Cambridge IGCSE · Mathematics (0580) · Notes

Estimation and limits of accuracy

Read online at pastopic.com/cambridge/mathematics-0580/notes/estimation-and-limits-of-accuracy

Last checked 28 September 2026

Read first: Fractions, decimals, ordering and the four operations

What you need to know

Core and Extended share the rounding, estimating and single-value bounds. Working out the bounds of a **calculation** is Extended only. By the end of this topic you should be able to:

1. **Round a number to a given accuracy**: to the nearest 10, 100, 1000 (or any other unit), to a number of **decimal places**, or to a number of **significant figures**.
2. **Estimate the answer to a calculation** by rounding each number first, usually to 1 significant figure, and working out the simpler calculation without a calculator.
3. **Round an answer sensibly for its context**: money to the cent, whole numbers of people or buses, and 3 significant figures when nothing else is asked.
4. **Give the upper and lower bounds of a value that has been rounded**, such as a length measured to the nearest centimetre, and write them as an inequality like $1.635 \leqslant l < 1.645$.
5. **Extended only:** find the upper and lower bounds of the **result of a calculation** that uses rounded values, such as the largest possible perimeter or area of a rectangle, the smallest possible speed from a rounded distance and time, or the largest possible density. (Core candidates are not asked to do this.)

Understand it

Rounding to the nearest 10, 100 or 1000

To round, find the digit in the place you are rounding to, then look at the **next digit to the right** (the "decider"):

- 5 or more: round **up** (add 1 to the digit you are keeping);
- 4 or less: leave the digit as it is.

Every digit after it becomes 0 if it is before the decimal point, and is dropped if it is after it.

7385 to the nearest 100: the hundreds digit is 3 and the decider is 8, so round up to 7400. To the nearest 10 it is 7390 (decider 5, round up), and to the nearest 1000 it is 7000 (decider 3).

The zeros matter. 7385 to the nearest 100 is 7400, **not** 74: the rounded number must be about the same size as the original.

Decimal places

"Correct to 2 decimal places" means keep two digits after the point. 3.8462 to 2 decimal places: keep 3.84, the decider is 6, so 3.85. To 1 decimal place it is 3.8 (decider 4).

When rounding up turns a 9 into 10, carry: 2.698 to 2 decimal places is 2.70. Keep the final 0: "2 decimal places" means two digits after the point, and 2.7 has only one.

Significant figures

Significant figures count from the **first non-zero digit**, whatever side of the point it is on.

- Zeros **at the start** of a decimal are not significant: in $0.004\,716$ the first significant figure is the 4. To 2 significant figures: keep 47, decider 1, so 0.0047.
- Zeros **between** other digits are significant: 30.96 has four significant figures. To 3 significant figures it is 31.0 (keep 30.9, decider 6, and the 9 carries).
- Zeros at the end of a whole number keep it the right size: $58\,360$ to 2 significant figures is $58\,000$, not 58.

Estimating a calculation

An estimate is a quick check that a calculator answer is about right, or a way to answer without a calculator. Round **every** number to 1 significant figure, then do the easier sum:

$$\frac{61.8 \times 4.13}{0.487} \approx \frac{60 \times 4}{0.5} = \frac{240}{0.5} = 480.$$

Dividing by 0.5 is the same as multiplying by 2. Dividing by 0.2 is multiplying by 5, and dividing by 0.1 is multiplying by 10.

Two traps: 1 significant figure of 96.4 is 100 (the 9 rounds up and carries), and 1 significant figure of 0.0381 is 0.04.

Is the estimate too big or too small? If you rounded the numbers you multiply **up**, the estimate is bigger than the exact answer. 48 items at $\$3.85$ each is about $50 \times 4 = 200$ dollars; both numbers were rounded up, so the real cost is **less** than $\$200$.

Rounding to a sensible accuracy

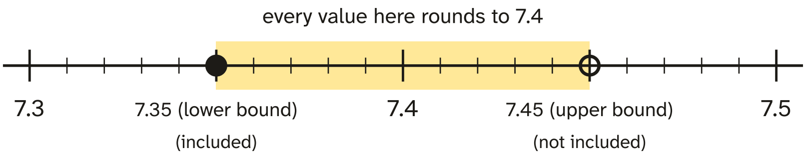
Round the answer to suit what it measures:

- **money**: to the nearest cent, so $\$100$ shared between 7 people is $\$14.29$ each ($100 \div 7 = 14.285\ldots$);
- **things you count** (people, buses, tins): a whole number, and think about which way. 250 students in buses that seat 48 need $250 \div 48 = 5.2\ldots$, so 6 buses, because 5 buses leave some students behind;

- **anything else**: the question's accuracy, or 3 significant figures if none is given (angles to 1 decimal place).

Bounds of a rounded value

A measurement written as 7.4 kg, correct to 1 decimal place, is not exactly 7.4 kg. It is any mass that **rounds to** 7.4. The smallest such mass is 7.35 (the **lower bound**). The largest is just below 7.45, because 7.45 itself would round up to 7.5. We still call 7.45 the **upper bound**.



So a value rounded to the nearest **unit** u lies within **half a unit** either side:

$$\text{lower bound} = \text{value} - \tfrac{1}{2}u, \qquad \text{upper bound} = \text{value} + \tfrac{1}{2}u.$$

The value is given as	The unit u	Half the unit	Bounds
7.4 kg, to 1 decimal place	0.1	0.05	$7.35 \leqslant m < 7.45$
2600 people, to the nearest 100	100	50	$2550 \leqslant n < 2650$
240 g, to the nearest 5 g	5	2.5	$237.5 \leqslant m < 242.5$
4.3 m, to the nearest 10 cm	0.1 m	0.05 m	$4.25 \leqslant l < 4.35$
3.62 m, to the nearest cm	0.01 m	0.005 m	$3.615 \leqslant l < 3.625$

Read the unit carefully. "To the nearest 10 cm" with an answer in metres means the unit is 0.1 m. "To the nearest 5 g" means the unit is 5, so half of it is 2.5.

The inequality uses $\leqslant$ at the lower bound (it is included) and $<$ at the upper bound (it is not).

Bounds of a calculation (Extended only)

When rounded values go into a calculation, the answer has bounds too. To find them, ask: **which bound of each value makes the answer as big (or as small) as possible?**

For example, $a = 9$ cm and $b = 4$ cm, each to the nearest cm, so $8.5 \leqslant a < 9.5$ and $3.5 \leqslant b < 4.5$:

Calculation	Upper bound uses	Upper bound	Lower bound uses	Lower bound
$a + b$	upper $+$ upper	$9.5 + 4.5 = 14$	lower $+$ lower	$8.5 + 3.5 = 12$
$a - b$	upper $-$ **lower**	$9.5 - 3.5 = 6$	lower $-$ **upper**	$8.5 - 4.5 = 4$

Calculation	Upper bound uses	Upper bound	Lower bound uses	Lower bound
$a \times b$	upper $\times$ upper	$9.5 \times 4.5 = 42.75$	lower $\times$ lower	$8.5 \times 3.5 = 29.75$
$a \div b$	upper $\div$ **lower**	$9.5 \div 3.5 = 2.714\ldots$	lower $\div$ **upper**	$8.5 \div 4.5 = 1.888\ldots$

Adding and multiplying are what you would expect. Subtracting and dividing **cross over**: to make a difference big, start big and take away as little as possible; to make a fraction big, make the top big and the bottom small.

Always put the bounds in **before** calculating. Working out $9 \times 4 = 36$ and then adding or taking away 0.5 gives nothing useful.

Key facts and formulas

None of these is in the List of formulas printed in the exam. The formula for a density, pressure or similar quantity is given in the question when you need it; speed $=$ distance $\div$ time is not.

Formula	Status
Round up if the next digit is 5 or more; leave it if it is 4 or less	Learn it
Significant figures start at the first non-zero digit	Learn it
Estimate: round every number to 1 significant figure, then calculate	Learn it
Bounds of a value rounded to the nearest u: value $\pm\frac{1}{2}u$, written lower $\leqslant x <$ upper	Learn it
(Extended) Upper bound of $a + b$ or $a \times b$: use both upper bounds	Learn it
(Extended) Upper bound of $a - b$: upper $a -$ lower b; lower bound: lower $a -$ upper b	Learn it
(Extended) Upper bound of $a \div b$: upper $a \div$ lower b; lower bound: lower $a \div$ upper b	Learn it
Speed $=$ distance $\div$ time	Learn it
Density $=$ mass $\div$ volume	Given in the question

How to do it

In the questions we have tagged for this topic (89 questions from Papers 1–4, 2021–2025, one of them printed on two papers), the types came up this often. 8 of the 89 questions mix two types, so the counts add up to more than 89.

Question type	Questions
Bounds of a rounded value	27
Bounds of a calculation (Extended)	25
Rounding to a given accuracy	23
Estimating by rounding to 1 significant figure	22

1. Bounds of a rounded value (27 questions)

Usually "Complete this statement about the value of m: $\ldots \leqslant m < \ldots$", worth 2 marks, one for each bound.

1. **Find the unit** the value was rounded to: the nearest 10, the nearest 0.1 (1 decimal place), the nearest 0.01 (2 decimal places or the nearest cm in metres), and so on.
2. **Halve it.**
3. **Take it away** for the lower bound and **add it** for the upper bound.
4. **Write them in order**: lower bound on the left, upper bound on the right.

For example, 3.9 kg correct to the nearest 100 g: 100 g $= 0.1$ kg, half is 0.05 kg, so $3.85 \leqslant m < 3.95$.

Variations you will meet:

- **A different unit in the accuracy**, such as a length in metres "correct to the nearest 10 centimetres" or a mass in kg "to the nearest 100 g". Change the unit to the one the value is in first.
- **Rounded to the nearest 5, 20 or 50**: half of 5 is 2.5, so 65 g to the nearest 5 g gives $62.5 \leqslant m < 67.5$.
- **Large counts**: 6300 to the nearest 100 gives $6250 \leqslant n < 6350$.
- **"Show that A may be more than B"** for two values rounded differently: write both sets of bounds and give one possible value of each that shows it (see Example 2).
- **Just one bound**, such as "find the lower bound of the mass": give the single number.

2. Bounds of a calculation, Extended only (25 questions)

1. **Write down both bounds of every rounded value.** Exact values (a count, "exactly 2 hours", the 6 sides of a hexagon) have no bounds.
2. **Choose the bound of each value** that makes the answer largest (for the upper bound) or smallest (for the lower bound). Use the table in "Understand it": subtraction and division cross over.
3. **Calculate** with those bounds, and give the full answer (or 3 significant figures).

For example, a block has mass 530 g, correct to the nearest 10 g, and volume 74 cm^3, correct to the nearest cm^3. Density $=$ mass $\div$ volume, so the lower bound of the density is

$$\frac{\text{lower mass}}{\text{upper volume}} = \frac{525}{74.5} = 7.046\ldots = 7.05\ \text{g/cm}^3\ (3\ \text{s.f.}).$$

Variations you will meet:

- **Perimeter and area** of rectangles and triangles: add or multiply the bounds of each side. A regular shape has one rounded side used several times: the lower bound of the perimeter of a regular pentagon with sides 13 cm, to the nearest cm, is $5 \times 12.5 = 62.5$ cm.
- **Speed $=$ distance $\div$ time**: the lower bound of a speed is lower distance $\div$ upper time. Times "to the nearest half hour" have bounds a **quarter** of an hour either side; times in minutes must be changed to hours (for km/h) by dividing by 60.
- **Density, or another formula** such as $I = \frac{V}{R}$: same rule, top and bottom cross over.
- **Working backwards from an area or a total**, such as the width of a rectangle from its area and length: width $=$ area $\div$ length, so the upper bound is upper area $\div$ lower length.
- **A length left over** after pieces are cut off: upper bound $=$ upper whole $-$ lower pieces.
- **The difference between two counts or times**: upper bound $=$ upper of the bigger $-$ lower of the smaller.
- **How many whole pieces or items**: find the bound, then think. The largest number of 1.4 m pieces (to the nearest 10 cm) from 30 m of rope (to the nearest metre) is $30.5 \div 1.35 = 22.5\ldots$, so 22 pieces: round **down**, as a part piece doesn't count. The number of tins needed "to be sure" uses the upper bound of the area, and rounds **up**.
- **An angle in a right-angled triangle**: $\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ is a division, so the smallest angle uses the lower opposite side and the upper hypotenuse.
- **A volume or a cube**: the upper bound of x^3 is (upper x)^3.
- **Answer in hours and minutes**: find the bound in hours, then multiply the decimal part by 60.

3. Rounding to a given accuracy (23 questions)

Usually 1 mark, often at the start of a longer Number question.

1. **Find the last digit you keep**: the hundreds digit for "nearest 100", the second digit after the point for "2 decimal places", the third significant figure for "3 significant figures".
2. **Look at the next digit** and round up if it is 5 or more.
3. **Fill with zeros** up to the decimal point so the number stays the same size, and keep any final zero that the accuracy needs.

For example, $50\,961$ to the nearest hundred is $51\,000$ (the 9 rounds up and carries); $0.006\,38$ to 2 significant figures is 0.0064; 12.0964 to 2 decimal places is 12.10.

Variations you will meet:

- **Two roundings of the same number**, such as the nearest 10 and the nearest 100: round from the **original** number each time, not from your first answer.
- **Decimal places and significant figures side by side**: 1 decimal place and 2 significant figures can give different answers (see Quick check 1).
- **"Explain why you cannot be certain" how a number was rounded**: several accuracies can give the same result. For example, 5300 could be 5283 rounded to the nearest 100, or 5304 rounded to the nearest 10.

- **Give a calculator answer to a set accuracy**, such as 3 decimal places: write the full display first, then round.

4. Estimating by rounding to 1 significant figure (22 questions)

Usually 2 marks: one for the rounded numbers, one for the answer. The question says "You must show all your working".

1. **Round every number to 1 significant figure** and write the new calculation down in full.
2. **Work it out without a calculator**: top and bottom separately, then divide.
3. **Give that value** as the estimate. Don't use a calculator on the original numbers.

For example,

$$\frac{19.6 + 31.2}{0.41 \times 5.2} \approx \frac{20 + 30}{0.4 \times 5} = \frac{50}{2} = 25.$$

Variations you will meet:

- **Numbers that round to a power of 10**, such as $9.6 \to 10$ or $0.96 \to 1$.
- **Decimals below 1 on the bottom**, such as $\div 0.2$: multiply by 5 instead.
- **A formula**, such as $b = dm + 2mk$: round each letter's value first, then substitute.
- **"Show that an estimate is $\ldots$"**: write every rounded number and the working that reaches the given answer.
- **"Is the estimate greater or less than the exact answer? Explain"**: say which numbers were rounded up or down and what that does. Rounding the numbers you multiply up makes the estimate too big.
- **A money estimate**, such as 61 tickets at $\$7.95$: $60 \times 8 = 480$ dollars.

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 $40\,582$ correct to the nearest thousand. **[1]**

(b) Write $0.070\,46$ correct to 3 significant figures. **[1]**

(c) By writing each number correct to 1 significant figure, find an estimate for the value of

$$\frac{83.7 \times 0.315}{0.0187}.$$

You must show all your working. **[2]**

(a) The thousands digit is 0 and the decider is 5, so round up: $41\,000$. **B1**

(b) The first significant figure is the 7. Keep 7, 0, 4; the decider is 6, so 0.0705. **B1**

(c) $83.7 \to 80$, $0.315 \to 0.3$ and $0.0187 \to 0.02$:

$$\frac{80 \times 0.3}{0.02}$$

M1 for all three rounded numbers written in the calculation.

$= \dfrac{24}{0.02} = 1200$. **A1**

(A calculator gives $1409.9\ldots$, so the estimate is close.)

Example 2

(a) The length, l metres, of a table is 1.64 m, correct to the nearest centimetre. Complete this statement about the value of l. **[2]**

$$\ldots\ldots \leqslant l < \ldots\ldots$$

(b) Box P has a mass of 260 kg, correct to the nearest 10 kg. Box Q has a mass of 257 kg, correct to the nearest kilogram. Show that box P may be lighter than box Q. **[2]**

(a) The nearest centimetre is the nearest 0.01 m, and half of that is 0.005 m.

$1.635 \leqslant l < 1.645$ **B1 B1** (one mark for each bound)

(b) P: $255 \leqslant P < 265$. Q: $256.5 \leqslant Q < 257.5$. **M1** for the lower bound of P or the bounds of Q.

P could be 255 kg and Q could be 257 kg, and $255 < 257$, so P may be lighter than Q. **A1**

Example 3 (Extended)

A cyclist rides 36 km, correct to the nearest kilometre. The ride takes 1.6 hours, correct to the nearest 0.1 hour.

(a) Calculate the lower bound of the cyclist's average speed. **[3]**

(b) Calculate the upper bound of the average speed. **[2]**

(a) Distance: $35.5 \leqslant d < 36.5$. Time: $1.55 \leqslant t < 1.65$. **B1** for one correct bound seen.

Speed $=$ distance $\div$ time, so the lower bound is lower distance $\div$ upper time: **M1**

$$\frac{35.5}{1.65} = 21.515\ldots = 21.5 \text{ km/h (3 s.f.)}.$$

A1

(b) Upper distance ÷ lower time: **M1**

$$\frac{36.5}{1.55} = 23.548\ldots = 23.5 \text{ km/h (3 s.f.)}.$$

A1

Example 4 (Extended)

A rectangular lawn measures 12.6 m by 8.3 m, both correct to 1 decimal place.

(a) Calculate the lower bound of the perimeter of the lawn. **[2]**

(b) Calculate the upper bound of the area of the lawn. **[2]**

(c) One box of grass seed covers exactly 25 m². Find the smallest number of boxes that must be bought to be sure of covering the whole lawn. **[2]**

(a) Lower bounds: 12.55 and 8.25. **M1** for either seen.

$2 \times (12.55 + 8.25) = 41.6$ m. **A1**

(b) Upper bounds: 12.65 and 8.35. **M1** for multiplying them.

$12.65 \times 8.35 = 105.6275$ m². **A1**

(c) To be **sure**, cover the largest possible area: $105.6275 \div 25 = 4.225\,1$. **M1**

4 boxes might not be enough, so 5 boxes. **A1**

Common mistakes

- **Truncating instead of rounding.** Examiners often see digits simply chopped off. 4.867 to 1 decimal place is 4.9, not 4.8: always look at the next digit.
- **Losing the place-holding zeros.** $73\,250$ to the nearest thousand is $73\,000$, not 73. Check your answer is about the same size as the number you started with.
- **Confusing decimal places with significant figures.** Read which one the question asks for; 0.4072 is 0.41 to 2 significant figures but 0.407 to 3 decimal places.
- **Estimating with a calculator.** Typing the exact numbers in and rounding the answer earns nothing: the mark is for the rounded numbers. Round **every** number first, and write them down.
- **Rounding to the wrong accuracy when estimating**, such as leaving 0.73 as it is or rounding it to 1, or writing trailing zeros like 5.0 or 20.0 (these are not 1 significant figure). $0.73 \to 0.7$.
- **Adding or taking away a whole unit, not half.** 5.8 to 1 decimal place gives $5.75 \leqslant x < 5.85$, not 5.7 to 5.9. Examiners report answers like 11.1 to 11.3 for a value of 11.2.

- **Using the wrong half for "nearest 5" or "nearest half hour".** 45 to the nearest 5 is 42.5 to 47.5, not 40 to 50. 3 hours to the nearest half hour is 2.75 to 3.25 hours, not 2.5 to 3.5.
- **Putting the bounds the wrong way round**, or writing the upper bound as something like 5.8499. The upper bound is 5.85, on the right of the inequality.
- **(Extended) Using two upper (or two lower) bounds in a subtraction or division.** Examiners see "upper − upper" every year. For a difference or a fraction, the bounds cross over.
- **(Extended) Calculating with the given values, then adjusting the answer.** $26 \div 4$ is 6.5; taking off 0.5 is not a bound. Put the bounds in first.
- **(Extended) Applying the bound after multiplying.** For 6 equal sides of 10 cm (to the nearest cm), the lower perimeter is $6 \times 9.5 = 57$, not $60 - 0.5$.
- **Rounding a count the wrong way.** "How many can be made" rounds down; "how many are needed" rounds up.

How to get the marks

- **"Complete this statement"**: each bound is a separate mark. Put the lower bound on the left. If you swap them you usually get only one mark for both.
- **"Correct to 2 decimal places"** (or significant figures): give exactly that many digits, including a final zero if the rounding ends in one.
- **"By writing each number correct to 1 significant figure"** and **"You must show all your working"**: the first mark is for seeing all the rounded numbers in the calculation. An answer without them, even if right, can score zero.
- **The estimate is the value of the rounded calculation**, worked out in full. The calculator value of the original numbers is not accepted.
- **(Extended) Show the bounds you use.** Most bounds questions give a method mark for one correct bound seen, such as the lower bound of a distance, even if the final answer is wrong. "nfww" (not from wrong working) means the right answer from the wrong bounds earns nothing.
- **(Extended) Final answer**: give the exact value if it is short, otherwise the full calculator value or 3 significant figures. Don't round the bounds themselves.
- **Context counts**: money to the nearest cent, whole items rounded the right way, and units in the answer.
- **"Explain" or "Show that"**: give the numbers **and** a short sentence that answers the question, naming one possible value of each quantity.

Quick check

1. Write 29.649 correct to (a) 1 decimal place, (b) 2 significant figures.
2. By writing each number correct to 1 significant figure, find an estimate for $\dfrac{9.12 \times 58.7}{3.06 + 1.84}$. Show your working.
3. The time, t seconds, for a race is 12.8 seconds, correct to 1 decimal place. Complete the statement $\ldots \leqslant t < \ldots$

4. (Extended) Two rods measure 7.2 cm and 4.6 cm, both correct to the nearest millimetre. Find the lower bound and the upper bound of the difference in their lengths.
5. (Extended) A tank holds 900 litres, correct to the nearest 50 litres. It is filled at 12 litres per minute, correct to the nearest litre per minute. Calculate the upper bound of the time it takes to fill the tank.

Answers

1. (a) Keep 29.6; the decider is 4, so 29.6. (b) Keep 29; the decider is 6, so 30.
2. $\dfrac{9 \times 60}{3+2} = \dfrac{540}{5} = 108$.
3. $12.75 \leqslant t < 12.85$.
4. The bounds are 7.15 to 7.25 and 4.55 to 4.65. Lower bound $= 7.15 - 4.65 = 2.5$ cm; upper bound $= 7.25 - 4.55 = 2.7$ cm.
5. Time $=$ volume $\div$ rate, so the upper bound is upper volume $\div$ lower rate $= 925 \div 11.5 = 80.434\ldots = 80.4$ minutes (3 s.f.).

Past questions to try

- **0580/12/M/J/25 Q22**: bounds of a mass in kg given to the nearest 100 g.
- **0580/13/M/J/25 Q13**: an estimate with a decimal less than 1 in the calculation.
- **0580/43/M/J/25 Q22**: the lower bound of a mass, then the upper bound of the density of a cube (Extended).
- **0580/41/M/J/25 Q22**: the upper bound of $I = \frac{V}{R}$, with V to the nearest 10 (Extended).