1 Powers & Roots

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NOTATION

7^3

index
= power
= exponent

base

$7^3 = 7\times7\times7 = 343$ — the index tells you how many to multiply, **not** 7×3.

HOW WE SAY IT

8^2	"8 squared" = 8×8 = 64
8^3	"8 cubed" = 8×8×8 = 512
8^4	"8 to the power 4"

LEARN THESE

- **Squares:**
  1, 4, 9, 16, 25, 36, 49, 64, 81, 100, ... 225 (up to 15^2).
- **Cubes:**
  1, 8, 27, 64, 125, 216, 343, 512, 729, 1000 (up to 10^3).

POWERS OF NEGATIVE NUMBERS

$(-4)^2 = -4\times-4 =$ **16** (brackets: square it all)

$-4^2 = -(4\times4) =$ **−16** (no brackets: square the 4 only)

$(-4)^3 =$ **−64** and $-4^3 =$ **−64**

- **Even** power of a negative → **positive**.
- **Odd** power of a negative → **negative**.

ROOTS — THE INVERSE

- A **square root** $\sqrt{\ }$ undoes squaring: $\sqrt{25} = 5$ (because $5^2 = 25$).
- A **cube root** $\sqrt[3]{\ }$ undoes cubing: $\sqrt[3]{64} = 4$ (because $4^3 = 64$).
- $\sqrt{\ }$ of a **negative** has **no real value** — squares are always positive.
- But $\sqrt[3]{\ }$ of a negative **does** exist: $\sqrt[3]{-64} = -4$.

REPEATED MULTIPLICATION

- A **power** (index/exponent) means repeated multiplication of the **base**.
- $2^5 = 2\times2\times2\times2\times2 = 32$
- $3^4 = 3\times3\times3\times3 = 81$

HANDY TRICKS

- **Squares ending in 5:** answer ends in 25; the front = tens digit × (one more). 35^2: 3×4 = 12 → 1225.
- **Cube roots** (perfect cubes): last digit gives the units, the leading digits give the tens.

ON THE CALCULATOR

- Use the $x^{\square}$ (power) and $\sqrt[\square]{\square}$ (root) buttons.
- For a negative base, put it in **brackets** first: $(-7)^5$.

MORE PRACTICE

$2^5 =$ **32** $5^3 =$ **125** $10^4 =$ **10 000**

$\sqrt{81} =$ **9** $\sqrt[3]{27} =$ **3** $\sqrt[4]{16} =$ **2**

$(-2)^4 =$ **16** $(-2)^5 =$ **−32**

$\sqrt[3]{-8} =$ **−2** — odd roots of negatives **do** exist.

SQUARE VS DOUBLE

- 5^2 means 5×5 = 25, **not** 5×2 = 10.
- 4^3 means 4×4×4 = 64, **not** 4×3.

⚠ COMMON EXAM MISTAKES (recurring errors flagged in examiners' reports)

- ✕ Writing $-4^2 = 16$ — without brackets it is −16; only $(-4)^2 = 16$.
- ✕ Reading 7^3 as 7×3 = 21 instead of 7×7×7.
- ✕ Squaring by **doubling**: $5^2 = 10$ instead of 25.
- ✕ Thinking $\sqrt{-25} = -5$ — it has no real value; and forgetting $\sqrt[3]{\ }$ of a negative **does** exist.
- ✕ Not bracketing a negative base on the calculator, so -7^5 is mis-typed.

Revise it: cover a panel, write what you remember, then check.

2 Order of Operations

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THE ORDER — E · M · A

( ) **Brackets change the order** — always do what is inside them **first**.

- **E** **Exponents & Roots** — powers & roots
- **M** **Multiplication & Division** — left → right
- **A** **Addition & Subtraction** — left → right

The order is **E, M, A**. Brackets are not part of it — they **change** it.

WHY THIS ORDER?

- **Multiplication** is repeated addition, so it is "stronger" than addition.
- **Exponents** (powers) come from repeated multiplication, so they are stronger still.
- **Brackets** change the order — they say "do this first".

COMMUTATIVITY — CAN I SWAP THE ORDER?

- **Yes** for **addition**: $3 + 5 = 5 + 3$.
- **Yes** for **multiplication**: $3 \times 5 = 5 \times 3$.
- **No** for **subtraction**: $5 - 3 \neq 3 - 5$.
- **No** for **division**: $6 \div 2 \neq 2 \div 6$.
- **No** for **powers**: $2^3 \neq 3^2$ ($8 \neq 9$).

WORKED EXAMPLES

$10 + 2 \times 3 = 10 + 6 = \mathbf{16}$ (× before +)

$(10 + 2) \times 3 = 12 \times 3 = \mathbf{36}$ (brackets first)

$3 \times 2^2 + 5 \times 3 = 12 + 15 = \mathbf{27}$

$12 \div 4 + 2 = 3 + 2 = \mathbf{5}$

SAME LEVEL? GO LEFT TO RIGHT

- $20 - 5 + 2$ → work left to right → $15 + 2 = 17$ (**not** 13).
- $24 \div 4 \times 2 \to 6 \times 2 = 12$ (**not** 3).

BRACKETS CHANGE THE ANSWER

Same numbers, different brackets:

$8 + 4 \times (5 - 2) = 8 + 12 = \mathbf{20}$

$(8 + 4) \times 5 - 2 = 60 - 2 = \mathbf{58}$

$(8 + 4) \times (5 - 2) = 12 \times 3 = \mathbf{36}$

POWERS COME BEFORE × ÷

- $2 + 3 \times 4^2 = 2 + 3 \times 16 = 2 + 48 = 50$
- Do the power first, then the multiply, then the add.

MORE PRACTICE

$20 - 3 \times 4 = \mathbf{8}$ (not 68)

$(20 - 3) \times 4 = \mathbf{68}$

$18 \div (2 + 4) = \mathbf{3}$

$5 + 2^3 \times 2 = \mathbf{21}$

$36 \div 6 \times 2 = \mathbf{12}$ (left to right, not 3)

FRACTION LINES ACT AS BRACKETS

- A fraction line groups the whole top and the whole bottom.
- $(8 + 4) \div (6 - 3) = 12 \div 3 = 4$.

⚠ COMMON EXAM MISTAKES (recurring errors flagged in examiners' reports)

- ✕ Working strictly **left to right**: $10 + 2 \times 3 = 36$ instead of 16.
- ✕ Doing **addition before multiplication** (or subtraction before division).
- ✕ Forgetting **brackets and powers come first**.
- ✕ With × and ÷ (or + and −) at the same level, not going **left to right**.
- ✕ Not matching the written order when typing into a **calculator**.

Revise it: say the order E, M, A (and how brackets change it), then test yourself on the worked examples.

3 Introduction to Algebra

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ALGEBRA CONVENTIONS

- Drop the ×: $3 \times p = 3p$.
- Write division as a **fraction**: $3 \div p = \frac{3}{p}$.
- **Number first**: $p \times 3 = 3p$.
- Letters in **alphabetical order**: $4 \times q \times r \times p = 4pqr$.
- $1x$ is written simply as x.

KEY DEFINITIONS

- **Variable** — a letter for an unknown number.
- **Coefficient** — the number in front of a variable (in 3p it is **3**).
- **Constant** — a fixed number.
- **Term** — a number, a variable, or number×variable (joined by × ÷).
- **Expression** — terms joined by + – (no equals sign).
- **Formula** — a statement of equality with a **subject**, e.g. $A = \pi r^2$.

WHAT THE NOTATION MEANS

- $7x = 7 \times x$
- $xy^2 = x \times y \times y$
- $(xy)^2 = xy \times xy = x \times x \times y \times y$

COLLECTING LIKE TERMS

Like terms = same variables to the **same power**.
Add/subtract the **coefficients**.

$6p + 9p + 4q + 7p = \mathbf{22p + 4q}$

$-7x + 5y - y - 6x = \mathbf{-13x + 4y}$

$y^4 + y^2 + 3y^4 - 4q^4 = \mathbf{4y^4 + y^2 - 4q^4}$

MULTIPLYING & DIVIDING TERMS

- **Multiply:** multiply the numbers, **add** the powers of the same letter.
- $a^4 \times a^2 = a^6 \quad 8x^4y^7 \times x^2y^4 = 8x^6y^{11}$
- **Divide:** divide the numbers, **subtract** the powers of the same letter.
- $a^6 \div a^2 = a^4 \quad 10x^8y^5 \div 5xy^3 = 2x^7y^2$

SUBSTITUTION

Replace the letter with its value — **always use brackets**.

$6x$ when $x = 5$: $6(5) = \mathbf{30}$ (not 65!)

$x^2 + 1$ when $x = 4$: $(4)^2 + 1 = \mathbf{17}$

$3a + 2b$ when $a = 5$, $b = -1$: $3(5) + 2(-1) = \mathbf{13}$

SUBSTITUTING INTO A FORMULA

$T = \frac{2}{3}w + 3$, find T when $w = 6$

$T = \frac{2}{3}(6) + 3 = 4 + 3 = \mathbf{7}$

FORMING EXPRESSIONS

- "4 more than a number" → $n + 4$
- "4 lots of a number" → $4n$
- "a number divided by 5" → $n/5$
- "3 less than a number" → $n - 3$ (**not** $3 - n$).
- "double a number, then add 7" → $2n + 7$.

MORE PRACTICE

$5a + 3b - 2a + b = \mathbf{3a + 4b}$

$4 \times 3p = \mathbf{12p} \quad 2m \times 5m = \mathbf{10m^2}$

$15y \div 3 = \mathbf{5y}$

If $a = 4$: $5a - 3 = \mathbf{17}$, $a^2 + a = \mathbf{20}$

EXPRESSION, EQUATION OR FORMULA?

- **Expression:** no equals sign — $3x + 2$.
- **Equation:** has = and can be solved — $3x + 2 = 11$.
- **Formula:** a rule linking quantities — $A = l \times w$.

⚠ COMMON EXAM MISTAKES (recurring errors flagged in examiners' reports)

- ✕ **Multiplying the powers** instead of adding: $a^4 \times a^2 = a^8$ instead of a^6.
- ✕ Substituting 6x with x = 5 as 65 instead of 6×5 = 30. **Use brackets: 6(5).**
- ✕ $3a + 2a = 5a^2$ — collecting like terms only changes the **coefficient**: 5a.
- ✕ $3a \times 2a = 6a$ or $5a^2$ instead of $6a^2$.
- ✕ Adding or multiplying **unlike terms** (e.g. $3a + 2b = 5ab$).
- ✕ **Omitting brackets** when substituting a negative value.

Revise it: write out the conventions, then simplify a few expressions with the answers covered.