt{3} \]
   \[ \text{Step 1: Group terms with like radicands} \]
   \[ = 2\sqrt{5} + 6\sqrt{5} + 8\sqrt{3} - 3\sqrt{3} \]
   \[ \text{Step 2: Add or subtract the coefficients.} \]
   \[ = (2 + 6)\sqrt{5} + (8 - 3)\sqrt{3} \]
   \[ = 8\sqrt{5} + 5\sqrt{3} \]
   \[ \text{Solution:} \quad 2\sqrt{5} + 8\sqrt{3} + 6\sqrt{5} - 3\sqrt{3} = 8\sqrt{5} + 5\sqrt{3} \]
### TRY THESE B

Add or subtract each expression and simplify.

- **a.** \(2\sqrt{7} + 3\sqrt{7}\)
- **b.** \(5\sqrt{6} + 2\sqrt{5} - \sqrt{6} + 7\sqrt{5}\)
- **c.** \(2\sqrt{2} + \sqrt{8} + 3\sqrt{2}\)

### 4.

The club advisor also needs to know how much wood to buy for the legs of the kites. Each kite will be 3 ft tall.

- **a.** Complete the table below.

<table>
<thead>
<tr>
<th>Kite</th>
<th>Dimensions of base (feet)</th>
<th>Length of one crossbar (feet)</th>
<th>Length of one leg (feet)</th>
<th>Wood needed for legs (feet)</th>
<th>Wood needed for crossbars (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 by 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2 by 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3 by 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1 by 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>2 by 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3 by 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **b.** How much balsa wood should the club advisor buy if the club is going to build the six kites described above?

- **c.** Explain how you reached your conclusion.
5. a. Complete the table below and simplify the radical expressions Column 3 and Column 5.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>(\sqrt{a} \cdot \sqrt{b})</th>
<th>ab</th>
<th>(\sqrt{ab})</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Use the patterns you observe in the table above to write an equation that relates \(\sqrt{a}\), \(\sqrt{b}\), and \(\sqrt{ab}\).

c. All the values of \(a\) and \(b\) in Item 5(a) are perfect squares. Choose some values for \(a\) and \(b\) that are not perfect squares and use a calculator to show that the equation you wrote in Item 5(b) is true for those numbers as well.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>(\sqrt{a} \cdot \sqrt{b})</th>
<th>ab</th>
<th>(\sqrt{ab})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>Simplified form</th>
<th>B</th>
<th>Simplified form</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2 (\sqrt{4}))((\sqrt{9}))</td>
<td>2(\sqrt{4 \cdot 9})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3 (\sqrt{4}))(5(\sqrt{16}))</td>
<td>(3 (\cdot) 5)(\sqrt{4 \cdot 16})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 (\sqrt{7}))(3 (\sqrt{14}))</td>
<td>(2 (\cdot) 3)((\sqrt{7 \cdot 14}))</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SUGGESTED LEARNING STRATEGIES: Predict and Confirm

e. Write a verbal rule that explains how to multiply radical expressions.

**Multiplication Property of Radicals**

\[(a\sqrt{b})(c\sqrt{d}) = ac\sqrt{bd},\]

where \(b \geq 0, d \geq 0.\)

To multiply radical expressions, the index must be the same. Find the product of the coefficients and the product of the radicands. Simplify the radical expression.

**EXAMPLE 3**

Multiply each expression and simplify.

a. \((3\sqrt{6})(4\sqrt{5}) = (3 \cdot 4)(\sqrt{6 \cdot 5}) = 12\sqrt{30}\)

b. \((2\sqrt{10})(3\sqrt{6}) = (2 \cdot 3)\sqrt{10 \cdot 6} = 6\sqrt{60} = 6\sqrt{4 \cdot 15} = (6 \cdot 2)\sqrt{15} = 12\sqrt{15}\)

c. \((2x\sqrt{6x})(5\sqrt{3x^2}) = 10x\sqrt{6x \cdot 3x^2} = 10x(\sqrt{18x^3}) = 10x(\sqrt{9x^2 \cdot 2x}) = (10x)(3x)(\sqrt{2x}) = 30x^2\sqrt{2x}\)

**TRY THESE C**

Multiply each expression and simplify.

a. \((2\sqrt{10})(5\sqrt{3})\)

b. \((3\sqrt{8})(2\sqrt{6})\)

c. \((4\sqrt{12})(5\sqrt{18})\)

d. \((3\sqrt{5a})(2a\sqrt{15a^2})\)

**Division Property of Radicals**

\[
\frac{a\sqrt{b}}{c\sqrt{d}} = \frac{a}{c} \sqrt{\frac{b}{d}},
\]

where \(b \geq 0, d > 0.\)
To divide radical expressions, the index must be the same. Find the quotient of the coefficients and the quotient of the radicands. Simplify the expression.

**EXAMPLE 4**

Divide each expression and simplify.

a. \( \frac{\sqrt{6}}{\sqrt{2}} = \sqrt{\frac{6}{2}} = \sqrt{3} \)

b. \( \frac{2\sqrt{10}}{3\sqrt{2}} = \frac{2}{3} \sqrt{\frac{10}{2}} = \frac{2}{3} \sqrt{5} \)

c. \( \frac{8\sqrt{24}}{2\sqrt{3}} = \frac{8}{2} \sqrt{\frac{24}{3}} = 4\sqrt{8} = 4\sqrt{4 \cdot 2} = 4(2\sqrt{2}) = 8\sqrt{2} \)

**TRY THESE D**

Divide each expression and simplify.

a. \( \frac{\sqrt{22}}{\sqrt{2}} \)

b. \( \frac{4\sqrt{42}}{5\sqrt{6}} \)

c. \( \frac{10\sqrt{54}}{2\sqrt{2}} \)

d. \( \frac{12\sqrt{75}}{3\sqrt{3}} \)

A radical expression in simplified form does not have a radical in the denominator. Most frequently, the denominator is rationalized. You rationalize the denominator by simplifying the expression to get a perfect square under the radicand in the denominator.

\[
\frac{\sqrt{a}}{\sqrt{b}} \cdot 1 = \frac{\sqrt{a}}{\sqrt{b}} \cdot \frac{\sqrt{b}}{\sqrt{b}} = \frac{\sqrt{ab}}{\sqrt{b^2}} = \frac{\sqrt{ab}}{b}
\]

**EXAMPLE 5**

Rationalize the denominator. \( \frac{\sqrt{5}}{\sqrt{3}} \)

**Step 1:** Multiply the numerator and denominator by \( \sqrt{3} \).

\[
\frac{\sqrt{5}}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{\sqrt{15}}{\sqrt{9}} = \frac{\sqrt{15}}{3}
\]

**Step 2:** Simplify.

Solution: \( \frac{\sqrt{5}}{\sqrt{3}} = \frac{\sqrt{15}}{3} \)

**MATH TERMS**

Rationalize means to make rational. You can rationalize the denominator without altering the value of the expression by multiplying the fraction by an appropriate form of 1.

**CONNECT TO AP**

In calculus, both numerators and denominators are rationalized. The procedure for rationalizing a numerator is similar to that for rationalizing a denominator.
TRY THESE E
Rationalize the denominator in each expression.

a. $\frac{\sqrt{11}}{\sqrt{6}}$

b. $\frac{2\sqrt{7}}{\sqrt{5}}$

c. $\frac{3\sqrt{5}}{\sqrt{8}}$

CHECK YOUR UNDERSTANDING
Write your answers on notebook paper. Show your work.

Express each expression in simplest radical form.

1. $\sqrt{40}$

2. $\sqrt{128}$

3. $\sqrt{162}$

4. $4\sqrt{27} + 6\sqrt{8}$

5. $8\sqrt{6} + 2\sqrt{12} + 5\sqrt{3} - \sqrt{54}$

6. $8\sqrt{98} + 3\sqrt{32} - 2\sqrt{75}$

7. $(4\sqrt{7})(2\sqrt{3})$

8. $\sqrt{2}(\sqrt{2} + 3\sqrt{6})$

9. $\frac{\sqrt{75}}{\sqrt{5}}$

10. $\sqrt{\frac{5}{8}}$

11. $\left(\frac{1}{2}\right)\left(\frac{\sqrt{3}}{\sqrt{5}}\right)$

12. $\sqrt{27} + \sqrt{\frac{1}{27}}$

13. Find the difference of $9\sqrt{20}$ and $2\sqrt{5}$.

A. $7\sqrt{15}$

B. $16\sqrt{5}$

C. $9\sqrt{5}$

D. $7\sqrt{5}$

14. Find the product of $(2 + \sqrt{3})$ and $(\sqrt{6} + \sqrt{8})$.

A. $4\sqrt{6}$

B. $4 + 2\sqrt{3} + 3\sqrt{2} + 2\sqrt{6}$

C. $6\sqrt{6} + 7\sqrt{2}$

D. $7\sqrt{2} + 4\sqrt{6}$

15. The time, $T$, in seconds, it takes the pendulum of a clock to swing from one side to the other side is given by the formula $T = \pi \sqrt{\frac{l}{32}}$ where $l$ is the length of the pendulum, in feet. The clock ticks each time the pendulum is at the extreme left or right point.

a. If the pendulum is 4 feet long, how long does it take the pendulum to swing from left to right? Give an exact value in terms of $\pi$.

b. If the pendulum is shortened will the clock tick more or less often? Explain how you arrived at your conclusion.

16. MATHEMATICAL REFLECTION What conditions must be satisfied for a radical expression to be in simplified form?
Exponential Functions and Radicals

DECISIONS, DECISIONS

Carlos is looking to spend up to $7000 on his first car. He’s narrowed his choices to two different vehicles. The first vehicle is a three-year old sports car with a sale price of $7000. The second vehicle is a classic 1956 Chevy Bel-Air his neighbor is selling for $3125. Whichever car he buys, he plans to keep until he graduates from college in seven years.

1. The value of the sports car will depreciate by 12% each year.
   a. Write a function that will allow Carlos to determine the value of the sports car after each year.
   b. Use your function to determine the value of the sports car seven years from now. Round your answer to the nearest dollar.

2. If kept in good condition, the value of the Bel-Air will appreciate by 8% each year.
   a. Write a function that will allow Carlos to determine the value of the car after each year.
   b. Use your function to determine the value of the Bel-Air seven years from now. Round your answer to the nearest dollar.

3. Sketch a graph of the value of each car over the next seven years.

4. During which year will the values of each car be the same? Explain two different methods you could use to determine your answer.

If Carlos chooses to buy the Bel-Air, he plans to rent a storage unit during December and January of each year in order to preserve the condition of the car. Store More, Inc. offers a 14’ × 16’ unit, and X-tra Space Enterprises offers a 12’ × 18’ unit.

5. Each company bases its monthly rental price on the hypotenuse of the floor of the unit.
   a. Determine the hypotenuse of the floor of the Store More, Inc. unit in simplest radical form.
   b. Determine the hypotenuse of the floor of the X-tra Space Enterprises unit in simplest radical form.
Exponential Functions and Radicals

Use after Activity 4.3

DECISIONS, DECISIONS

6. The sale price of the Bel-Air, $3125, can also be written as $5^5$. Use the laws of exponents listed below to provide an example of a problem that would produce an answer of $5^5$. Justify your reasoning for each example.

\[ a^m \cdot a^n \quad b. \quad \frac{a^m}{a^n} \quad c. \quad \frac{1}{a^n} \quad d. \quad (a^m)^n \]

<table>
<thead>
<tr>
<th>Math Knowledge #1b, 2b, 6a, b, c, d</th>
<th>Exemplary</th>
<th>Proficient</th>
<th>Emerging</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student:</td>
<td>The student:</td>
<td>The student:</td>
<td></td>
</tr>
<tr>
<td>- Determines the correct value of</td>
<td>- Determines the correct value of</td>
<td>- Attempts to determine the correct value of the</td>
<td></td>
</tr>
<tr>
<td>both cars and rounds the answer</td>
<td>one of the cars and rounds the</td>
<td>cars, but neither answer is correct.</td>
<td></td>
</tr>
<tr>
<td>correctly. (1b, 2b)</td>
<td>answer correctly; attempts</td>
<td>- Writes a correct example for only two of the</td>
<td></td>
</tr>
<tr>
<td>- Writes correct examples for the</td>
<td>to determine the value of the</td>
<td>expressions given.</td>
<td></td>
</tr>
<tr>
<td>expressions given. (6a, b, c, d)</td>
<td>other car.</td>
<td>- Gives correct rules of exponents for</td>
<td></td>
</tr>
<tr>
<td>- Gives the correct rules of</td>
<td>- Writes correct examples for</td>
<td>at least two items.</td>
<td></td>
</tr>
<tr>
<td>exponents. (6a, b, c, d)</td>
<td>only three of the expressions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>given.</td>
<td>- Gives correct rules of exponents for</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>only one item.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Problem Solving #1a, 2a, 4, 5a, b</th>
<th>Exemplary</th>
<th>Proficient</th>
<th>Emerging</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student:</td>
<td>The student:</td>
<td>The student:</td>
<td></td>
</tr>
<tr>
<td>- Writes a correct function for the</td>
<td>- Writes a correct function for</td>
<td>- Attempts to write the functions, but</td>
<td></td>
</tr>
<tr>
<td>yearly value of both cars. (1a, 2a)</td>
<td>the yearly value of one of the</td>
<td>neither is correct.</td>
<td></td>
</tr>
<tr>
<td>- Correctly determines the year the</td>
<td>cars.</td>
<td>- Gives an incorrect year.</td>
<td></td>
</tr>
<tr>
<td>values will be the same. (4)</td>
<td>Correctly determines the year the</td>
<td>- Attempts to determine the</td>
<td></td>
</tr>
<tr>
<td>- Correctly determines the</td>
<td>values will be the same, based on</td>
<td>hypotenuse, but the method used is</td>
<td></td>
</tr>
<tr>
<td>hypotenuse of both floors. (5a, b)</td>
<td>the graphs drawn.</td>
<td>incorrect.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uses the correct method to</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>determine the hypotenuse but makes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>computational errors.</td>
<td></td>
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</table>

<table>
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<th>Exemplary</th>
<th>Proficient</th>
<th>Emerging</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student correctly sketches the</td>
<td>The student correctly sketches</td>
<td>The student attempts to sketch the</td>
<td></td>
</tr>
<tr>
<td>graphs of both of the given functions.</td>
<td>the graph of only one of the given</td>
<td>graphs of the functions, but</td>
<td></td>
</tr>
<tr>
<td></td>
<td>functions.</td>
<td>neither is correct.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication #4</th>
<th>Exemplary</th>
<th>Proficient</th>
<th>Emerging</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student explains two methods that</td>
<td>The student explains one method</td>
<td>The student attempts to explain the</td>
<td></td>
</tr>
<tr>
<td>can be used to determine the correct</td>
<td>that can be used to determine the</td>
<td>methods, but both explanations are</td>
<td></td>
</tr>
<tr>
<td>year the values of the cars would be</td>
<td>correct year the values of the</td>
<td>incomplete or contain errors.</td>
<td></td>
</tr>
<tr>
<td>the same. (4)</td>
<td>cars would be the same; the second</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>explanation is incomplete, but</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>contains no mathematical errors.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A solar panel is a device that collects and converts solar energy into electricity or heat. The solar panel consists of interconnected solar cells. The panels can have differing numbers of solar cells and can come in square or rectangular shapes.

1. How many solar cells are in the panel below?

2. If a solar panel has four rows as the picture does, but can be extended to have an unknown number of columns, \( x \), write an expression to give the number of solar cells that could be in the panel.

3. If a solar panel could have \( x \) rows and \( x \) columns of solar cells, write an expression that would give the total number of cells in the panel.

4. If you had 5 panels like those found in Item 3, write an expression that would give the total number of solar cells.

All the answers in Items 1–4 are called terms. A term is a number, variable or the product of a number and variable(s).

5. Write the sum of your answers from Items 1, 2, and 4.
Expressions like the one in Item 5 are called polynomials. A polynomial is a single term or the sum of two or more terms.

6. List the terms of the polynomial you found in Item 5.

7. What are the coefficients and constant terms of the polynomial in Item 5?

The degree of a term is the sum of the exponents on the variables contained in the term.

8. Find the degree and coefficient of each term in the polynomial $4x^5 + 12x^3 + x^2 - x + 5$.

<table>
<thead>
<tr>
<th>Term</th>
<th>Degree</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4x^5$</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>$12x^3$</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>$x^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-x$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. For the polynomial $2x^3y - 6x^2y^2 + 9xy - 13y^2 + 5x + 15$, list each term and identify its degree and coefficient.
Adding and Subtracting Polynomials
Polynomials in the Sun

SUGGESTED LEARNING STRATEGIES: Note Taking, Vocabulary Organizer, Interactive Word Wall

The **degree of a polynomial** is the largest degree of any term in the polynomial.

**10.** Find the degree and constant term of each polynomial.

<table>
<thead>
<tr>
<th>Polynomial</th>
<th>Degree of Polynomial</th>
<th>Constant Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2x^2 + 3x + 7$</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>$-5y^3 + 4y^2 - 8y - 3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$36 + 12x + x^2$</td>
<td></td>
<td>36</td>
</tr>
</tbody>
</table>

The **standard form of a polynomial** is a polynomial written in **descending order** of degree. The **leading coefficient** is the coefficient of a polynomial's leading term when it is written in standard form.

![Diagram of standard form of a polynomial]

A polynomial can be classified by the number of terms it has when it is in simplest form.

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of Terms $n$</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>monomial</td>
<td>1</td>
<td>8 or $-2x$ or $3x^2$</td>
</tr>
<tr>
<td>binomial</td>
<td>2</td>
<td>$3x + 2$ or $4x^2 - 7x$</td>
</tr>
<tr>
<td>trinomial</td>
<td>3</td>
<td>$-x^2 - 3x + 9$</td>
</tr>
<tr>
<td>polynomial</td>
<td>$n &gt; 3$</td>
<td>$9x^4 - x^3 - 3x^2 + 7x - 2$</td>
</tr>
</tbody>
</table>
11. Fill in the missing information in the table below.

<table>
<thead>
<tr>
<th>Polynomial</th>
<th>Number of Terms</th>
<th>Name</th>
<th>Leading coefficient</th>
<th>Constant term</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3x^2 - 5x$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-2x^2 + 13x + 6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$15x^2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$5p^3 + 2p^2 - p - 7$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a^2 - 25$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.23x^2 + 0.54x^2 - 0.58x + 0.0218$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-9.8t^2 - 20t + 150$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. If a square solar panel with an unknown number of cells along the edge can be represented by $x^2$, how many cells would be in one column of the panel?

A square solar panel with $x$ rows and $x$ columns can be represented by the algebra tile:

A column of $x$ cells can be represented by using the tile $x$, and a single solar cell can be represented by $\boxed{+1}$.

Suppose there were 3 square solar panels that each had $x$ columns and $x$ rows, 2 columns with $x$ cells, and 3 single solar cells. You can represent $3x^2 + 2x + 3$ using algebra tiles.
13. Represent $2x^2 - 3x + 2$ using algebra tiles. Draw a picture of the representation below.

**Adding Polynomials**
Adding polynomials using algebra tiles can be done by:
- modeling each polynomial
- identifying and removing zero pairs
- writing the new polynomial

**EXAMPLE 1**
Add $(3x^2 - 3x - 5) + (2x^2 + 5x + 3)$ using algebra tiles.

**Step 1:** Model the polynomials.

<table>
<thead>
<tr>
<th>$3x^2 - 3x - 5$</th>
<th>$2x^2 + 5x + 3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^2$</td>
<td>$x^2$</td>
</tr>
<tr>
<td></td>
<td>$-x$</td>
</tr>
<tr>
<td></td>
<td>$-x$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
</tbody>
</table>

**Step 2:** Identify and remove zero pairs.

<table>
<thead>
<tr>
<th>$x^2$</th>
<th>$x^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x^2$</td>
</tr>
<tr>
<td></td>
<td>$-x$</td>
</tr>
<tr>
<td></td>
<td>$-x$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
<tr>
<td></td>
<td>$+1$</td>
</tr>
</tbody>
</table>

**Step 3:** Combine like tiles.

<table>
<thead>
<tr>
<th>$x^2$</th>
<th>$x^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x^2$</td>
</tr>
<tr>
<td></td>
<td>$x$</td>
</tr>
<tr>
<td></td>
<td>$x$</td>
</tr>
<tr>
<td></td>
<td>$x$</td>
</tr>
<tr>
<td></td>
<td>$-1$</td>
</tr>
</tbody>
</table>

**Step 4:** Write the polynomial for the model in Step 3.

$5x^2 + 2x - 2$

Solution: $(3x^2 - 3x - 5) + (2x^2 + 5x + 3) = 5x^2 + 2x - 2$
TRY THESE A
Add using algebra tiles.

a. \((x^2 - 2) + (2x^2 + 5)\)

b. \((2y^2 + 3y + 6) + (3y^2 - 4)\)

c. \((2x^2 + 3x + 9) + (-x^2 - 4x - 6)\)

d. \((5 - 3x + x^2) + (2x + 4 - 3x^2)\)

14. Can you use algebra tiles to add \((4x^4 + 3x^2 + 15) + (x^4 + 10x^3 - 4x^2 + 22x - 23)\)? If so, model the polynomials and add. If not, explain why.

Like terms in an expression are the terms that have the same variable and exponent for that variable. All constants are like terms.

15. State whether the terms are like or unlike terms. Explain.

a. \(2x; 2x^3\)

b. \(5; 5x\)

c. \(-3y; 3y\)

d. \(x^2y; xy^2\)

e. \(14; -0.6\)

16. Using vocabulary from this unit, describe a method that could be used to add polynomials without using algebra tiles.
The method you described in Item 16 can be used to add polynomials algebraically.

**EXAMPLE 2**

Add \((3x^3 + 2x^2 - 5x + 7) + (4x^2 + 2x - 3)\) horizontally and vertically.

**Horizontally**

**Step 1:** Find like terms.  
\((3x^3 + 2x^2 - 5x + 7) + (4x^2 + 2x - 3)\)

**Step 2:** Group like terms.  
\((3x^3) + (2x^2 + 4x^2) + (-5x + 2x) + (7 - 3)\)

**Step 3:** Add the coefficients of like terms.  
\(3x^3 + 6x^2 - 3x + 4\)

**Solution:**  
\((3x^3 + 2x^2 - 5x + 7) + (4x^2 + 2x - 3) = 3x^3 + 6x^2 - 3x + 4\)

**Vertically**

**Step 1:** Vertically align the like terms.  
\(3x^3 + 2x^2 - 5x + 7\)

**Step 2:** Add the coefficients of like terms.  
\(+ 4x^2 + 2x - 3\)

**Solution:**  
\((3x^3 + 2x^2 - 5x + 7) + (4x^2 + 2x - 3) = 3x^3 + 6x^2 - 3x + 4\)

**TRY THESE B**

Add using either the horizontal or the vertical method.

- **a.** \((4x^2 + 3) + (x^2 - 3x + 5)\)
- **b.** \((10y^2 + 8y + 6) + (17y^2 - 11)\)
- **c.** \((9x^2 + 15x + 21) + (-13x^2 - 11x - 26)\)
- **d.** \((18 + 21x^3) + (3x + 4 - 52x^2)\)
Subtracting Polynomials
Subtracting polynomials using algebra tiles can be done by
- modeling the first polynomial
- modeling the additive inverse of the second polynomial
- identifying and removing zero pairs
- writing the new polynomial

EXAMPLE 3
Subtract \((2x^2 + x - 3) - (x^2 + 4x + 1)\) using algebra tiles.

Step 1: Model \(2x^2 + x - 3\) and the additive inverse of \(x^2 + 4x + 1\).

Step 2: Identify and remove zero pairs.

Step 3: Combine like tiles.

Step 4: Write the polynomial for the model in Step 4. \(x^2 - 3x - 4\)

Solution: \((2x^2 + x - 3) - (x^2 + 4x + 1) = x^2 - 3x - 4\)

TRY THESE

a. Use algebra tiles to represent the additive inverse of \(3x^2 - 2x - 4\). Then draw the representation.
TRY THESE C (continued)
Subtract using algebra tiles.

b. \((3x^2 - 1) - (2x^2 + 6)\)

c. \((3y^2 + 4y + 7) - (2y^2 - 2)\)

d. \((x^2 + x + 2) - (-2x^2 - 5x - 7)\)

e. \((4 + 2x + 4x^2) - (2x + 4 - 3x^2)\)

To subtract a polynomial you add its opposite, or subtract each of its terms.

EXAMPLE 4
Subtract \((2x^3 + 8x^2 + x + 10) - (5x^2 - 4x + 6)\) horizontally and vertically.

Horizontally

Step 1: Distribute the negative.

\(2x^3 + 8x^2 + x + 10 - 5x^2 + 4x - 6\)

Step 2: Find like terms.

Step 3: Group like terms

Step 4: Combine coefficients of like terms.

Solution: \((2x^3 + 8x^2 + x + 10) - (5x^2 - 4x + 6) = 2x^3 + 3x^2 + 5x + 4\)

Vertically

Step 1: Vertically align the like terms.

\[
\begin{array}{c}
2x^3 + 8x^2 + x + 10 \\
-(5x^2 - 4x + 6) \\
\hline
2x^3 + 8x^2 + x + 10 \\
-5x^2 + 4x - 6 \\
\hline
2x^3 + 3x^2 + 5x + 4
\end{array}
\]

Solution: \((2x^3 + 8x^2 + x + 10) - (5x^2 - 4x + 6) = 2x^3 + 3x^2 + 5x + 4\)
TRY THESE D
Subtract using either the horizontal or the vertical method.

a. \((5x^2 - 5) - (x^2 + 7)\)

b. \((2x^2 + 3x + 2) - (-5x^2 - 2x - 9)\)

c. \((y^2 + 3y + 8) - (4y^2 - 9)\)

d. \((12 + 5x + 14x^2) - (8x + 15 - 7x^2)\)

17. Suppose there are 10 solar panels that have \(3x^2 + 7x + 3\) cells on each panel. Write a polynomial that represents the total number of solar cells in all 10 panels combined.

**CHECK YOUR UNDERSTANDING**

Write your answers on notebook paper. Show your work.

For Items 1–5, use the polynomial \(4x^3 + 3x^2 - 9x + 7\).

1. Name the coefficients of the polynomial
2. List the terms, and specify the degree of each term.
3. What is the degree of the polynomial?
4. What is the leading coefficient of the polynomial?
5. What is the constant term of the polynomial?

Find the sum or difference.

6. \((3x^2 + 2x + 7) + (-2x^3 + 3x^2 - 8x - 6)\)
7. \((2x^3 + 4x - 9) - (-7x^3 + 2x^2 - 5x + 13)\)
8. Describe the similarities and differences in adding and subtracting polynomials. What method of adding polynomials do you feel most comfortable with?
Tri-Com Consulting is a company that sets up local area networks in offices. In setting up a network, consultants need to consider not only where to place computers, but also where to place peripheral equipment, such as printers.

Tri-Com typically sets up local area networks of computers and printers in square or rectangular offices. Printers are placed in each corner of the room. The primary printer A serves the first 25 computers and the other three printers, B, C, and D, are assigned to other regions in the room. Below is an example.

1. If each dot represents a computer, how many computers in this room will be assigned to each of the printers?

2. What is the total number of computers in the room? Describe two ways to find the total.
Another example of an office in which Tri-Com installed a network had 9 computers along each wall. The computers are aligned in an array with the number of computers in each region determined by the number of computers along the wall.

3. A technician claimed that since $9 = 5 + 4$, the number of computers in an office could be written as an expression using only the numbers 5 and 4. Is the technician correct? Explain.

4. Show another way to determine the total number of computers in the office.

5. Use the diagram above and the distributive property to explain why the expression $(5 + 4)(5 + 4)$ could be used to find the total number of computers.
ACTIVITY 4.5 continued

Multiplying Polynomials

Tri-Com Computers

SUGGESTED LEARNING STRATEGIES: Look for a Pattern, Create Representations, Graphic Organizer, Activating Prior Knowledge

6. The office to the right has $8^2$ computers. Fill in the number of computers in each section if it is split into a $(5 + 3)^2$ configuration.

7. What is the total number of computers? Describe two ways to find the total.

8. For each possible office configuration below, draw a diagram like the one next to Item 6. Label the number of computers on the edge of each section and find the total number of computers in the room by adding the number of computers in each section.

a. $(2 + 3)^2$  

b. $(4 + 1)^2$

c. $(3 + 7)^2$
Tri-Com has a minimum requirement of 25 computers per installation arranged in a 5 by 5 array. Some rooms are larger than others and can accommodate more than 5 computers along each wall to complete a square array. It is helpful to use a variable expression to represent the total number of computers needed for any office having \( x \) more than the 5 computer minimum along each wall.

9. One technician said that \( 5^2 + x^2 \) would be the correct way to represent the total number of computers in the office space. Use the diagram to explain how the statement is incorrect.

10. Write an expression for the sum of the number of computers in each region in Item 9.

11. For each of the possible room configurations, find the total number of computers in the room.

   a. \((2 + x)^2\)
   
   b. \((x + 3)^2\)
   
   c. \((x + 6)^2\)
The graphic organizer below can be used to help arrange the multiplications of the distributive property. It does not need to be related to the number of computers in an office. For example, this graphic organizer shows $5 \cdot 7 = (3 + 2)(4 + 3)$.

12. Draw a graphic organizer to represent the expression $(5 + 2)(2 + 3)$. Label each inner rectangle and find the sum.

13. Draw a graphic organizer to represent the expression $(6 - 3)(4 - 2)$. Label each inner rectangle and find the sum.
14. Multiply the binomials in Item 13 using the distributive property. What do you notice?

You can use the same graphic organizer to multiply binomials that contain variables. The following diagram represents \((x - 2)(x - 3)\).

\[
\begin{array}{c|c}
\hline
x & -2 \\
\hline
x & \\
\hline
-3 & \\
\hline
\end{array}
\]

15. Use the graphic organizer above to represent the expression \((x - 2)(x - 3)\). Label each inner rectangle and find the sum.

16. Multiply the binomials in Item 15 using the distributive property. What do you notice?
17. Find the product of the binomials. If you want, draw a graphic organizer like the one above Item 15.
   a. \((x - 7)(x - 5)\)
   b. \((8 + x)(4 - x)\)
   c. \((x + 7)(x + 5)\)
   d. \((x + y)^2\)

18. Compare and contrast the use of the graphic organizer and the use of the distributive property to find the product of two binomials.

19. Find the product of the two binomials.
   a. \((x + 5)(x - 5)\)
   b. \((4 + x)(4 - x)\)
   c. \((x - 7)(x + 7)\)
   d. \((2x - 3)(2x + 3)\)
20. The product of binomials of the form \((a + b)(a - b)\), has a special pattern called a **difference of two squares**. Use this pattern to explain how to find the product of \((a + b)(a - b)\).

21. Find the product of the two binomials. Look for a pattern.

   a. \((x + 5)^2\)
   
   b. \((4 + x)^2\)
   
   c. \((x + 7)^2\)
   
   d. \((2x + 3)^2\)
   
   e. \((x - 5)^2\)
   
   f. \((4 - x)^2\)
   
   g. \((x - 7)^2\)
   
   h. \((2x - 3)^2\)
ACTIVITY 4.5 continued

### Multiplying Polynomials

#### Tri-Com Computers

22. The **square of a binomial**, \((a + b)^2\) or \((a - b)^2\), also has a special pattern. Look for a pattern in the products you found for Item 21. Use this pattern to explain how to find the square of any binomial.

A graphic organizer can also be used to multiply polynomials that have more than two terms, such as a binomial times a trinomial. The graphic organizer at the right can be used to multiply \((x + 2)(x^2 + 2x + 3)\).

23. Draw a graphic organizer in the My Notes section to represent the expression \((x - 3)(x^2 + 5x + 6)\). Label each inner rectangle and find the sum.

24. How many boxes would you need to represent the multiplication of \((x^3 + 5x^2 + 3x - 3)(x^4 - 6x^3 - 7x^2 + 5x + 6)\) using the graphic organizer?

   a. Explain how you determined your answer.

   b. Would you use the graphic organizer for other multiplications with this many terms? Why/why not?

The distributive property can be used to multiply any size polynomial by another. Multiply each term in the first polynomial by each term in the second polynomial.

\[(x - 3)(5x^2 - 2x + 1) = 5x^3 - 17x^2 + 7x - 3\]
25. Find the product of the two polynomials.
   
   a. \( x(x + 5) \)
   
   b. \( (x - 3)(x + 6) \)
   
   c. \( (x + 7)(3x^2 - x - 1) \)
   
   d. \( (3x - 7)(4x^2 + 4x - 3) \)

26. How can you predict the number of terms the product should have before you combine like terms?

CHECK YOUR UNDERSTANDING

Write your answers on notebook paper. Show your work.

Find each product.
1. \( (8 + 9)^2 \)
2. \( (11 + 6)(9 + 2) \)
3. \( (x + 12)(x - 10) \)
4. \( (x + 9)(x - 6) \)

Use a difference of two squares pattern to find each product.
5. \( (x - 13)(x + 13) \)
6. \( (p - k)(p + k) \)

7. Use the square of a binomial pattern to find the product \( (x - 15)^2 \).

8. **MATHEMATICAL REFLECTION** Why do the products of \( (x - 3)^2 \) and \( (x + 3)(x - 3) \) have a different number of terms?
A company named Factor Steele Buildings builds metal buildings. They manufacture prefabricated buildings that are customizable. All the buildings come in square or rectangular designs. Most office buildings have an entrance area or Great Room, large offices, and cubicles. The diagram below shows the front face of one of their designs. The distance $c$ represents space available for large offices, and $p$ represents the space available for the great room.

1. To determine how much material is needed to cover the front wall of the building, represent the total area as a product of a monomial and a binomial.

2. Represent the same area from Item 1 as a sum of two monomials.

3. What property can be used to show that the two quantities in Items 1 and 2 are equal?

ACADEMIC VOCABULARY

A factor is any of the numbers or symbols that when multiplied together form a product. For example, 2 is a factor of $2x$, because 2 can be multiplied by $x$ to get $2x$.

To factor a number or expression means to write the number or expression as a product of its factors.
In Item 2 the number 10 is the greatest common factor of the polynomial $10c + 10p$. The greatest common factor (GCF) of a polynomial is the greatest monomial that divides into each term of the polynomial without a remainder.

4. Factor Steele Buildings has an expression that they use to input the length of the large office space and it gives the area of an entire space. This expression needs to be simplified. Determine the GCF of the polynomial $6c^2 + 12c - 9$. Explain your choice.

To Factor a Monomial (the GCF) from a Polynomial

**Steps to Factoring**

- Determine the GCF of all terms in the polynomial.
- Write each term as the product of the GCF and another factor.
- Use the Distributive Property to factor out the GCF.

**Example**

- $4x^2 + 2x - 8$
  - GCF = 2
  - $2(2x^2) + 2(x) + 2(-4)$
  - $2(2x^2 + x - 4)$

**TRY THESE A**

Factor a monomial from each polynomial.

- **a.** $36x + 9$
- **b.** $6x^4 + 12x^2 - 18x$
- **c.** $15t^3 + 10t^2 - 5t$
- **d.** $125n^6 + 250n^5 + 25n^3$
Factor Steele Buildings can create many floor plans with different size spaces. In the diagram below the great room has length and width equaling $x$ units, and each cubicle has a length and width equaling 1 unit. Use the diagram below for Items 5–8.

5. Represent the area of the entire office above as a sum of the areas of all the rooms.

6. Write the area of the entire office as a product of two binomials.

7. How are the answers to Items 5 and 6 related? What property can you use to show this relationship?
The graphic organizer you used in Tri-Com Computers can be used to represent the office, and help factor a trinomial of the form $x^2 + bx + c$.

**8.** Complete the graphic organizer below to show the product of $(x + 3)(x + 2)$.

```
   |   |
---|---|
   |   |
---|---|
   |   |
---|---|
```

**9.** Write your answer for Item 8 as a sum of all the regions.

The binomials you multiplied in Item 8 are the factors of the trinomial that represented the entire office in Item 9.

**10.** Complete the graphic organizer and write the sum in simplified form.

```
   |   |
---|---|
   |   |
---|---|
   |   |
---|---|
```

**11.** Write the binomial factors that were multiplied together to create the graphic organizer in Item 10.
12. Use the pattern in the graphic organizer to analyze a trinomial of the form \( x^2 + bx + c \). How are the numbers in your binomial factors related to the constant term \( c \), and to \( b \), the coefficient of \( x \)?

13. The following steps can be used to factor \( x^2 + 12x + 32 \). Describe what was done in each step to find the factors of \( x^2 + 12x + 32 \).

   a. Step 1
   
   
   b. Step 2
   
   
   c. Step 3
   
   
   d. Step 4
   
   \( x^2 + 12x + 32 = (x + 4)(x + 8) \)
14. Fill in the missing sections of the graphic organizer for the trinomial \(x^2 - 6x + 8\). Express the trinomial as a product of two binomials.

\[
\begin{array}{c|c}
\hline 
1^2 & \_ \\
\hline 
\_ & -4x \\
\_ & 8 \\
\hline 
\end{array}
\]

15. Make a graphic organizer like the one above for the trinomial \(x^2 + 14x + 45\). Express the trinomial as a product of two binomials.
TRY THESE B
Factor each polynomial.

a. $x^2 + 15x + 56$

b. $x^2 + 22x + 120$

c. $x^2 + 6x - 27$

d. $x^2 - 14x + 48$

When attempting to factor trinomials that have a leading coefficient of 1, such as $x^2 + bx + c$, you must focus on the values of $b$ and $c$.

EXAMPLE
Factor: $x^2 - 6x - 27 = (x \pm ?)(x \pm ?)$.

Step 1: Identify the constant term $c$. $-27$

Step 2: Identify $b$, the coefficient of $x$. $-6$

Step 3: Find two numbers whose product is equal to $c$ ($-27$) and whose sum is equal to $b$ ($-6$).

<table>
<thead>
<tr>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>-1</td>
<td>26</td>
</tr>
<tr>
<td>-27</td>
<td>1</td>
<td>-26</td>
</tr>
<tr>
<td>9</td>
<td>-3</td>
<td>6</td>
</tr>
<tr>
<td>-9</td>
<td>3</td>
<td>-6</td>
</tr>
</tbody>
</table>

Step 4: Write the binomial factors $(x - 9)(x + 3)$.

TRY THESE C
Factor each trinomial. Write the answer as a product of two binomials.

a. $x^2 + 8x + 15$

b. $x^2 - 5x - 14$

c. $x^2 - 16x + 48$

d. $24 + 10x + x^2$
16. The polynomial $x^2 - 9$ has two binomial factors. Write the polynomial $x^2 - 9$ as a product of two binomials.

17. Factor each polynomial into two binomial factors:

<table>
<thead>
<tr>
<th>Polynomial</th>
<th>1st Factor</th>
<th>2nd Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^2 - 9$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 - 16$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 - 25$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$81 - x^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$4x^2 - 49$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$36x^2 - 4y^2$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18. Explain how to factor a polynomial of the form $a^2 - b^2$. 
19. Factor each polynomial into two binomial factors.

<table>
<thead>
<tr>
<th>Polynomial</th>
<th>1st Factor</th>
<th>2nd Factor</th>
<th>First term in each factor</th>
<th>Second term in each factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^2 + 6x + 9$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 - 6x + 9$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 + 8x + 16$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 - 8x + 16$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 + 10x + 25$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x^2 - 10x + 25$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20. Explain how to factor polynomials of the form $a^2 + 2ab + b^2$, and $a^2 - 2ab + b^2$.

There are times when polynomials have more than two factors. Use your skills in factoring out monomials and binomials from a polynomial to answer Items 21–23.

21. a. What is the GCF of the polynomial $2x^3 + 16x^2 + 32x$?

   b. Use distributive property to factor out the GCF. Write the polynomial as a product of a monomial and a trinomial.

   c. Factor the trinomial into the product of two binomials. Write the original polynomial as a product of two binomials and a monomial.
Your answer to Item 21 is completely factored when each of its factors is prime. Factoring will be used to help solve equations. A polynomial that is factored in this way will allow a polynomial equation to be solved more readily.

**TRY THESE D**

Completely factor each polynomial.

a. $4x^3 - 64x$

b. $5x^2 - 50x + 80$

c. $4x^3 - 8x^2 - 60x$

d. $2x^3 - 2x^2 - 4x$

---

**CHECK YOUR UNDERSTANDING**

Write your answers on notebook paper. Show your work.

1. Factor the GCF from $4x^3 + 2x^2 + 6x$.
2. Factor the trinomial $x^2 + 11x + 30$.
3. Factor the trinomial $x^2 - 6x + 9$.
4. Factor the trinomial $x^2 + x - 30$.
5. Factor $9x^2 - 144$ completely.
6. Factor $x^2 + 22x + 121$ completely.
7. Factor $3x^3 + 9x^2 + 6x$ completely.
8. **MATHEMATICAL REFLECTION** How does factoring a trinomial relate to the process of multiplying a binomial?
You can factor trinomials of the form $ax^2 + bx + c$ with leading coefficient, $a > 0$, in more than one way. In this activity, $a$, $b$, and $c$ are integers having no common factors other than one.

Recall that $2 \times 2$ boxes were used as graphic organizers to multiply binomials and to factor trinomials of the form $x^2 + bx + c$. A method for factoring a trinomial where $a > 0$ uses a $3 \times 3$ box organizer similar to a tic-tac-toe grid.

**Directions**

To factor a trinomial of the form $ax^2 + bx + c$ where $a > 0$, follow these steps:

**Step 1:** Identify the values of $a$, $b$, and $c$ from the trinomial. Put $a$ in Box A and $c$ in Box B. Put the product of $a$ and $c$ in Box C.

**Step 2:** List the factors of the number from Box C and identify the pair whose sum is $b$. Put the two factors you find in Boxes D and E.

**Step 3:** Find the greatest common factor of Boxes A and E and put it in Box G.

**Step 4:** In Box F, place the number you multiply by Box G to get Box A.

**Step 5:** In Box H, place the number you multiply by Box F to get Box D.

**Step 6:** In Box I, place the number you multiply by Box G to get Box E.

**Solution:** The binomial factors whose product gives the trinomial are: 

$$(Fx + I)(Gx + H)$$

**EXAMPLE 1**

Factor $4x^2 - 4x - 15$.

The factors of $-60$ will have opposite signs. Since $b$ is negative, the larger factor will be negative. Consider the factors of $-60$ and identify the pair whose sum is $-4$. You will put these factors in Boxes D and E in the next step.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Factor</th>
<th>Sum</th>
<th>Factor</th>
<th>Factor</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$+1$</td>
<td>$-60$</td>
<td>$-59$</td>
<td>$+4$</td>
<td>$-15$</td>
<td>$-11$</td>
</tr>
<tr>
<td>$+2$</td>
<td>$-30$</td>
<td>$-28$</td>
<td>$+5$</td>
<td>$-12$</td>
<td>$-7$</td>
</tr>
<tr>
<td>$+3$</td>
<td>$-20$</td>
<td>$-17$</td>
<td>$+6$</td>
<td>$-10$</td>
<td>$-4$</td>
</tr>
</tbody>
</table>

**Math Tip**
The factors of $C$ will have opposite signs if $C < 0$. If $b < 0$ the factor with the greater absolute value will be negative.
ACTIVITY 4.7 continued

Factoring Trinomials

Factoring by the Letters

**LEARNING STRATEGIES:** Predict and Confirm, Discussion Group, Graphic Organizer

My Notes

**ACTIVITY 4.7 continued**

Factoring Trinomials

Factoring by the Letters

**LEARNING STRATEGIES:** Predict and Confirm, Discussion Group, Graphic Organizer

**Solution:** The trinomial $4x^2 - 4x - 15$ can be factored as $(2x + 3)(2x - 5)$.

**TRY THESE**

**a.** Factor $3x^2 + 4x - 4$.

Fill in the numbers as you follow the directions.

**Step 1:** Identify $a = _____, b = _____, c = _____$ Put $a$ in the Box A and $c$ in Box B. Put the product of $a$ and $c$ in Box C.

**Step 2:** List the factors of the number from Box C and identify the pair whose sum is $b$. Put the two factors you find in Boxes D and E.
TRY THESE A (continued)

Step 3: Find the greatest common factor of Boxes A and E and put it in Box G.

Step 4: In Box F, place the number you multiply by Box G to get Box A.

Step 5: In Box H, place the number you multiply by Box F to get Box D.

Step 6: In Box I, place the number you multiply by Box G to get Box E.

Step 7: The binomial factors whose product is the given trinomial are \((Fx + I)(Gx + H)\).

Solution: The factors of \(3x^2 + 4x - 4\) are ______________________.

If possible, factor the following trinomials using the graphic organizer.

b. \(10x^2 + 19x + 6\)  
c. \(6x^2 - 11x - 7\)

d. \(12x^2 - 11x + 2\)  
e. \(5x^2 + 2x - 18\)

EXAMPLE 2

Factor \(2x^2 - 11x + 15\) using a guess and check method.

<table>
<thead>
<tr>
<th>Possible binomial factors</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>((2x ) (x ))</td>
<td>(a = 2). Can be factored as (2 \cdot 1).</td>
</tr>
<tr>
<td>((2x - ) (x - ))</td>
<td>(c = 15). Both factors have the same sign. (b = -11). Both factors will be negative. (15) can be factored as (1 \cdot 15, 15 \cdot 1, 3 \cdot 5, 5 \cdot 3)</td>
</tr>
<tr>
<td>((2x - 1)(x - 15))</td>
<td>Product: (2x^2 - 31x + 15), incorrect</td>
</tr>
<tr>
<td>((2x - 15)(x - 1))</td>
<td>Product: (2x^2 - 17x + 15), incorrect</td>
</tr>
<tr>
<td>((2x - 3)(x - 5))</td>
<td>Product: (2x^2 - 13x + 15), incorrect</td>
</tr>
<tr>
<td>((2x - 5)(x - 3))</td>
<td>Product: (2x^2 - 11x + 15), correct factors</td>
</tr>
</tbody>
</table>

Math Tip

The factors of \(c\) will have the same sign if \(c > 0\). If \(b < 0\), both factors will be negative. If \(b > 0\), both factors will be positive.
EXAMPLE 3
Factor $3x^2 + 8x - 11$ using a guess and check method.

<table>
<thead>
<tr>
<th>Possible binomial factors</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(3x)(x)$</td>
<td>$a = 3$. Can be factored as $3 \cdot 1$.</td>
</tr>
<tr>
<td>$(3x - ) (x + )$ or $(3x + ) (x - )$</td>
<td>$c = -11$. The factors have different signs. $b = +8$. The factor with the greater absolute value will be positive. $11$ can be factored as $11 \cdot 1, 1 \cdot 11$.</td>
</tr>
<tr>
<td>$(3x + 11)(x - 1)$</td>
<td>Product: $3x^2 + 8x - 11$, correct factors</td>
</tr>
<tr>
<td>$(3x - 11)(x + 1)$</td>
<td>Product: $3x^2 - 8x - 11x$, incorrect</td>
</tr>
<tr>
<td>$(3x - 1)(x + 11)$</td>
<td>Product: $3x^2 + 32x - 11$, incorrect</td>
</tr>
<tr>
<td>$(3x + 1)(x - 11)$</td>
<td>Product: $3x^2 - 32x - 11$, incorrect</td>
</tr>
</tbody>
</table>

TRY THESE B
Factor the following trinomials into binomials, if possible.

- **a.** $2x^2 + 15x + 7$
- **b.** $3x^2 - 5x - 8$
- **c.** $4x^2 - 27x + 7$
- **d.** $6x^2 + 13x - 5$

CHECK YOUR UNDERSTANDING
Write your answers on notebook paper. Show your work.

Factor the following trinomials, if possible.

1. $10x^2 + x - 3$
2. $4x^2 + 7x + 3$
3. $3x^2 - 13x + 12$
4. $6x^2 - 7x - 5$
5. $7x^2 + 3x - 4$
6. $5x^2 - 4x + 3$
7. **MATHEMATICAL REFLECTION** Consider the 3-by-3 graphic organizer used for factoring trinomials. Look at a grid that you used in this lesson. Write about the patterns you see among the nine numbers in the grid and explain why they occur.
Simplifying Rational Expressions
Totally Rational

LEARNING STRATEGIES: Activate Prior Knowledge, Shared Reading, Think/Pair/Share, Note Taking, Group Presentation, Interactive Word Wall

A field trip costs $800 for the charter bus plus $10 per student for $x$ students. The cost per student is represented by:

\[
\frac{10x + 800}{x}
\]

The cost-per-student expression is a rational expression. A rational expression is the ratio of two polynomials.

Just like fractions, rational expressions can be simplified and combined using the operations of addition, subtraction, multiplication and division.

When a rational expression has a polynomial in the numerator and a monomial in the denominator, it may be possible to simplify the expression by dividing each term of the polynomial by the monomial.

EXAMPLE 1
Simplify by dividing: \[\frac{12x^5 + 6x^4 - 9x^3}{3x^2}\]

Step 1: Rewrite the rational expression to indicate each term of the numerator divided by the denominator.

\[
\frac{12x^5}{3x^2} + \frac{6x^4}{3x^2} - \frac{9x^3}{3x^2}
\]

Step 2: Divide. Use the Quotient of Powers Property

\[
4x^{5-2} + 2x^{4-2} - 3x^{3-2}
\]

\[
4x^3 + 2x^2 - 3x
\]

Solution: \[4x^3 + 2x^2 - 3x\]

TRY THESE A
Simplify by dividing.

a. \[\frac{5y^4 - 10y^3 - 5y^2}{5y^2}\]

b. \[\frac{32n^6 - 24n^4 + 16n^2}{-8n^2}\]
To simplify a rational expression, first factor the numerator and denominator. Remember that factors can be monomials, binomials or even polynomials. Then, divide out the common factors.

**EXAMPLE 2**
Simplify $\frac{12x^2}{6x^3}$.

*Step 1:* Factor the numerator and denominator.
$$
\frac{2 \cdot 6 \cdot x \cdot x}{6 \cdot x \cdot x \cdot x}
$$

*Step 2:* Divide out the common factors.
$$
\frac{2 \cdot 6 \cdot x \cdot x}{6 \cdot x \cdot x \cdot x}
$$

**Solution:** $\frac{2}{x}$

**EXAMPLE 3**
Simplify $\frac{2x^2 - 8}{x^2 - 2x - 8}$.

*Step 1:* Factor the numerator and denominator.
$$
\frac{2(x + 2)(x - 2)}{(x + 2)(x - 4)}
$$

*Step 2:* Divide out the common factors.
$$
\frac{2(x + 2)(x - 2)}{(x + 2)(x - 4)}
$$

**Solution:** $\frac{2(x - 2)}{x - 4}$

**TRY THESE B**
Simplify each rational expression.

| a. $\frac{6x^4y}{15xy^3}$ | b. $\frac{x^2 + 3x - 4}{x^2 - 16}$ | c. $\frac{15x^2 - 3x}{25x^2 - 1}$ |

The value of the denominator in a rational expression cannot be zero, since division by zero is undefined.

- In Example 2, $x$ cannot equal 0 since the denominator $6 \cdot (0)^3 = 0$.
- To find the excluded values of $x$ in Example 3, first factor the denominator. You can see that $x \neq -2$ because that would make the factor $x + 2 = 0$. Also, $x \neq 4$ because that would make the factor $x - 4 = 0$. Therefore, in Example 3, $x$ cannot equal $-2$ or 4.
To multiply rational expressions first factor the numerator and denominator of each expression. Next, divide out any common factors. Then simplify, if possible.

**EXAMPLE 4**

Multiply \( \frac{2x - 4}{x^2 - 2x} \cdot \frac{3x + 3}{x^2 - 2} \). Simplify your answer if possible.

**Step 1:** Factor the numerators and denominators.

\[
\frac{2(x - 2)}{(x + 1)(x - 1)} \cdot \frac{3(x + 1)}{x(x - 2)}
\]

**Step 2:** Divide out common factors.

\[
\frac{2(x - 2) \cdot 3(x + 1)}{(x + 1)(x - 1)(x)(x - 2)}
\]

**Solution:** \( \frac{6}{x(x - 1)} \)

To divide rational expressions, use the same process as dividing fractions. Write the division as multiplication of the reciprocal. Then solve the multiplication problem.

**EXAMPLE 5**

Divide \( \frac{x^2 - 5x + 6}{x^2 - 9} \div \frac{2x - 4}{x^2 + 2x - 3} \). Simplify your answer.

**Step 1:** Rewrite the division as multiplication of the reciprocal.

\[
\frac{x^2 - 5x + 6}{x^2 - 9} \cdot \frac{x^2 + 2x - 3}{2x - 4}
\]

**Step 2:** Factor the numerators and the denominators.

\[
\frac{(x - 2)(x - 3)}{(x + 3)(x - 3)} \cdot \frac{(x + 3)(x - 1)}{2(x - 2)}
\]

**Step 3:** Divide out common factors.

\[
\frac{(x - 2)(x - 3)(x + 3)(x - 1)}{(x + 3)(x - 3)(2)(x - 2)}
\]

**Solution:** \( \frac{x - 1}{2} \)

**TRY THESE C**

Multiply or divide. Simplify your answer.

a. \( \frac{2x + 2}{x^2 - 16} \cdot \frac{x^2 - 5x + 4}{4x^2 - 4} \)

b. \( \frac{3xy}{3x^2 - 12} \div \frac{xy + y}{x^2 + 3x + 2} \)
To add or subtract rational expressions with the same denominator, add or subtract the numerators and then simplify if possible.

**EXAMPLE 6**
Simplify \( \frac{10}{x} - \frac{5}{x} \).

**Step:** Subtract the numerators.

**Solution:** \( \frac{10}{x} - \frac{5}{x} = \frac{10 - 5}{x} = \frac{5}{x} \)

**EXAMPLE 7**
Simplify \( \frac{2x}{x + 1} + \frac{2}{x + 1} \).

**Step 1:** Add the numerators.

**Step 2:** Factor.

**Step 3:** Divide out common factors.

**Solution:** 2

**TRY THESE D**
Add or subtract. Simplify your answer.

a. \( \frac{3}{x^2} - \frac{x}{x^2} \)

b. \( \frac{2}{x + 3} - \frac{6}{x + 3} + \frac{x}{x + 3} \)

c. \( \frac{x}{x^2 - x} + \frac{4x}{x^2 - x} \)
**ACTIVITY 4.8 continued**

**Simplifying Rational Expressions**

**Totally Rational**

**LEARNING STRATEGIES:** Activating Prior Knowledge, Note Taking, Graphic Organizer, Group Presentation, Identify a Subtask

To add or subtract rational expressions with unlike denominators, find a common denominator. The least common multiple (LCM) of the denominators is used for the common denominator.

The easiest way to find the LCM is to factor each expression. The LCM is the product of each factor common to the expressions as well as any non-common factors.

**EXAMPLE 8**

Find the LCM of \( x^2 - 4 \) and \( 2x + 4 \).

**Step 1:** Factor each expression.

\[
x^2 - 4 = (x + 2)(x - 2)
\]

\[
2x + 4 = 2(x + 2)
\]

**Step 2:** Identify the factors.

Common Factor: \( x + 2 \)

Factors Not in Common: \( 2 \) and \( x - 2 \)

**Step 3:** The LCM is the product of the factors in Step 2.

**Solution:** LCM: \( 2(x + 2)(x - 2) \)

**TRY THESE E**

a. Find the LCM of \( 2x + 2 \) and \( x^2 + x \).

Factor each expression:

\[
\]

Factors in Common: \( x \) and \( 2 \)

Factors Not in Common: \( \)

LCM: \( \)

b. Find the LCM of \( x^2 - 2x - 15 \) and \( 3x + 9 \).

**MATH TERMS**

The **least common multiple** is the smallest multiple that two or more numbers have in common.

The numbers 10 and 25 have many common multiples. The number 50 is the least common multiple.
Now you are ready to add and subtract rational expressions with different denominators. First find the LCM of the denominators. Next write each fraction with the LCM as the denominator. Then add or subtract. Simplify if possible.

**EXAMPLE 9**

Subtract \( \frac{2}{x} - \frac{3}{x^2 - 2x} \). Simplify your answer if possible.

**Step 1:** Find the LCM.

Factor the denominators.

\[
\frac{x}{x(x - 2)} \quad \text{The LCM is } x(x - 2)
\]

**Step 2:** Multiply the numerator and denominator of the first term by \((x - 2)\). The denominator of the second term is the LCM.

\[
\frac{2}{x} \cdot \frac{(x - 2)}{(x - 2)} - \frac{3}{x(x - 2)}
\]

**Step 3:** Use the distributive property in the numerator.

\[
\frac{2x - 4}{x(x - 2)} - \frac{3}{x(x - 2)}
\]

**Step 4:** Subtract the numerators.

\[
\frac{2x - 7}{x(x - 2)}
\]

Solution: \( \frac{2x - 7}{x(x - 2)} \)

**EXAMPLE 10**

Add \( \frac{-4}{5 - p} + \frac{3}{p - 5} \). Simplify your answer if possible.

**Step 1:** Find a common denominator. \( p - 5 \)

**Step 2:** Multiply the numerator and denominator of the first term by \(-1\).

\[
\frac{-4}{5 - p} \cdot \frac{-1}{-1} + \frac{3}{p - 5}
\]

**Step 3:** Multiply.

\[
\frac{4}{p - 5} + \frac{3}{p - 5}
\]

**Step 4:** Add.

\[
\frac{7}{p - 5}
\]

Solution: \( \frac{7}{p - 5} \)
TRY THESE F
a. Add $\frac{1}{x^2 - 1} + \frac{2}{x + 1}$. Directions are provided to help you.

Factor each denominator:

<table>
<thead>
<tr>
<th>Common Factors:</th>
<th>Factors Not in Common:</th>
<th>LCM:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x - 1, x + 1$</td>
<td>$x + 1$</td>
<td>$x^2 - 1$</td>
</tr>
</tbody>
</table>

Fill in the blanks on the left and write the algebraic steps on the right.

Factor the denominator of the first term.
Multiply the numerator and denominator of the second term by ________.
Add the numerators.
Use the distributive property.
Combine like terms.
Solution:
TRY THESE F (continued)
Add or subtract. Simplify your answer.

b. \( \frac{3}{x + 1} - \frac{x}{x - 1} \)

c. \( \frac{2}{x} - \frac{3}{x^2 - 3x} \)

d. \( \frac{2}{x^2 - 4} + \frac{x}{x^2 + 4x + 4} \)

Find the least common multiple.
9. \( 2x + 4 \) and \( x^2 - 4 \)
10. \( x + 3, x^2 + 6x + 9, \) and \( x^2 - 7x - 30 \)

Perform the indicated operation.
11. \( \frac{x}{x + 1} - \frac{2}{x + 3} \)
12. \( \frac{2}{3x - 3} - \frac{x}{x^2 - 1} \)

13. MATHEMATICAL REFLECTION What have you learned about simplifying rational expressions as a result of this activity?
Polynomial Operations and Factoring

MEASURING UP

When you apply for a job at Ship-It-Quik you have to perform computations involving volume and surface area. For a rectangular prism, the volume is \( V = lwh \) and surface area is \( SA = 2lw + 2wh + 2lh \) where \( l, w, \) and \( h \) are length, width and height, respectively.

1. In the first part of the job application, you have to verify whether or not the following computations are correct. Explain your reasoning by showing your work.

   Volume:
   \[ 2x^2 + 15x + 36 \]

   Surface Area:
   \[ 10x^2 + 90x + 72 \]

2. For the second part of the job application, you are given a box whose volume is \( 3x^3 + 21x^2 + 30x \). Two of the dimensions are shown, \( 3x \) and \( x + 2 \). What is the other dimension?

3. For the final part of the job application, find the volume of a cylinder with radius \( 3x^2y \) and height \( 2xy \). Use the formula \( V = \pi r^2 h \) where \( r \) is the radius and \( h \) is the height. Simplify your answer as much as possible.
## Polynomial Operations and Factoring

### MEASURING UP

<table>
<thead>
<tr>
<th>Math Knowledge #1, 2, 3</th>
<th>Exemplary</th>
<th>Proficient</th>
<th>Emerging</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student:</td>
<td>Correctly verifies whether the computations are correct for both the volume and the surface area. (1)</td>
<td>Attempts to verify the validity of the computations for both attributes, but only one is correct.</td>
<td>Attempts to verify the validity of the computations for both attributes, but neither is correct.</td>
</tr>
<tr>
<td>• Finds the correct third dimension. (2)</td>
<td>Uses the correct method to find the third dimension but makes a mathematical error.</td>
<td>Attempts but is unable to find the third dimension.</td>
<td></td>
</tr>
<tr>
<td>• Correctly uses the formula to find and simplify the expression for the volume of the cylinder. (3)</td>
<td>Correctly substitutes in the formula but makes a mathematical error when simplifying it.</td>
<td>Substitutes in the formula incorrectly.</td>
<td></td>
</tr>
</tbody>
</table>

| Communication #1 | | |
|------------------|--------------------------------------------------|
| The student correctly justifies his/her verification of both answers given. (1) | The student correctly justifies his/her verification of only one of the answers given; the second justification is incomplete but contains no mathematical errors. | The student attempts to justify his/her verification, but the answer contains mathematical errors. |
**ACTIVITY 4.1**

1. \( \frac{x^2}{5x} = \)
   - a. \( x \)
   - b. \( \frac{x}{5} \)
   - c. \( 5x \)
   - d. \( \frac{5}{x} \)

2. \( 3x^{-2}y^3 \cdot 5xy = \)
   - a. \( \frac{8y^3}{x^2} \)
   - b. \( \frac{15y^4}{x} \)
   - c. \( 3 - x \)
   - d. \( \frac{3x + 3}{x} \)

3. \( -4x^2(-3xy^4)^2 = \)
   - a. \( -24x^4y^6 \)
   - b. \( 48x^4y^6 \)
   - c. \( 24x^4y^8 \)
   - d. \( -36x^4y^8 \)

4. \( \left( \frac{4}{x^3} \right)^{-3} = \)
   - a. \( -12x^6 \)
   - b. \( -12x^9 \)
   - c. \( \frac{x^9}{64} \)
   - d. \( \frac{64}{x^6} \)

5. Mars is about \( 1.2 \times 10^8 \) miles from Earth. If the Mars Polar Lander is sending messages back to Earth at about \( 1.86 \times 10^5 \) miles per second (the speed of light), how long will it take for the data to arrive?

**ACTIVITY 4.2**

Graph each of the following functions. Choose an appropriate scale for your coordinate grid.

6. \( y = (2.5)^x \)
7. \( y = (0.75)^x \)
8. \( y = 3(1.5)^x \)
9. \( y = 8(0.25)^x \)

For each of the following descriptions of exponential functions, write the function.

10. Initial value is 50. Constant ratio is 3.5.
11. Initial value is 100. Constant ratio is 0.9.
12. Initial value is 10. Constant ratio is 0.25.
13. Initial value is \( \frac{1}{3} \). Constant ratio is 3.

**ACTIVITY 4.3**

Express each expression in simplest radical form.

14. \( \sqrt{56} \)
15. \( \sqrt{324} \)
16. \( \sqrt{12x^2} \)
17. \( \sqrt{25a^3b^4} \)
18. \( 5\sqrt{15} - 2\sqrt{15} \)
19. \( 14\sqrt{6} + 3\sqrt{2} - 2\sqrt{8} \)
20. \( 5 - 3\sqrt{7} \)
21. \( 2\sqrt{63} + 6\sqrt{28} + 8\sqrt{45} \)
22. \( (\sqrt{20})(\sqrt{10}) \)
23. \( (\frac{\sqrt{2}}{3})(\sqrt{\frac{3}{2}}) \)
ACTIVITY 4.4
For Items 1–5, use the polynomial 
\(3x^2 - \frac{7}{8}x^3 + 13x + \frac{4}{3}\).

29. Name the coefficients of the polynomial.

30. List the terms, and specify the degree of each term.

31. What is the degree of the polynomial?

32. What is the leading coefficient of the polynomial?

33. What is the constant term of the polynomial?

**Add or subtract.**

34. \((9x^2 + 3x + 5) + (x^4 + x^2 - 12x - 4)\)

35. \((4x^3 + 9x - 22) - (8x^3 + 3x^2 - 7x + 11)\)

36. \(\frac{2}{3}x^2 + \frac{1}{5}x + \frac{5}{8} + \left(-\frac{1}{2}x^3 + \frac{4}{3}x^2 - \frac{3}{5}x - \frac{3}{8}\right)\)

37. \(\frac{3}{4}x^3 + 4x - \frac{5}{6} - \left(-\frac{1}{2}x^3 + 2x^2 - 5x + \frac{2}{3}\right)\)

ACTIVITY 4.5
Find the product.

38. \(\left(\frac{1}{4} + \frac{2}{3}\right)^2\)

39. \((4 + 6)(15 + 8)\)

40. \((x - 11)(x - 13)\)

41. \((x - \frac{1}{2})(x + \frac{3}{7})\)

42. \((2x - 7)(2x + 7)\)

43. \((3w - 2y)(3w + 2y)\)

44. \((6x - 8)^2\)

45. \((x - 4)(2x^2 - 5x - 10)\)

ACTIVITY 4.6
46. Find the GCF of: \(34x^3 + 17x^4 + 51x^2\).

**Factor each polynomial.**

47. \(x^2 + 20x + 51\)

48. \(x^2 - 5x + 6\)

49. \(x^2 - 22x + 72\)

50. \(16x^2 - 169\)

51. \(x^2 + 8x + 16\)

52. \(5x^3 + 45x^2 + 40x\)

ACTIVITY 4.7
Factor the trinomials, if possible.

53. \(6x^2 + 11x + 4\)

54. \(9x^2 - 34x - 8\)

55. \(8x^2 + 14x - 15\)

56. \(10x^2 - 13x + 3\)

57. \(3x^2 + x - 4\)

58. \(2x^2 - 9x + 10\)

59. \(6x^2 + 7x - 2\)

60. \(5x^2 - 7x + 2\)
ACTIVITY 4.8

61. Simplify by dividing. $\frac{35a^7 + 15a^5 - 10a^3}{5a^5}$
   a. $7a^4 + 3a^2 - 2$
   b. $7a^4 + 3a^2 - 2a$
   c. $7a^4 + 3a^5 + 2$
   d. $7a^7 + 3a^5 - 2a^3$

62. Simplify $\frac{x^2 - 25}{5x + 25}$.
   a. $x - 5$
   b. $\frac{x}{5} + 1$
   c. $\frac{x - 5}{5}$
   d. $\frac{x - 5}{x + 5}$

63. $\frac{3x + 3}{x^2} \cdot \frac{x^2 - x}{x^2 - 1} =
   a. 3
   b. $\frac{3}{x}$
   c. $3 - x$
   d. $\frac{3x + 3}{x}$

64. $\frac{x^2 - 10x + 24}{x^2 - 36} \div \frac{5x - 20}{x^2 + 3x - 18}$
   a. $x - 3$
   b. $\frac{x - 3}{5}$
   c. $\frac{x + 6}{5}$
   d. $\frac{x - 4}{5(x - 3)}$

65. Find the LCM of $x^2 - 6x + 9$ and $4x - 12$.
   a. $(x - 3)$
   b. $4(x - 3)$
   c. $(x - 3)(x + 3)$
   d. $4(x - 3)^2$

66. $\frac{x}{x - 6} + \frac{x - 12}{x - 6} =
   a. 2
   b. 4
   c. $\frac{12}{x - 6}$
   d. $\frac{x^2 - 12x}{(x - 6)^2}$

67. $\frac{x}{x - 1} - \frac{1}{x} =
   a. 1
   b. $\frac{1}{x}$
   c. $1 - x$
   d. $\frac{x^2 - x + 1}{x^2 - x}$
An important aspect of growing as a learner is to take the time to reflect on your learning. It is important to think about where you started, what you have accomplished, what helped you learn, and how you will apply your new knowledge in the future. Use notebook paper to record your thinking on the following topics and to identify evidence of your learning.

**Essential Questions**

1. Review the mathematical concepts and your work in this unit before you write thoughtful responses to the questions below. Support your responses with specific examples from concepts and activities in the unit.
   - How do multiplicative patterns model the physical world?
   - How are adding and multiplying polynomial expressions different from each other?

**Academic Vocabulary**

2. Look at the following academic vocabulary words:
   - coefficient
   - polynomial
   - degree of a polynomial
   - radical expression
   - difference of two squares
   - rational expression
   - factor
   - term

Choose three words and explain your understanding of each word and why each is important in your study of math.

**Self-Evaluation**

3. Look through the activities and Embedded Assessments in this unit. Use a table similar to the one below to list three major concepts in this unit and to rate your understanding of each.

<table>
<thead>
<tr>
<th>Unit Concepts</th>
<th>Is Your Understanding Strong (S) or Weak (W)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept 1</td>
<td></td>
</tr>
<tr>
<td>Concept 2</td>
<td></td>
</tr>
<tr>
<td>Concept 3</td>
<td></td>
</tr>
</tbody>
</table>

a. What will you do to address each weakness?

b. What strategies or class activities were particularly helpful in learning the concepts you identified as strengths? Give examples to explain.

4. How do the concepts you learned in this unit relate to other math concepts and to the use of mathematics in the real world?
1. Which expression is equal to \((-3xy^2)^3\)?
   A. \(-9x^3y^6\)
   B. \(-9x^3y^5\)
   C. \(-27x^3y^6\)
   D. \(-27x^3y^5\)

2. What is the value of \(x\), if the value of \(\sqrt{2x}\) is 4?

3. What is the value of \(x\) in the equation \(\frac{x - 2}{3} = \frac{x + 1}{4}\)?
4. The current $I$ that flows through an electrical appliance is determined by $I = \sqrt{\frac{P}{R}}$, where $P$ is the power required and $R$ is the resistance of the appliance. The current is measured in amperes, the power in watts, and the resistance in ohms. A hair dryer has a resistance of 8 ohms and draws 15 amperes of current. How much power does it use? Show your work.

**Answer and Explain**

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Write your answer and explanation in the space provided.