Cambridge (CIE) IGCSE Maths: Extended

Your notes

Rounding, Estimation & Bounds

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Rounding & estimation

How do I round a number to a given place value?

- Identify the **digit** in the **required place value**
- **Circle the number to the right** of the required place value
  - If the circled number is **5 or more** then you round to the **bigger number**
  - If the circled number is **less than 5** then you round to the **smaller number**
  - Put a **zero** in any **following place values before the decimal point**
    - E.g. 1567.45 to the nearest 100 would be 16**00**

How do I round a number to a given decimal place?

- Identify the **position** of the **decimal place** you are rounding to
- **Circle the number to the right** of the required decimal place
  - If the circled number is **5 or more** then you round to the **bigger number**
  - If the circled number is **less than 5** then you round to the **smaller number**
    - E.g. 2.435123 to the nearest 2 d.p. would be 2.44
- When rounding to decimal places make sure you leave your answer with the **required amount of decimal places**
  - Do not put any zeros **after** the position of the decimal place you are rounding to
    - E.g. 1267 to the nearest 100 is 13**00**
    - But 1.267 to two decimal places (nearest 100th) is 1.27 not 1.270
  - If asked for a **certain number of decimal places**, you must give an answer with that number of decimal places
    - E.g. 2.395 to two decimal places is 2.40 (do not write 2.4)

Worked Example

Round the following numbers to 2 decimal places.

(i) 345.254

(ii) 0.295 631

(iii) 4.998

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Answer:

(i)

Identify the second decimal place (5)
Circle the digit to the right of the second decimal place (4)

$$345.25\textcircled{4}$$

As this digit is less than 5 we will round the number down (the 5 stays as a 5)
No zeroes are required after the second decimal place

345.25 (2 d.p.)

(ii)

Identify the second decimal place (9)
Circle the digit to the right of the second decimal place (5)

$$0.29\textcircled{5}631$$

As this digit is greater than or equal to 5 we will round the number up

- The 9 increases by 1 to 10, which means that the 29 after the decimal point increases to 30

$$0.30$$

The zero at the end shows we have rounded to two decimal places

0.30 (2 d.p.)

(iii)

Identify the second decimal place (9)
Circle the digit to the right of the second decimal place (8)

$$4.99\textcircled{8}$$

As this digit is greater than or equal to 5 we will round the number up

- The 9 increases by 1 to 10, which means that the 4.99 increases to 5.00

$$5.00$$

The two zeroes show we have rounded to 2 decimal places

5.00 (2 d.p.)

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How do I round a number to a given significant figure?

- To find the **first significant figure** when reading from left to right, find the **biggest place value** that has a **non-zero digit**
  - The first significant figure of 3097 is 3
  - The first significant figure of 0.006207 is 6

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- The zeros **before** the 6 are **not** significant
- The zero **after** the 6 **is** significant

- Count along to the **right** from the first significant figure to **identify** the **position** of the **required significant figure**
  - **Do** count zeros that are between other non-zero digits
    - E.g. 0 **is** the **second** significant figure of 3<u>0</u>97
    - 9 is the **third** significant figure of 30<u>9</u>7
- Use the **normal rules for rounding**
- For **large numbers**, complete places **up to the decimal point** with **zeros**
  - E.g. 34 568 to 2 significant figures is 35 **000**
- For **decimals**, complete places **between** the **decimal point** and the **first significant figure** with **zeros**
  - E.g. 0.003 435 to 3 significant figures is **0.00**3 44

How do I know what degree of accuracy to give my answer to?

- If a question requires your answer to be an **exact value**
  - You can leave it as a **simplified fraction**
    - E.g. $\frac{5}{6}$
  - You can leave it in terms of π or a **square root**
    - E.g. 4π, or $\sqrt{3}$
  - If it is an **exact decimal** up to and including 5 s.f., you can write it out without rounding it
    - E.g. 0.9375, or 850.25
- If the answer is **not exact**, an exam question will often state the **required degree of accuracy** for an answer
  - E.g. Give your answer to 2 significant figures
- If the degree of accuracy is not asked for, use **3 significant figures**
  - All **working** and the **final answer** should show values correct to at least 4 significant figures
  - The final answer should then be **rounded** to 3 significant figures
- In **money calculations**, unless the required degree of accuracy is stated in the question, you can look at the **context**
  - Round to **2 decimal places**

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- E.g. £64.749214 will round to £64.75
- Or to the nearest whole number, if this seems sensible (for example, other values are whole numbers)
  - £246 029.8567 rounds to £246 030
- When calculating **angles**, all values should be given correctly to **1 decimal place**
  - An angle of 43.5789° will round to 43.6°
  - An angle of 135.211...° will round to 135.2°



Examiner Tips and Tricks

You should always write down the unrounded answer before rounding. Normally, you get the mark provided that your final answer is in a suitable range.

When might I need to estimate up or down?

- If a **real life scenario** is given, this may influence if you need to round **up or down**
- For example, if a class of 31 students requires at least 1 adult for every 10 children
  - 31 ÷ 10 = **3.1** adults are needed
  - 3 adults would not be enough, this would only be enough for 30 students
  - Therefore you would **round up**, to **4** adults
- Alternatively, consider a farmer filling crates that each hold 12 apples
  - How many crates can he fill if he has 50 apples?
    - 50 ÷ 12 = 4.16... crates will be filled
    - He cannot make a 5th full crate, as this would require 60 apples
    - Therefore, you would round down, to 4 crates



Examiner Tips and Tricks

In an exam question check that you have written your answer correctly by considering if the value you have ended up with makes sense.

Remember the importance of zeros to indicate place value.

E.g. Round 2 530 457 to 3 significant figures, 253 (without the zeros) and 2 530 000 are very different sizes!





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Worked Example

Round the following numbers to 3 significant figures.

(i) 345 256

(ii) 0.002 956 314

(iii) 3.997

Answer:

(i)

The first (non-zero) significant digit is in the hundred thousands column (3)
The third significant figure is therefore the value in the thousands column (5)

Circle the digit on the right of the third significant figure (2)

$$345\,\textcircled{2}56$$

This digit is less than 5 so round down (the 5 stays as a 5)

345 000 (3 s.f.)

(ii)

The first significant digit is in the thousandths column (2)
The third significant figure is therefore in the hundred thousandths column (5)

Circle the digit to the right of the third significant figure (6)

$$0.002\,95\textcircled{6}\,314$$

6 is greater than 5 so we need to round up (the 5 increases by 1 to 6)

0.002 96 (3 s.f.)

(iii)

The first significant digit is in the units column (3)
The third significant figure is therefore in the hundredths column (9)

Circle the digit to the right of the third significant figure (7)

$$3.99\textcircled{7}$$

This value is greater than 5 so it will round up

- The 9 increases by 1 to 10, which means that the 3.99 increases to 4.00

$$4.00$$

The two zeroes are needed to show that we have rounded to 3 significant figures

4.00 (3 s.f.)

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Why do I need to estimate?

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- **Estimation** can be used to find **approximations** for difficult calculations
- You can estimate a calculation to **check your answers**
  - You can identify if there is a mistake in your working out if your answer is much bigger or smaller than your estimated value



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How do I estimate?

- **Round** each number in the question to a sensible degree, then perform the **calculation**
  - The exam question will usually tell you what to round each number to before carrying out any calculations
- The **general rule** is to round numbers to **1 significant figure**
  - $7.8 \rightarrow 8$
  - $18 \rightarrow 20$
  - $3.65 \times 10^{-4} \rightarrow 4 \times 10^{-4}$
  - $1080 \rightarrow 1000$
- In certain cases it may be more **sensible** (or easier) to round to something convenient
  - $16.2 \rightarrow 15$
  - $9.1 \rightarrow 10$
  - $1180 \rightarrow 1200$
- **Avoid** rounding values to **zero**

How do I know if I have underestimated or overestimated?

- For **addition** $a + b$ and **multiplication** $a \times b$

a (rounded **up**) and/or ***b*** (rounded **up**)	Overestimate
a (rounded **down**) and/or ***b*** (rounded **down**)	Underestimate

- For **subtraction** $a - b$ and **division** $a \div b$

a (rounded **up**) and/or ***b*** (rounded **down**)	Overestimate
a (rounded **down**) and/or ***b*** (rounded **up**)	Underestimate
a (rounded **up**) and ***b*** (rounded **up**)	Not easy to tell
a (rounded **down**) and ***b*** (rounded **down**)	Not easy to tell

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Examiner Tips and Tricks

Estimation exam questions often involve small decimals.

Avoid rounding to 0, especially if the small decimal is the denominator of a fraction, as dividing by 0 is undefined.

Worked Example

Calculate an **estimate** for $\frac{17.3 \times 3.81}{11.5}$.

State, with a reason, whether the estimate is an overestimate or an underestimate.

Answer:

Round each number to 1 significant figure

$$17.3 \rightarrow 20$$
$$3.81 \rightarrow 4$$
$$11.5 \rightarrow 10$$

Perform the calculation with the rounded numbers

$$\frac{20 \times 4}{10} = \frac{80}{10} = 8$$

An estimate is 8

This is an overestimate as the numerator was rounded up and the denominator was rounded down

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Bounds & error intervals

What are bounds?

- **Bounds** are the values that a **rounded number** can lie between
  - The **smallest value** that a number can take is the **lower bound (LB)**
  - The **largest value** that a number must be less than is the **upper bound (UB)**
- The bounds for a number, x, can be written as $\text{LB} \leq x < \text{UB}$
  - Note that the **lower bound** is **included** in the range of values x but the **upper bound is not**

How do I find the upper and lower bounds for a rounded number?

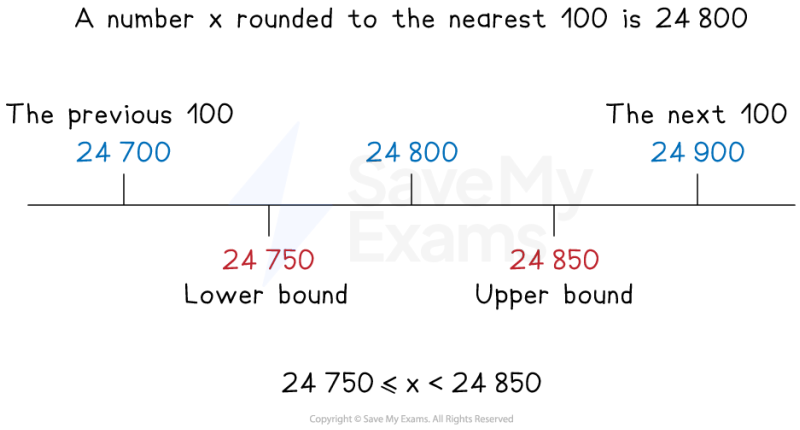
- Identify the **degree of accuracy** to which the number has been **rounded**
  - E.g. 24 800 has been rounded correct to the nearest 100
- **Divide** the degree of accuracy by **2**
  - E.g. If an answer has been rounded to the nearest 100, half the value is 50
- **Add** this value to the number to find the **upper bound**
  - E.g. 24 800 + 50 = 24 850
- **Subtract** this value from the number to find the **lower bound**
  - E.g. 24 800 - 50 = 24 750
- The **error interval** is the range between the upper and lower bounds
  - Error interval: **LB ≤ x < UB**
  - E.g. 24 750 ≤ 24 800 < 24 850

Examiner Tips and Tricks

It can help to draw a number line. Identify the numbers with the same accuracy that come immediately before and after the rounded number.

- The lower bound is the midpoint between the rounded number and the previous number at that accuracy
- The upper bound is the midpoint between the rounded number and the next number at that accuracy

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Worked Example

The length of a road, l, is given as $l = 3.6$ km, correct to 1 decimal place.

Find the lower and upper bounds for l.

Answer:

The degree of accuracy is 1 decimal place, or 0.1 km
Divide this value by 2

$$0.1 \div 2 = 0.05$$

The true value could be up to 0.05 km above or below the given value

Upper bound: 3.6 + 0.05 = 3.65 km

Lower bound: 3.6 - 0.05 = 3.55 km

Upper bound: 3.65 km
Lower bound: 3.55 km

This could also be written as $3.55 \leq l < 3.65$

Calculations using bounds

How do I find the bounds of a calculation?

- To find the **upper bound** of a calculation, consider how the result can be made as **large as possible**
- To find the **lower bound** of a calculation, consider how the result can be made as **small as possible**
- E.g. For an addition, $a + b$
  - The **upper** bound will be when both a and b are at their upper bounds

- The **lower** bound will be when both a and b are at their lower bounds
- Sometimes you need **different bounds** in the same question
  - The upper bound of $\frac{a}{b}$ is the upper bound of a divided by the lower bound of b
    - **Increasing** the **numerator** makes the fraction **bigger**, $\frac{2}{1} < \frac{3}{1} < \frac{4}{1} < \ldots$
    - But **increasing** the **denominator** make the fraction **smaller**, $\frac{1}{2} > \frac{1}{3} > \frac{1}{4} > \ldots$
- How to find the upper and lower bound for each operation is summarised in the table below

	Upper Bound	Lower Bound
$a+b$	Upper + Upper	Lower + Lower
$a-b$	Upper - Lower	Lower - Upper
$a \times b$	Upper × Upper	Lower × Lower
$\frac{a}{b}$	Upper ÷ Lower	Lower ÷ Upper

- You will need to use **more than one** of these if the expression includes **multiple operations**
  - E.g. consider the upper bound for $\frac{a}{b-c}$
    - You need the upper bound for a and lower bound for $b-c$
    - This means you need the upper bound for b and lower bound for c
  - E.g. consider the lower bound for $\frac{a}{b}-c$
    - You need the lower bound for $\frac{a}{b}$ and upper bound for c
    - This means you need the lower bound for a and upper bound for b

How do I use upper and lower bounds in contexts?

- Questions often give real-life **contexts** and ask about bounds

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- For example
  - To see if two cars will fit on the back of a truck
  - Use the upper bounds of the lengths of the two cars
  - This is like finding the upper bound of $a + b$
- For example
  - To find the minimum speed (speed = distance ÷ time)
  - Divide the lower bound of the distance by the upper bound of the time
  - This is like finding the lower bound of $\frac{a}{b}$



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How can bounds help with calculations?

- You can use bounds to determine the **level of accuracy** of a calculation
  - E.g. If a value has a lower bound of 8.33217... and upper bound of s 8.33198...
    - The true value is between 8.33217... and 8.33198...
  - Find the level of accuracy for which **both bounds** round to the **same number**
    - This happens at 4 sf (rounding to 8.332)
    - To 5 sf they are different (lower is 8.3322 and upper is 8.3320)
  - Therefore you know the original value rounds to 8.332 to 4 significant figures



Worked Example

A room measures 4 m by 7 m, where each measurement is made to the nearest metre.

Find the upper and lower bounds for the area of the room.

Answer:

Find the bounds for each dimension, you could write these as error intervals, or just write down the upper and lower bounds

As they have been rounded to the nearest metre, the true values could be up to 0.5 m bigger or smaller

$$3.5 \leq 4 < 4.5$$
$$6.5 \leq 7 < 7.5$$

Calculate the lower bound of the area, using the two smallest measurements

$$3.5 \times 6.5$$

Lower Bound = 22.75 m^2

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Calculate the upper bound of the area, using the two largest measurements

4.5×7.5

Upper Bound = 33.75 m^2



Worked Example

David is trying to work out how many fencing panels he needs to buy in order to construct a fence along one side of his garden path.

Fencing panels are 50 cm long, measured to the nearest 10 cm.

The length of the path is 6 m, measured to the nearest 10 cm.

Find the minimum number of fencing panels David will need to buy.

Answer:

Find the bounds for each measurement

As they have been rounded to the nearest 10 cm, the true values could be up to 5 cm bigger or smaller

Change quantities into the same units

Length of the fencing panels: $45 \leq 50 < 55$ cm
or in metres: $0.45 \leq 0.5 < 0.55$ m

Length of the path: $5.95 \leq 6 < 6.05$ m

The minimum number of fencing panels needed will be when the path is as short as possible (5.95 m), and the panels are as long as possible (0.55 m)

$$\text{Minimum number of fencing panels} = \frac{5.95}{0.55} = 10.8181...$$

Assuming we can only purchase a whole number of fencing panels, round up to nearest integer

The minimum number of fencing panels to be bought is 11



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