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Chapter 2

2.2 Laws of Exponents

Key Ideas

Laws of exponents are important because they offer us a quick way to perform operations to simplify expressions.

Laws of Exponents

For $a \neq 0$, p is an integer and m and n are natural numbers.

Product of Powers $a^m \times a^n = a^{m+n}$ ← same base

Quotient of Powers $a^m \div a^n = a^{m-n}$ ← same base

Power of a Power $(a^m)^n = a^{mn}$

Negative Exponent $a^{-p} = \frac{1}{a^p}$

Identity Exponent $a^1 = a$

Zero Exponent $a^0 = 1$

Examples

$$\begin{aligned} 4^3 \times 4^2 \\ = 4 \times 4 \times 4 \times 4 \times 4 \\ = 4^5 \end{aligned}$$

$$\begin{aligned} 4^3 \times 4^2 &\leftarrow \text{product of powers} \\ = 4^{3+2} &\leftarrow \text{adding the exponents} \\ = 4^5 \end{aligned}$$

$$\begin{aligned} 4^5 \div 4^2 \\ = \frac{4 \times 4 \times 4 \times \cancel{4}^1 \times \cancel{4}^1}{\cancel{4}_1 \times \cancel{4}_1} \\ = 4^3 \end{aligned}$$

$$\begin{aligned} 4^5 \div 4^2 &\leftarrow \text{quotient of powers} \\ = 4^{5-2} &\leftarrow \text{subtracting the exponents} \\ = 4^3 \end{aligned}$$

$$\begin{aligned} (4^3)^2 \\ = 4^3 \times 4^3 \\ = 4 \times 4 \times 4 \times 4 \times 4 \times 4 \\ = 4^6 \end{aligned}$$

$$\begin{aligned} (4^3)^2 &\leftarrow \text{power of a power} \\ = 4^{3 \times 2} &\leftarrow \text{multiplying the exponents} \\ = 4^6 \end{aligned}$$

Fill in the blanks.

① $a^m \times a^n = a^{m+n}$

a. $5^3 \times 5^2 = 5^{\square} \times 5^{\square}$
 $= 5^{\square}$

b. $7^2 \times 7^4 = \square^{2+4}$
 $= \square^6$

② $a^m \div a^n = a^{m-n}$

a. $5^3 \div 5^2 = 5^{\square} \div 5^{\square}$
 $= 5^{\square}$

b. $2^6 \div 2^2 = \square^{6-2}$
 $= \square^4$

③ $(a^m)^n = a^{mn}$

a. $(2^3)^5 = 2^{\square} \times \square$
 $= 2^{\square}$

b. $(3^4)^2 = \square^{4 \times 2}$
 $= \square^8$

④ $a^{-p} = \frac{1}{a^p}$

a. $5^{-2} = \frac{1}{5^{\square}}$

b. $3^{-6} = \frac{1}{\square^6}$

⑤ $a^1 = a$

a. $7^1 = \square$

b. $6^1 = \square$

⑥ $a^0 = 1$

a. $5^0 = \square$

b. $4^0 = \square$

Try these!



Fill in the blanks.

⑦ a. $3^2 \times 3^5 = 3^{\square} + \square = \underline{\hspace{2cm}}$

b. $4^8 \div 4^6 = 4^{\square} - \square = \underline{\hspace{2cm}}$

c. $(6^3)^4 = 6^{\square} \times \square = \underline{\hspace{2cm}}$

d. $(4^2)^5 = 4^{\square} \times \square = \underline{\hspace{2cm}}$

e. $3^{-2} = \frac{1}{3^{\square}}$

f. $4^0 = \underline{\hspace{2cm}}$

g. $5^1 = \underline{\hspace{2cm}}$

h. $2^{-5} = \underline{\hspace{2cm}}$

i. $9^0 = \underline{\hspace{2cm}}$

j. $2^0 = \underline{\hspace{2cm}}$

k. $4^{-3} = \underline{\hspace{2cm}}$

l. $3^{-4} = \underline{\hspace{2cm}}$

Evaluate each multiplication or division of powers. Write the answer as a single power. Show your work.

⑧ $3^2 \times 3^4$
= _____
= _____

⑨ $5^3 \times 5^2$

⑩ $6^4 \times 6^2$

⑪ $8^4 \div 8^3$

⑫ $10^5 \div 10^3$

⑬ $10^5 \div 10^1$

⑭ $2^0 \times 2^7$

⑮ $7^9 \div 7^0$

Write each answer as a single power.

⑯ $(2^3)^2 = \underline{\hspace{2cm}}$

⑰ $(4^2)^3 = \underline{\hspace{2cm}}$

⑱ $(8^5)^2 = \underline{\hspace{2cm}}$

⑲ $(10^2)^2 = \underline{\hspace{2cm}}$

⑳ $(3^2)^4 = \underline{\hspace{2cm}}$

㉑ $(8^0)^7 = \underline{\hspace{2cm}}$

㉒ $(9^2)^5 = \underline{\hspace{2cm}}$

㉓ $(4^6)^5 = \underline{\hspace{2cm}}$

Express each answer as a power with a positive exponent.

⑳ 2^{-2}

㉑ 5^{-2}

㉒ 10^{-3}

㉓ 6^{-2}

㉔ 3^{-3}

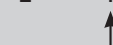
㉕ $(\frac{1}{3})^{-2}$

㉖ $(\frac{1}{5})^{-3}$

㉗ $(\frac{2}{3})^{-2}$

Hint 

$$\left(\frac{1}{2}\right)^{-2} = \left(\frac{2}{1}\right)^2 = 2^2$$

 $\frac{2}{1}$ is the reciprocal of $\frac{1}{2}$.

Chapter 2

2.4 Squares and Square Roots

Key Ideas

Squares are powers with an exponent of 2. When a number is raised to the power of 2, we say the number is squared. On the other hand, square roots are the opposite of squares.

Square Root Rules

Consider $a \geq 0$.

- $\sqrt{a} \times \sqrt{a} = a$
- $\sqrt{a^2} = a$

Consider $a, b \geq 0$.

- $\sqrt{ab} = \sqrt{a} \times \sqrt{b}$
- $\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$, where $b \neq 0$
- If $a^2 = b$, then $\sqrt{b} = a$.

Examples

$$\sqrt{9} \times \sqrt{9} = 9 \leftarrow \sqrt{a} \times \sqrt{a} = a$$

$\begin{matrix} \uparrow & \uparrow \\ 3 & 3 \end{matrix}$

$$\sqrt{9^2} = 9 \leftarrow \sqrt{a^2} = a$$

$\begin{matrix} \uparrow \\ \sqrt{81} \end{matrix}$

$$\sqrt{36} = \sqrt{4} \times \sqrt{9} \leftarrow \sqrt{ab} = \sqrt{a} \times \sqrt{b}$$

$\begin{matrix} \uparrow & \uparrow & \uparrow \\ 6 & 2 & 3 \end{matrix}$

$$\sqrt{\frac{9}{4}} = \frac{\sqrt{9}}{\sqrt{4}} \leftarrow \sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$$

$\begin{matrix} \uparrow & \uparrow \\ \frac{3}{2} & \frac{3}{2} \end{matrix}$

$$4^2 = 16, \text{ so } \sqrt{16} = 4 \leftarrow \sqrt{\frac{a^2}{b}} = \frac{a}{\sqrt{b}}$$

Fill in the blanks.

① $\sqrt{a} \times \sqrt{a} = a$

a. $\sqrt{4} \times \sqrt{4} = \square$

b. $\sqrt{10} \times \sqrt{10} = \square$

② $\sqrt{a^2} = a$

a. $\sqrt{16^2} = \square$

b. $\sqrt{20^2} = \square$

③ $\sqrt{ab} = \sqrt{a} \times \sqrt{b}$

a. $\sqrt{9 \times 16} = \sqrt{9} \times \sqrt{\square}$

b. $\sqrt{25 \times 2} = \sqrt{25} \times \sqrt{\square}$

④ $\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$

a. $\sqrt{\frac{100}{4}} = \frac{\sqrt{100}}{\sqrt{\square}}$

b. $\sqrt{\frac{16}{4}} = \frac{\sqrt{\square}}{\sqrt{4}}$

⑤ If $a^2 = b$,
then $\sqrt{b} = a$.

a. $5^2 = 25$

$\sqrt{25} = \square$

b. $4.5^2 = 20.25$

$\sqrt{20.25} = \square$

c. $\left(\frac{3}{4}\right)^2 = \frac{9}{16}$

$\sqrt{\frac{9}{16}} = \square$

Try these!



Evaluate each square root without using a calculator.

⑥ $\sqrt{5^2} = \underline{\hspace{2cm}}$

⑦ $\sqrt{8} \times \sqrt{8} = \underline{\hspace{2cm}}$

⑧ $\sqrt{10^2} = \underline{\hspace{2cm}}$

⑨ $\sqrt{7} \times \sqrt{7} = \underline{\hspace{2cm}}$

⑩ $\sqrt{12^2} = \underline{\hspace{2cm}}$

⑪ $(\sqrt{3.5})^2 = \underline{\hspace{2cm}}$

⑫ $\sqrt{4 \times 4} = \underline{\hspace{2cm}}$

⑬ $\sqrt{2} \times \sqrt{32} = \underline{\hspace{2cm}}$

⑭ $\sqrt{4.5 \times 2} = \underline{\hspace{2cm}}$

⑮ $\sqrt{\frac{36}{9}} = \underline{\hspace{2cm}}$

⑯ $\sqrt{\frac{8}{0.5}} = \underline{\hspace{2cm}}$

⑰ $\frac{\sqrt{18}}{\sqrt{2}} = \underline{\hspace{2cm}}$

Simplify the square roots. Show your work.

$$\begin{aligned} \textcircled{18} \quad & \sqrt{12} \\ &= \sqrt{\square \times 3} \\ &= \sqrt{\square} \times \sqrt{3} \\ &= \square \sqrt{3} \end{aligned}$$

⑲ $\sqrt{20}$

⑳ $\sqrt{27}$

㉑ $\sqrt{50}$

㉒ $\sqrt{32}$

㉓ $\sqrt{54}$

㉔ $\sqrt{48}$

㉕ $\sqrt{72} = \underline{\hspace{2cm}}$

㉖ $\sqrt{120} = \underline{\hspace{2cm}}$

㉗ $\sqrt{150} = \underline{\hspace{2cm}}$

㉘ $\sqrt{200} = \underline{\hspace{2cm}}$

㉙ $\sqrt{243} = \underline{\hspace{2cm}}$

㉚ $\sqrt{363} = \underline{\hspace{2cm}}$

Hint 

To simplify a square root, first rewrite the number within the root as a product of the largest perfect square possible and another number. Then find the square roots to simplify.

e.g. $\sqrt{75}$

$$\begin{aligned} &= \sqrt{25 \times 3} \quad \leftarrow \begin{array}{l} 25 \text{ is the largest} \\ \text{perfect square} \\ \text{possible.} \end{array} \\ &= \sqrt{25} \times \sqrt{3} \\ &= 5\sqrt{3} \end{aligned}$$