Cambridge IGCSE · Mathematics (0580) · Notes

Standard form

Read online at pastopic.com/cambridge/mathematics-0580/notes/standard-form

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Read first: Powers, roots, indices and surds

What you need to know

The learning outcomes are the same for Core and Extended. The only difference is where you use them: Core candidates calculate with standard form only on Paper 3, where a calculator is allowed. By the end of this topic you should be able to:

1. **Recognise and use standard form**, $A \times 10^n$, where A is at least 1 and less than 10 ($1 \leqslant A < 10$) and n is a whole number, positive or negative. Know when a number is **not** in standard form and say why.
2. **Convert numbers into standard form and back again**, both very large numbers (such as $350\,000 = 3.5 \times 10^5$) and very small ones (such as $0.000\,48 = 4.8 \times 10^{-4}$).
3. **Calculate with numbers in standard form**: multiply, divide, square, add and subtract them, compare and order them, and use them in real problems. Give the answer in standard form when asked.
4. **Extended only:** do these calculations **without a calculator** (Paper 2), using the laws of indices.

Understand it

Why standard form?

Very large and very small numbers are hard to read and easy to miscopy. The mass of the Earth is about $5\,970\,000\,000\,000\,000\,000\,000\,000$ kg; counting those zeros is slow and risky. Standard form writes the same number as

$$5.97 \times 10^{24}\ \text{kg}.$$

The first part, 5.97, gives the **digits**. The power of 10 tells you **how big** the number is: how many places the decimal point moves.

The rule

A number is in standard form when it is written as

$$A \times 10^n, \qquad 1 \leqslant A < 10, \qquad n \text{ an integer}.$$

So A has **exactly one non-zero digit before the decimal point**.

Number	In standard form?	Why
3.5×10^5	Yes	3.5 is between 1 and 10
7×10^{-3}	Yes	A can be a whole number from 1 to 9
34×10^3	No	34 is 10 or more; it should be 3.4×10^4
0.8×10^5	No	0.8 is less than 1; it should be 8×10^4
10×10^6	No	A must be **less than** 10; it should be 1×10^7

Powers of 10

Multiplying by 10 moves every digit one place to the left; dividing by 10 moves it one place to the right. So

$$10^3 = 1000, \qquad 10^1 = 10, \qquad 10^0 = 1, \qquad 10^{-1} = \frac{1}{10} = 0.1, \qquad 10^{-3} = \frac{1}{1000} = 0.001.$$

A **positive** power makes a **big** number (at least 10). A **negative** power makes a **small** number (less than 1). A power of 0 gives a number from 1 to just under 10.

Writing a number in standard form

1. **Place the point after the first non-zero digit** to get A.
2. **Count how many places the point moved** to get from A back to the original number. That count is n.
3. **Sign of n:** if the original number is 10 or more, n is positive; if it is less than 1, n is negative.

A large number. $350\,000$: $A = 3.5$. From 3.5 to $350\,000$ the point moves 5 places to the right, so $350\,000 = 3.5 \times 10^5$.

A small number. $0.000\,48$: $A = 4.8$. From 4.8 to $0.000\,48$ the point moves 4 places to the left, so $0.000\,48 = 4.8 \times 10^{-4}$.

A quick check for small numbers: the power is minus the position of the first non-zero digit after the point. In $0.000\,48$ the 4 is in the 4th decimal place, so the power is -4.

Keep every significant digit: $0.006\,05 = 6.05 \times 10^{-3}$, not 6.5×10^{-3}, and don't round unless the question asks.

Writing a standard form number as an ordinary number

Do the moves the other way round: n places to the **right** if n is positive, to the **left** if n is negative, filling gaps with zeros.

- 6.1×10^3: move 3 right, 6100.
- 2.06×10^{-3}: move 3 left, $0.002\,06$.

Counting zeros. In 3.58×10^{50} the point moves 50 places right. Two of those places are filled by the digits 5 and 8, so $50 - 2 = 48$ zeros follow the 8.

Fixing a number that is nearly in standard form

If A is too big or too small, change A and balance it with the power:

- 34×10^3: $34 = 3.4 \times 10^1$, so $34 \times 10^3 = 3.4 \times 10^{1+3} = 3.4 \times 10^4$.
- 0.25×10^{-5}: $0.25 = 2.5 \times 10^{-1}$, so $0.25 \times 10^{-5} = 2.5 \times 10^{-6}$.

The rule of thumb: A **gets smaller, power goes up;** A **gets bigger, power goes down**, by the same number of places.

Multiplying and dividing

Group the numbers and the powers of 10 separately, then use the laws of indices ($10^a \times 10^b = 10^{a+b}$ and $10^a \div 10^b = 10^{a-b}$):

$$(4 \times 10^3) \times (6 \times 10^5) = (4 \times 6) \times 10^{3+5} = 24 \times 10^8 = 2.4 \times 10^9.$$
$$(2 \times 10^4) \div (8 \times 10^{-3}) = (2 \div 8) \times 10^{4-(-3)} = 0.25 \times 10^7 = 2.5 \times 10^6.$$

Squaring squares A **and** doubles the power: $(3 \times 10^4)^2 = 9 \times 10^8$ and $(5 \times 10^{-3})^2 = 25 \times 10^{-6} = 2.5 \times 10^{-5}$.

The last step is often a "fix" like the ones above, because $A \times B$ can be 10 or more and $A \div B$ can be less than 1.

Adding and subtracting

You **cannot** add the As and add the powers. $(4 \times 10^3) + (2 \times 10^3)$ is 6×10^3, but $(4 \times 10^3) + (2 \times 10^2)$ is $4000 + 200 = 4200$, not 6×10^5. Either:

- **change to ordinary numbers**, add, and change back: $6.3 \times 10^5 + 4.1 \times 10^4 = 630\,000 + 41\,000 = 671\,000 = 6.71 \times 10^5$; or
- **write both with the same power**, then add the numbers in front: $63 \times 10^4 + 4.1 \times 10^4 = 67.1 \times 10^4 = 6.71 \times 10^5$.

The second way is the only one that works when the powers are huge or are letters. $5 \times 10^{30} - 5 \times 10^{28} = 500 \times 10^{28} - 5 \times 10^{28} = 495 \times 10^{28} = 4.95 \times 10^{30}$.

Using a calculator

On Papers 3 and 4, type standard form numbers with the $\times 10^x$ key (it may be labelled **EXP** or **EE**), not by typing "$\times 10$ ^". For $(4.37 \times 10^5) \times (2.8 \times 10^{-9})$ type `4.37` $\times 10^x$ `5` $\times$ `2.8` $\times 10^x$ `(-)9` $=$ and you get $0.001\,223\,6$, which is 1.2236×10^{-3}, or 1.22×10^{-3} to 3 significant figures.

A calculator may show the answer as `4.2E-06` or 4.2×10^{-06}. Both mean 4.2×10^{-6}; write it that way, never as `4.2E-06` or 4.2^{-6}.

Key facts and formulas

None of these is on the List of formulas printed in the exam paper, so you must know them all.

Formula	Status
Standard form: $A \times 10^n$ with $1 \leqslant A < 10$ and n an integer	Learn it
$10^n = 1$ followed by n zeros; $10^0 = 1$; $10^{-n} = \dfrac{1}{10^n}$	Learn it
Number $\geqslant 10$: positive power; number < 1: negative power	Learn it
$(A \times 10^a) \times (B \times 10^b) = AB \times 10^{a+b}$	Learn it
$(A \times 10^a) \div (B \times 10^b) = (A \div B) \times 10^{a-b}$	Learn it
$(A \times 10^a)^2 = A^2 \times 10^{2a}$	Learn it
Adding or subtracting: make the powers equal first, $A \times 10^n + B \times 10^n = (A + B) \times 10^n$	Learn it
1 km $= 10^3$ m, 1 kg $= 10^3$ g, 1 litre $= 10^3$ cm³, 1 m³ $= 10^6$ cm³	Learn it

How to do it

In the questions we have tagged for this topic (45 questions from Papers 1–4, 2021–2025, one of them printed on two papers), the types came up this often. 14 of the 45 questions mix two or three types, so the counts add up to more than 45.

Question type	Questions
Converting into and out of standard form	24
Multiplying, dividing and squaring	19
Adding and subtracting	7
Ordering and comparing	5
Standard form in real problems	5

1. Converting into and out of standard form (24 questions)

Usually a one-mark part at the start of a question.

1. **Into standard form:** put the point after the first non-zero digit, count the places it moved, and give the power the right sign (positive for 10 or more, negative for less than 1).
2. **Out of standard form:** move the point n places (right for positive n, left for negative n) and fill with zeros.
3. **Check** by estimating: 4.07×10^{-3} must be a small number starting $0.00\ldots$

Variations you will meet:

- **Very small decimals with many zeros**, such as $0.000\,000\,53$: count the decimal place of the first non-zero digit (7th), so 5.3×10^{-7}.
- **Whole numbers with few digits**, such as 0.08 or 600: 8×10^{-2} and 6×10^{2}. A does not need a decimal point.
- **A number given in words or rounded first** ("three million and forty thousand", or a population correct to 3 significant figures): write it in figures, then convert. $3\,040\,000 = 3.04 \times 10^{6}$.
- **"Explain why . . . is not in standard form"**: say that A must be at least 1 and less than 10, and that the number given for A is not (for example "62 is more than 10"). Then give the correct form if asked.
- **Spotting the errors in someone's answer**: check A is between 1 and 10, and check any rounding (for example, 3 significant figures means three digits in A, correctly rounded).
- **"How many zeros follow the last digit"** of a huge number: the power minus the number of digits after the point in A.

2. Multiplying, dividing and squaring (19 questions)

1. **With a calculator** (Papers 3 and 4): type each number with the $\times 10^{x}$ key, and use brackets around a whole bottom line. Write down the full display, then change it to standard form and round only if asked.
2. **Without a calculator** (Paper 2, Extended; also any question whose powers are too big for a calculator, such as 10^{100}):
   - multiply (or divide) the front numbers;
   - add (or subtract) the powers;
   - fix the answer so the front number is between 1 and 10.
3. **Give the answer in standard form** if the question says so, even if the working used ordinary numbers.

Variations you will meet:

- **A power of a standard form number**, such as $(7 \times 10^{-4})^2 = 49 \times 10^{-8} = 4.9 \times 10^{-7}$. Square the front number and double the power.
- **An ordinary calculation with the answer in standard form**, such as 0.2^2 or 0.05×0.006: work it out (0.04 and 0.0003), then convert (4×10^{-2} and 3×10^{-4}).
- **A reciprocal**, such as $1 \div (4 \times 10^{5}) = 0.25 \times 10^{-5} = 2.5 \times 10^{-6}$.
- **Finding a missing number**, such as $(4 \times 10^{8}) \times n = 1.2 \times 10^{15}$: divide, $n = (1.2 \div 4) \times 10^{15-8} = 0.3 \times 10^{7} = 3 \times 10^{6}$.
- **Picking numbers from a list first** (the largest and the smallest), then multiplying: order them as in type 4 before you calculate.
- **"Correct to 2 (or 3) significant figures"**: round A at the very end. 5.2736×10^{6} to 2 s.f. is 5.3×10^{6}.

3. Adding and subtracting (7 questions)

1. **Write both numbers with the same power of** 10 (usually the smaller power), or change both to ordinary numbers.
2. **Add or subtract the front numbers**, keeping that power.

3. **Fix the answer** into standard form.

For $8.2 \times 10^6 + 9 \times 10^5$: $82 \times 10^5 + 9 \times 10^5 = 91 \times 10^5 = 9.1 \times 10^6$.

Variations you will meet:

- **Powers too big to write out**, such as $3 \times 10^{60} - 3 \times 10^{58}$: $300 \times 10^{58} - 3 \times 10^{58} = 297 \times 10^{58} = 2.97 \times 10^{60}$.
- **Letters in the powers** (Extended), such as $2.4 \times 10^k + 2.4 \times 10^{k-1}$: rewrite the first term with power $k-1$. $24 \times 10^{k-1} + 2.4 \times 10^{k-1} = 26.4 \times 10^{k-1} = 2.64 \times 10^k$.
- **A difference from a table** (two populations, two distances): subtract, and give the answer as an ordinary number or in standard form, whichever is asked.

4. Ordering and comparing (5 questions)

1. **Check every number really is in standard form**; fix any that are not.
2. **Compare the powers first:** the bigger the power, the bigger the number. Remember 10^{-2} is bigger than 10^{-3}.
3. **If two powers are equal, compare the front numbers.**
4. **Write the numbers as they were given**, in the order asked (usually smallest first).

If you are unsure, change them all to ordinary numbers and compare those. 6.5×10^{-2}, 9.1×10^{-3} and 2.2×10^{-2} are 0.065, 0.0091 and 0.022, so the order from smallest is 9.1×10^{-3}, 2.2×10^{-2}, 6.5×10^{-2}.

Variations you will meet:

- **"Which is larger? Give a reason"**: for example, 2.3×10^5 is larger than 9.8×10^4 because it has the larger power of 10 (and both are in standard form).
- **A mixed list** with some ordinary numbers and one number not in standard form: convert everything to one form first.
- **"Which country has the population nearest to..."**: write the target in standard form too, and compare.

5. Standard form in real problems (5 questions)

1. **Decide the operation.** "How many ... in ..." or "how many times bigger" means divide; "total" means multiply or add; "difference" means subtract; a density is mass $\div$ area (or volume).
2. **Get the units the same first**, such as kg to g ($\times 10^3$), cm³ to litres ($\div 1000$).
3. **Calculate** with a calculator, keeping the full display.
4. **Round and give the form asked**: standard form, 3 significant figures, with units.

Variations you will meet:

- **Tiny masses** (atoms, grains, cells): the number of objects is total mass $\div$ mass of one. For 0.6 g made of grains of 1.5×10^{-5} g each: $0.6 \div (1.5 \times 10^{-5}) = 40\,000 = 4 \times 10^4$ grains.
- **Comparing two densities or rates**: work out both, write them down, and say which is greater.

- **A volume in cm³ to litres**: $30\ \text{cm}^3 = 30 \div 1000 = 0.03 = 3 \times 10^{-2}$ litres.
- **A ratio of two standard form values** ("k times as far"): divide them, $\dfrac{3.6 \times 10^9}{1.2 \times 10^7} = 3 \times 10^2 = 300$.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

(a) Write $408\,000$ in standard form. **[1]**

(b) Write $0.000\,061\,9$ in standard form. **[1]**

(c) Write 5.2×10^{-4} as an ordinary number. **[1]**

(d) Write these numbers in order, starting with the smallest. **[2]**

$$3.1 \times 10^{-3} \qquad 2.9 \times 10^{-2} \qquad 0.0041 \qquad 4.6 \times 10^{-3}$$

(a) The point goes after the 4: 4.08. It moves 5 places back to $408\,000$, and the number is big, so 4.08×10^5. **B1**

(b) The first non-zero digit, 6, is in the 5th decimal place, so 6.19×10^{-5}. **B1** (Keep all three digits: 6.19, not 6.2.)

(c) Move the point 4 places left: $0.000\,52$. **B1**

(d) As ordinary numbers: 0.0031, 0.029, 0.0041, 0.0046. **M1** for changing all of them to ordinary numbers (or all to standard form).

3.1×10^{-3}, 0.0041, 4.6×10^{-3}, 2.9×10^{-2} **A1**

2.9×10^{-2} is the largest because -2 is the largest power. The other three all have power -3 (as $0.0041 = 4.1 \times 10^{-3}$), so compare 3.1, 4.1 and 4.6.

Example 2

This question is Extended. Calculators must not be used. Give each answer in standard form.

(a) Work out $(6 \times 10^5) \times (7 \times 10^{-2})$. **[2]**

(b) Work out $(3.6 \times 10^4) \div (9 \times 10^{-3})$. **[2]**

(c) Work out $5.4 \times 10^7 + 6 \times 10^6$. **[2]**

(d) Simplify $4.5 \times 10^n - 3 \times 10^{n-1}$. **[2]**

(a) $6 \times 7 = 42$ and $10^{5+(-2)} = 10^3$, so 42×10^3. **M1**

$= 4.2 \times 10^4$. **A1**

(b) $3.6 \div 9 = 0.4$ and $10^{4-(-3)} = 10^7$, so 0.4×10^7. **M1**

$= 4 \times 10^6$. **A1**

(c) $54 \times 10^6 + 6 \times 10^6 = 60 \times 10^6$. **M1** for writing both with the same power (or $54\,000\,000 + 6\,000\,000$).

$= 6 \times 10^7$. **A1**

(d) $4.5 \times 10^n = 45 \times 10^{n-1}$, so $45 \times 10^{n-1} - 3 \times 10^{n-1} = 42 \times 10^{n-1}$. **M1**

$= 4.2 \times 10^n$. **A1**

Example 3

A calculator is allowed in this question.

(a) Mars is 2.28×10^8 km from the Sun. Light travels at 3.00×10^5 km per second.

(i) Find the time, in seconds, that light takes to travel from the Sun to Mars. Give your answer in standard form. **[2]**

(ii) Change your answer to minutes. **[1]**

(b) One bacterium has a mass of 9.5×10^{-13} grams. Find the number of these bacteria in a sample of total mass 0.02 grams. Give your answer in standard form, correct to 3 significant figures. **[2]**

(c) A country has a population of 1.84×10^7 and an area of 2.3×10^5 km². Find its population density, where population density $=$ population $\div$ area. **[2]**

(a)(i) Time $= \dfrac{\text{distance}}{\text{speed}} = (2.28 \times 10^8) \div (3.00 \times 10^5)$ **M1**

$= 760$ s $= 7.6 \times 10^2$ s. **A1**

(a)(ii) $760 \div 60 = 12.666\ldots = 12.7$ minutes (3 s.f.). **B1**

(b) $0.02 \div (9.5 \times 10^{-13})$ **M1**

The calculator shows $2.105263158 \times 10^{10}$, so 2.11×10^{10} bacteria. **A1**

(c) $(1.84 \times 10^7) \div (2.3 \times 10^5)$ **M1**

$= 80$ people per km². **A1**

Common mistakes

- **The wrong sign on the power.** 0.0029 is small, so its power is negative: 2.9×10^{-3}, not 2.9×10^{3}. Examiners see this in almost every session. Check: a positive power means 10 or more.
- **Miscounting places.** $0.000\,58$ is 5.8×10^{-4}, not 10^{-5} or 10^{-3}. Count the decimal place of the first non-zero digit.
- **A front number that is not between 1 and 10**, such as 41.8×10^{5}, 406×10^{2} or 0.9×10^{-1}. These are correct values but not standard form, and usually lose a mark. Always do the final "fix".
- **Fixing the wrong way.** 27×10^{5} becomes 2.7×10^{6} (front smaller, power up), not 2.7×10^{4}.
- **Adding the powers when adding.** $5.2 \times 10^{6} + 2.6 \times 10^{5}$ is not 7.8×10^{11}; it is 5.46×10^{6}. Make the powers the same first.
- **Rounding when not asked.** 8.36×10^{-5} is not 8.4×10^{-5}. Keep every digit unless the question gives an accuracy.
- **Doing standard form and significant figures at once, and getting one wrong.** Write the full value in standard form first, such as 5.2736×10^{6}, then round A.
- **Squaring only the front number**, or only the power. $(6 \times 10^{-4})^2 = 36 \times 10^{-8} = 3.6 \times 10^{-7}$.
- **Losing zeros when changing to ordinary numbers** in a long calculation. Work in standard form, or count zeros carefully and check the size at the end.
- **Writing the calculator display** as the answer, such as `2.1E10`. Write 2.1×10^{10}.

How to get the marks

- **"Give your answer in standard form"**: the final answer must be $A \times 10^{n}$ with $1 \leqslant A < 10$. A correct value in another form, such as 415 or 0.036, usually earns 1 of the 2 marks, so still write it down.
- **Show a correct value before converting.** If you write 42×10^{3} and then convert it wrongly, the correct first step can still earn a method mark.
- **Non-calculator papers** (Papers 1 and 2): show the multiplication of the front numbers and the new power, such as $6 \times 7 = 42$ and 10^{5-2}, or the rewritten terms with equal powers.
- **Calculator papers** (Papers 3 and 4): write the calculation you typed, then the display, then the rounded answer. Non-exact answers go to 3 significant figures unless the question says otherwise.
- **"Correct to 2 significant figures" with standard form**: round A to two digits, such as 5.3×10^{6}.
- **"Explain" or "Give a reason"**: one clear sentence that uses the rule, such as "A must be less than 10 but 47.3 is more than 10", or "it has the larger power of 10".
- **Ordering**: give the numbers in the form they were printed, with the smallest first if asked. Showing them all as ordinary numbers often earns a method mark even if the order slips.
- **Real problems**: convert units first, include units in the answer, and answer the question asked (the number of objects, not the mass).

Quick check

1. (a) Write $0.000\,305$ in standard form. (b) Write 9.04×10^5 as an ordinary number.
2. Explain why 0.62×10^8 is not in standard form, and write it in standard form.
3. Without a calculator, work out $(2.5 \times 10^6) \times (8 \times 10^{-9})$. Give your answer in standard form.
4. (Extended) Without a calculator, work out $7.1 \times 10^9 - 9 \times 10^7$. Give your answer in standard form.
5. Use a calculator to work out $(8.15 \times 10^7) \div (3.26 \times 10^{-2})$. Give your answer in standard form.

Answers

1. (a) The 3 is in the 4th decimal place: 3.05×10^{-4}. (b) Move the point 5 places right: $904\,000$.
2. In standard form the front number must be at least 1 and less than 10, and 0.62 is less than 1. $0.62 = 6.2 \times 10^{-1}$, so $0.62 \times 10^{8} = 6.2 \times 10^{7}$.
3. $2.5 \times 8 = 20$ and $10^{6+(-9)} = 10^{-3}$, so $20 \times 10^{-3} = 2 \times 10^{-2}$.
4. $7.1 \times 10^{9} = 710 \times 10^{7}$, so $710 \times 10^{7} - 9 \times 10^{7} = 701 \times 10^{7} = 7.01 \times 10^{9}$.
5. $8.15 \div 3.26 = 2.5$ and $10^{7-(-2)} = 10^{9}$, so the answer is 2.5×10^{9} (the calculator shows $2\,500\,000\,000$).

Past questions to try

- **0580/22/M/J/25 Q11**: a small number in standard form, then adding two numbers with different powers (Extended, no calculator).
- **0580/42/F/M/25 Q9**: writing a small number in standard form, then squaring a standard form number.
- **0580/11/M/J/22 Q22**: a population table: a difference, then comparing two population densities.
- **0580/21/M/J/22 Q13**: subtracting two numbers with very large powers of 10 (Extended, no calculator).