Exponents & Radicals

Math 10-C
Chapter 4

Name:____________________
Class:____________________
Section 4.1 Warm-Up

1. For each equation, use the same number in each box to make a true statement.
   
a) \( \square \) \( \square \) = 64
   
b) \( \square \) \( \square \) = 100
   
c) \( \square \) \( \square \) = 25
   
d) \( \square \) \( \square \) = 144

2. Estimate the value of each square root.
   
a) \( \sqrt{27} \)
   
b) \( \sqrt{90} \)
   
c) \( \sqrt{78} \)

3. For each equation, use the same number in each box to make a true statement.
   
a) \( \square \) \( \square \) \( \square \) = 64
   
b) \( \square \) \( \square \) \( \square \) = 8
   
c) \( \square \) \( \square \) \( \square \) = 27
   
d) \( \square \) \( \square \) \( \square \) = 1000

4. Evaluate.
   
a) 2^3  b) 3^2  c) 5^3

5. Rewrite each number as a product of prime numbers.
   
a) 12  b) 90  c) 112
### Area of a Square

<table>
<thead>
<tr>
<th>Side Length</th>
<th>Area in Exponential Form</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$1^2$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>$2^2$</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>$3^2$</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>$4^2$</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>$5^2$</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>$6^2$</td>
<td>36</td>
</tr>
</tbody>
</table>

### Volume of a Cube

<table>
<thead>
<tr>
<th>Edge Length</th>
<th>Volume in Exponential Form</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$1^3$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>$2^3$</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>$3^3$</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>$4^3$</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>$5^3$</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>$6^3$</td>
<td>216</td>
</tr>
</tbody>
</table>
\[
\begin{array}{c}
484 \\
\frac{3}{16} \\
\times 16 \\
\frac{96}{160} \\
\frac{256}{256}
\end{array}
\]
Big Ideas:
When you have completed this chapter you will be able to...

- Solve problems that involve square roots and cube roots
- Solve problems involving powers with integral and rational exponents.
- Represent, identify and simplify irrational numbers

4.1 Square Roots and Cube Roots

Perfect Square: a number that can be written as a product of 2 equal factors. 
by no decimals
Ex: \(16 = 4 \times 4\)

Square Root: one of the numbers multiplied to give a square.

The number 81 is a perfect square. It is formed by multiplying two factors of 9 together.

EX.

\[81 = (9)(9) = 9^2\]

The square root of 81 is \(\sqrt{81}\) or 
\[\frac{\sqrt{9 \cdot 9}}{9} = \frac{9}{9} = 9\]
Perfect Cube: a number that is a product of 3 equal factors.

627 = 3 x 3 x 3

Cube Root:

The number 27 is a perfect cube. It is formed by multiplying 3 factors of 3 together.

EX. 27 = 3 x 3 x 3

The cube root of 27 is $\sqrt[3]{27}$ or $\frac{3}{2} \cdot \frac{3}{3} = \frac{3}{3}$

= 3

Some numbers can be a perfect square and a perfect cube!

EX. 64 = 8 x 8 = $8^2$  

$\therefore \sqrt{64} = 8$

no decimal

$\therefore$ perfect square

$\sqrt[3]{64} = 4$

no decimal

$\therefore$ perfect cube

$\sqrt{-81} \Rightarrow -9 \times -9$ Can't square root a (-) number

$\sqrt[3]{-8} \Rightarrow .2 \times .2 \times .2$ Yes you can.
3 Methods to Determine the Square or Cube Roots

1. Calculator
2. Use a diagram
3. Prime Factorization

**Prime Factorization:**
When finding the square root or cube root you can use the process of prime factorization.

Creating a factor tree helps to organize the prime factors.

Ex. 125

```
    125
   /   \
  5    25
 / 
5 x 5
```

**Diagrams:**

```
  729
 /  \
 9   81
 / \
9 x 9 x 9
```

```
  27 x 27
 / \
 9 x 9 x 9
```

V = 125 m³
**Calculator:**
Everyone’s calculator is a little different. Calculate the cube root of the following and in the box below indicate the calculator key strokes.

216

Assignment pg. 158-159 #1-10, 16 (Challenge)
4. Evaluate.

a) \( \sqrt[3]{1} \)

b) \( \sqrt[3]{8(27)} \)

c) \( \sqrt[3]{8000} \)

d) \( \frac{\sqrt[3]{64}}{2} \)

e) \( \sqrt[3]{\frac{27}{125}} \)

\[ \sqrt[3]{8(27)} = 6 \]

\[ \sqrt[3]{8} = 2 \]
f) $\sqrt[3]{64a^3} = 4a$
4.2  Integral Exponents

TRY IT!  Vertical Surface

Investigate Negative Exponents  (p. 163 in text)

1. On a sheet of paper, draw a line 16 cm long and mark it as shown.

2. Mark a point halfway between 0 and 16. Label the point with its value and its equivalent value in exponential form ($2^4$). Repeat this procedure until you reach a value of 1 cm.

   a) How many times did you halve the line segment to reach 1 cm?

   b) What do you notice about the exponents as you keep reducing the line segment by half?

3. a) Mark the halfway point between 0 and 1. What fraction does this represent?

   b) Using the pattern established in step 2, what is the exponential form of the fraction?

   c) Halve the remaining line segment two more times.

4. Use a table to summarize the line segment lengths and the equivalent exponential form in base 2.
<table>
<thead>
<tr>
<th>Line Segment Length</th>
<th>Exponential Form</th>
<th>Positive Exponents</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>$2^4$</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>$2^3$</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$2^2$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$2^1$</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$2^0$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>$2^{-1}$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>$\frac{1}{4}$</td>
<td>$2^{-2}$</td>
<td>$\frac{1}{4}$</td>
</tr>
<tr>
<td>$\frac{1}{8}$</td>
<td>$2^{-3}$</td>
<td>$\frac{1}{8}$</td>
</tr>
<tr>
<td>$\frac{1}{16}$</td>
<td>$2^{-4}$</td>
<td>$\frac{1}{16}$</td>
</tr>
<tr>
<td>$\frac{1}{32}$</td>
<td>$2^{-5}$</td>
<td>$\frac{1}{32}$</td>
</tr>
</tbody>
</table>

5. Reflect and Respond

a) Describe the pattern you observe in the exponents as the distance is halved.

b) Is there a way to rewrite each fraction so that it is expressed as a power with a positive exponent? Try it. Compare this form to the equivalent power with a negative exponent. What is the pattern?

c) Create a general form for writing any power with a negative exponent as an equivalent power with a positive exponent.
Does the Pattern work for powers with a base other than 2?

<table>
<thead>
<tr>
<th>Line Segment Length</th>
<th>Exponential Form</th>
</tr>
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<tbody>
<tr>
<td>64</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<tr>
<td>1</td>
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</tbody>
</table>
# 4.2 Integral Exponents

Exponent Laws help simplify expressions with integral exponents.

## Exponent Laws

<table>
<thead>
<tr>
<th>Rule</th>
<th>Ex.</th>
<th>Repeat Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product of Powers</td>
<td>$a^m a^n = a^{m+n}$</td>
<td>$2^2 \times 2^3 = 2^5$</td>
</tr>
<tr>
<td>Quotient of Powers</td>
<td>$\frac{a^m}{a^n} = a^{m-n}, a \neq 0$</td>
<td>$\frac{2^3}{2^2} = 2^1$</td>
</tr>
<tr>
<td>Power of a Power</td>
<td>$(a^m)^n = a^{mn}$</td>
<td>$3^2 \times 3^2 = 3^6$</td>
</tr>
<tr>
<td>Power of a Product</td>
<td>$(ab)^m = (a^m)(b^m)$</td>
<td>$2 \times 2 \times 2 \times 2 \times 2 \times 2$</td>
</tr>
<tr>
<td>Power of a Quotient</td>
<td>$\left(\frac{a}{b}\right)^n = \frac{a^n}{b^n}, b \neq 0$</td>
<td>$\frac{3^2}{3^2} = 3^0$</td>
</tr>
<tr>
<td>Zero Exponent</td>
<td>$a^0 = 1, a \neq 0$</td>
<td>$2^0$</td>
</tr>
</tbody>
</table>

A Power with a negative exponent can be written as a power with a positive exponent.

**Ex.**

- $a^{-n} = \frac{1}{a^n}, a \neq 0$  
  $2^{-3} = \frac{1}{2^3}$
- $\frac{1}{a^{-n}} = a^n, a \neq 0$  
  $\frac{1}{2^{-3}} = 2^3$

**Note:** When simplifying we usually use positive exponents.
Section 4.2 Warm-Up

1. Use the exponent laws to rewrite each expression as a single power.
   a) \((x^3) (x^5)\)
   b) \(\frac{y^8}{y^2}\)
   c) \(\frac{(b^5)(b)}{b^2}\)

2. Use the exponent laws to rewrite each expression as a single power.
   a) \((x^5)^2\)  b) \(\frac{y^7}{(y^2)^3}\)  c) \((b^2)^3 \cdot (b^4)^4\)

3. Simplify each expression.
   a) \((2x^3)^2\)  b) \((4y^2)^3\)  c) \((3x^6y^5)^2\)

4. Evaluate.
   a) \(\frac{3}{5} + \frac{2}{3}\)
   b) \(\left(\frac{1}{2}\right)^4\)
   c) \(5 \div \frac{2}{3}\)

5. What is the missing number?
   a) \(2\Box = 32\)
   b) \(\left(\frac{1}{2}\right)^\Box = \frac{1}{16}\)
   c) \(3\Box = 81\)
   d) \(\left(\frac{1}{3}\right)^\Box = \frac{1}{27}\)
Multiply or Divide Powers with the same base. (p. 165 in text)

-2 Methods: Add or subtract  or  Change to Positive Exponents

1. \((7^{-2})(7^7) = 7^{-2+7} = \sqrt[7]{7^5}\)
   \[
   \left(\frac{1}{7^2}\right)\left(\frac{7^7}{1}\right) = \frac{7^7}{7^2} = 7^{7-2} = \sqrt[7]{7^5}
   \]

2. \((0.3^{-2})(0.3^{-5})\)

3. \(\frac{w^5}{w^{-3}}\)

4. \(\frac{(3t)^4}{(3t)^{-3}}\)
Powers of Powers

HINT:

\((5^{-2})^4\)

HINT:

\(\left(2^{-2}(2^0)\right)^{-2}\)

HINT:

\(\left(\frac{3^3}{3^5}\right)^{-2}\)
HINT:

\[
\left[ \left( \frac{2}{5} \right)^3 \left( \frac{2}{5} \right)^5 \right]^{-2}
\]

Note: When performing the application of “exponent laws” there is multiple pathways/order of process. The focus therefore becomes on the accurate applications.

Which step/law do you like to apply 1st, why? Is it the most efficient order?

Watch For:

\[-3x^3 \text{ vs } (-3x)^3\]

What are the differences and similarities? Are these equivalent?

Assignment pg. 169-170 #1-7, 11, 20(challenge)
Section 4.3 Warm-Up

1. Calculate without using a calculator.
   a) \( \frac{3}{4} + \frac{5}{6} = \frac{9}{12} + \frac{10}{12} = \frac{19}{12} \)
   b) \( \frac{3}{8} - \frac{2}{8} = \frac{1}{8} \)
   c) \( \frac{5}{6} - \frac{1}{2} + \frac{3}{4} = \frac{10 - 6 + 9}{12} = \frac{13}{12} \)

2. Evaluate without using a calculator.
   a) \( 5^0 = 1 \)
   b) \( 2^{-3} = \frac{1}{2^3} = \frac{1}{8} \)
   c) \( \left( \frac{3}{4} \right)^2 = \left( \frac{3}{4} \right) \cdot \left( \frac{3}{4} \right) = \frac{9}{16} = 0.5625 \)
   d) \( \left( \frac{-5}{3} \right)^4 = \left( \frac{3}{-5} \right)^4 = \left( \frac{3}{-5} \right) \cdot \left( \frac{3}{-5} \right) \cdot \left( \frac{3}{-5} \right) \cdot \left( \frac{3}{-5} \right) = \frac{81}{625} \)

3. Use the exponent laws to rewrite each expression as a single power.
   a) \( (y^8)(y^{-2}) \)
   b) \( \frac{(b^5)(b^{-1})}{b^{-3}} \)
   c) \( (x^5)^{-2} \)
   d) \( \frac{y^7}{(y^{-4})^{-3}} \)

4. Convert each fraction to a decimal.
   a) \( \frac{7}{8} \)  b) \( \frac{4}{5} \)  c) \( \frac{11}{16} \)

5. A vehicle decreases in value by 15% each year. If it was worth $35,000 when it was new, what would be its value after three years? Give the answer to the nearest dollar.
5. A vehicle decreases in value by 15% each year. If it was worth $35,000 when it was new, what would be its value after three years? Give the answer to the nearest dollar.

\[
\frac{85}{100} = \frac{x}{35000}
\]

\[157\times 3 = 471\%
\]

\[0.85 \times 35000 = \]

\[0.85 \times 0.85 = \]

\[0.85 \times 0.85 \times 0.85 = \]

\[35000 \times 0.85 \times 0.85 \times 0.85 = \]

\[
\left(\frac{35000}{\text{original}}\right) \times (0.85)^3
\]

\[\text{after 15 years?}\]
b) \[ \frac{(b^5)(b^{-1})}{b^{-3}} = \frac{b^{5+(-1)}}{b^{-3}} = \frac{b^4}{b^{-3}} = b^{4+3} = b^7 \]

c) \[ (x^5)^{-2} = x^{5 \cdot -2} = x^{-10} = \frac{1}{x^{10}} \]

d) \[ \frac{y^7}{(y^{-4})^{-3}} = \frac{y^7}{y^{12}} = y^{7-12} = y^{-5} \]
$2 \sqrt{4} \div 6$

$2 \times 2 \cdot 3 = 12$
Investigate Rational Exponents

1. According to the product rule for powers
   \[(9^{\frac{3}{2}})(9^{\frac{1}{2}}) = 9^{\frac{1}{2} + \frac{1}{2}}\]
   \[= 9^1\]
   \[= 9\]
   You can reverse these statements to get
   \[9^1 = 9^{\frac{1}{2} + \frac{1}{2}}\]
   \[= (9^{\frac{1}{2}})(9^{\frac{1}{2}})\]
   What is the value of \(9^{\frac{1}{2}}\)? Check your answer with a calculator.

2. Predict values for \(4^{\frac{1}{2}}\), \(16^{\frac{1}{2}}\), \(36^{\frac{1}{2}}\), and \(49^{\frac{1}{2}}\). Use a calculator to check your predictions. Were you correct?

3. Predict the value of \(8^{\frac{1}{3}}\). Explain your thinking. Check your prediction.

4. Reflect and Respond
   a) Explain how determining \(49^{\frac{1}{2}}\) and your definition for square root are related.
   b) Express the 12th root of 2 as a power. Evaluate using your calculator. Express the answer to six decimal places.
   c) Use your calculator to determine the 12th power of your answer to part b). Explain why the answer is not 2.
A mountain pine beetle population can double every year if conditions are ideal. Assume the forest in Jasper National Park, AB, has a population of 20,000 beetles. The formula $P = 20,000(2)^n$ can model the population, $P$, after $n$ years.

1. How many beetles were there in the forest four years ago?
# 4.3 Rational Exponents

## Exponent Laws

Note that $a$ and $b$ are rational or variable bases and $m$ and $n$ are integral exponents.

<table>
<thead>
<tr>
<th>Exponent Law</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product of Powers</td>
<td>$(a^m)(a^n) = a^{m+n}$</td>
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</tr>
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</table>

A power with a **negative** exponent can be written as a power with a **positive** exponent.

**Ex.**

\[
\left(\frac{1}{x}\right)^{-4} = x^4
\]
Multiply or Divide Powers

1. \((t^3)(t^3)\) = \(t^{\frac{1}{3} + \frac{5}{5}} = t^1 = t^2\)

2. \((7^3)(7^{-\frac{1}{2}})\)
   - Use decimals (0.5)
   - \(7^3 + (-0.5)\)
   - \(7^{\frac{3}{2}} + (-\frac{1}{2})\)
   - Same answer

3. \(\frac{3}{4} \div \frac{3}{4}\)
   - Use decimals (0.75)
   - \(7 + 7\)

4. \(\frac{4^{1.6}}{64^{0.4}}\)
   - \(\frac{4^{1.6}}{(4^3)^{0.4}} = \frac{4^{1.6}}{4^{1.2}} = 4^{1.6 - 1.2}\)
   - \(4^{0.4}\)

64 = 4^3

5. \(64^{0.4} = (4^3)^{0.4}\)
Simplify Powers with Rational Exponents

HINT: Power of a Power

\[
\left(2x^4\right)^{0.5} = 2^{0.5} \cdot x^2
\]

HINT: Product of a Power, Common Denominators

\[
\left(x^2\right)^{\frac{1}{2}} = \left(x^{\frac{2}{2}}\right)^{\frac{3}{2}} = x^{\frac{3}{2}} = x^{\frac{1}{2}} \cdot x^{\frac{1}{2}} = \sqrt{x} \cdot \sqrt{x} = x
\]

\[
\sqrt{2} = 1.414...
\]

\[
2^\pi = 1.914...
\]
HINT: neg. power
- power of a power

\[
\left( \frac{2^3}{27} \right)^{-\frac{1}{3}} = \left( \frac{2^{\frac{7}{3}}}{2^{\frac{3}{3}}} \right)^{\frac{1}{3}} = \frac{2^{\frac{1}{3}}}{2^{\frac{2}{3}}} = \frac{2^{\frac{1}{3}}}{2} = \frac{2^{\frac{1}{3}}}{3}
\]

Assignment pg. 180-181 #1-7
Section 4.4 Warm-Up

1. Write the prime factorization for each number.
   a) 54
   b) 180
   c) 200

2. Evaluate.
   a) \( \sqrt[3]{125} \)
   b) \( -\sqrt{10000} \)
   c) \( \sqrt[3]{-64} \)

3. Rewrite each radical as a power.
   a) \( \sqrt[3]{7} \)
   b) \( \sqrt{-8} \)
   c) \( \sqrt[3]{x^5} \)

4. Evaluate each expression. Write each answer as an integer or a fraction.
   a) \( 27^{\frac{1}{3}} \)
   b) \( 16^{\frac{1}{2}} \)
   c) \( (-8)^{\frac{4}{3}} \)

5. Which of the following sequences of keystrokes will correctly evaluate \( \frac{3+9}{3} \)?
   Hint: There may be more than one correct sequence.
   a) \( 3 + 9 + 3 \)
   b) \( (3 + 9) + 3 \)
   c) \( 3 + 3 + 9 + 3 \)
   d) \( 3 + 3 + 9 \)
4c)

\[
\left(-8\right)^{-\frac{4}{3}} = \left(\frac{1}{-8}\right)^{\frac{4}{3}}
\]

\[
\sqrt[3]{(-8)^4}
\]

\[
\sqrt[3]{(-8)(-8)(-8)(-8)(-8)(-8)(-8)}
\]

\[
\begin{align*}
-2 & \quad 4 & \quad -2 \\
2 & & -2
\end{align*}
\]

16
\((-\sqrt[(-1)]{10000}) \Rightarrow (-1)(100) = -100\)
\[
\left( \frac{9}{25a^y} \right)^{\frac{1}{2}} = \frac{3}{5a^2}
\]

\[\therefore p = \frac{1}{2}\]

\[\sqrt{9} = 3\]

\[\sqrt{25a^4} = 5a^2\]

\[a^{-4} = \frac{1}{a^4}\]

\[\sqrt{a^4} = a^2 = a \cdot a\]
4.4 Irrational Numbers

What is an irrational number?

\[
\sqrt{5} = 2.236067977... \\
\pi = 3.14159256535
\]

Rational or irrational?:

\[
3 = \frac{3}{1} = \frac{6}{2} = \frac{12}{4} \\
9 = \frac{9}{1} = \frac{18}{2} = \frac{36}{4} \\
1.6 = \frac{16}{10}
\]

Pascal’s Triangle
Proof: Assume that $\sqrt{2}$ is rational.

$\sqrt{2}^2 = \left(\frac{a}{b}\right)^2 \Rightarrow 2b^2 = a^2$

$2 = \frac{a^2}{b^2}$

$\sqrt{2} = \frac{a}{b}$

$\sqrt{4a^2} = \left(\frac{a}{b}\right)^2 \Rightarrow 4b^2 = \frac{a^2}{b^2}$

$\sqrt{4b^2} = \sqrt{a^2}$

$\sqrt{2 \cdot 2 \cdot b \cdot b} = \sqrt{a \cdot a}$

$ab = a$
Rational numbers include \underline{integers}, \underline{whole \#s} and \underline{natural \#s}. These numbers and the irrational numbers form the set of \underline{Real Numbers}.

Vocabulary Check:

- \textit{Radical Sign}: the sign \( \sqrt[n]{x} \) indicating the root you are taking.
- \textit{Radicand}: base from exponential form.
- \textit{Index}: the number indicating which root is being taken.
Radicals: are powers with fractional exponents

Ex. \( x^{\frac{1}{2}} = \sqrt{x} \)

\[
3^{\frac{1}{2}} \cdot 3^{\frac{1}{2}} = 3^{\frac{1}{2} + \frac{1}{2}} = 3^1
\]

\[
\sqrt{3} \cdot \sqrt{3} = \left(\sqrt{3}\right)^2 = 3
\]

A power can be expressed as a radical in the following form:

Ex. \((x^{\frac{m}{n}})^n = x^{\frac{m}{n}n} = \left(\sqrt[n]{x}\right)^m\) or \(\sqrt[n]{x^m}\)

\[
y^{\frac{3}{2}} = \left(\sqrt[2]{y}\right)^3 = (2)^3 = 2 \cdot 2 \cdot 2 = 8
\]

A fractional exponent can be written in decimal form

Ex. \(
\sqrt[3]{6^{\frac{3}{5}}} = 6^{0.6}
\)

If the radicand is a number, you can evaluate a power with a fractional or decimal exponent.

Ex.
Convert from a Power to a Radical

HINT:

\[ (9x^{-4})^{\frac{1}{4}} \]

\[ 72^{\frac{1}{2}} \]

Convert from a Radical to a Power

HINT:

\[ \sqrt[4]{2^3} \]

\[ \sqrt{3^5} \]
Vocabulary Check:

Mixed Radical:

Entire Radical:

Convert Mixed Radicals to Entire Radicals

\[ 9^{3/4} \]

\[ 4.2 \sqrt{18} \]

\[ \frac{1}{2} \sqrt{10} \]
Convert Entire Radicals to Mixed Radicals

\[ \sqrt{40} \]

\[ \sqrt{108} \]

\[ \sqrt[3]{32} \]

Order Irrational Numbers (least to greatest)

HINT:

\[ 2\sqrt{54} \]

\[ \sqrt{192} \]

\[ 5\sqrt{10} \]

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