

Determining significant figures

When you read a measurement that someone has written using the significant figures convention, you can tell how precisely that measurement was made.

$$1.47\text{(3)} \text{ g} \pm 0.001$$

This was measured to the nearest +/- 0.001 g
The last digit is always UNCERTAIN (or estimated)

$$2\text{(1)} \text{ m} \pm 1$$

$$37.2\text{(6)} \text{ kg} \pm 0.01$$

Some other examples

$$3.207\text{(6)} \text{ g} \pm 0.0001 \text{ g}$$

$$27.\text{(3)} \text{ m} \pm 0.1 \text{ m}$$

A small problem

The number ZERO has several uses. It may be a measured number, but it may also be a mere "placeholder" that wasn't measured at all!

So how do we tell a measured zero from a placeholder? There are a few ways:

1: BEGINNING ZEROS: Beginning zeros are NEVER considered significant.

0.15 g

• 15 g
↑

This zero merely indicates that there is a decimal point coming up!

0.015 m (1.5 cm)

These zeros are placeholders. They'll disappear if you change the UNITS of this number!

0.00063 mm

None of these zeros are considered significant

2: END ZEROS are sometimes considered significant. They are significant if

- there is a WRITTEN decimal point in the number
- there is another written indicator that the zero is significant. Usually this is a line drawn over or under the last zero that is significant!

$1.50 \text{ km} \pm 0.01 \text{ km}$

This zero IS considered significant. There's a written decimal.

$1500 \text{ m} \pm 100 \text{ m}$

These zeros ARE NOT considered significant (no written decimal, and no other indication that the zeros are significant)

$143\bar{0}00 \text{ g} \pm 100 \text{ g}$

These zeros are not significant.

This zero IS significant. It's marked.

How many significant figures are there in each of these measurements?

76.070 g (± 0.001 g)
5

85000. mm
5 decimal point

0.001030 kg
4

156.0002 g
7

0.10 s
2

17000000 mg
2
(± 1000000 mg)

120000 km (± 100 km)
4

1350 ms (± 10 ms)
3
... not ± 1 ms

Calculations with measurements

When you calculate something using measured numbers, you should try to make sure the ANSWER reflects the quality of the data used to make the calculation.

An ANSWER is only as good as the POOREST measurement that went into finding that answer!

$$\begin{array}{r}
 14.206 \\
 154.72 \\
 + 1.6 \\
 + 0.222 \\
 \hline
 170.748
 \end{array}$$

How should we report this answer? How much uncertainty is in this answer?

$$\boxed{170.7} \quad (\pm 0.1)$$

- * If you add an uncertain number to either a certain or an uncertain number, then the result is uncertain!
- * If you add certain numbers together, the result is certain!

For addition and subtraction, round FINAL ANSWERS to the same number of decimal places as the measurement with the fewest decimal places. This will give an answer that indicates the proper amount of uncertainty.

For multiplication and division, round FINAL ANSWERS to the same number of SIGNIFICANT FIGURES as the measurement with the fewest SIGNIFICANT FIGURES!

$$\overset{4}{\underline{15.62}} \times \overset{3}{\underline{0.0667}} \times \overset{3}{\underline{35.0}} = 36.46489$$

How should we report this answer?

36.5

$$\overset{3}{\underline{25.4}} \times \overset{2}{\underline{0.00023}} \times \overset{5}{\underline{15.201}} = 0.088804242$$

How should we report this answer?

0.089

Round to TWO significant figures. The first two zeroes are beginning zeroes and are not considered significant. The first significant digit is the first "8" ...

A few more math with significant figures examples:

$$\overset{5}{15047} \times \overset{2}{11} \times \overset{4}{0.9876} = 163464.5892$$

~~16~~

160000

1.6×10^5

Placeholder zeros, even though they aren't SIGNIFICANT, still need to be included, so we know how big the number is!

Addition:

$$\begin{array}{r} 147.3 \\ 2432 \\ 0.97 \\ + 111.6 \\ \hline 2691.87 \end{array}$$

2692

DENSITY
CALCULATION

$$\begin{array}{r} \overset{6}{14.7068} \text{ g} \\ \hline 2.7 \text{ mL} \\ \hline \end{array}$$

$$= 5.446962963 \text{ g/mL}$$

5.4 g/mL

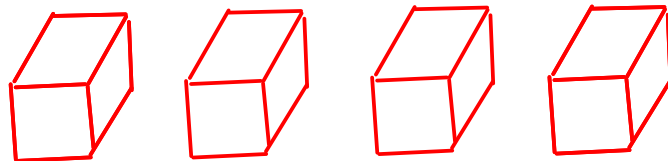
To improve the precision of this density measurement, we would have to improve the precision of the volume measurement - which has only two significant figures.

(If we improve the precision of the mass measurement, it won't affect the precision of the answer at all!)

Exact Numbers

- Some numbers do not have any uncertainty. In other words, they weren't measured!

1) Numbers that were determined by COUNTING!



How many blocks are to the left?

exactly 4

2) Numbers that arise from DEFINITIONS, often involving relationships between units

$$12 \text{ in} = 1 \text{ ft}$$

$$\text{km} = 10^3 \text{ m}$$

* All metric prefixes are exact!

- Treat exact numbers as if they have INFINITE significant figures or decimal places!

Example

You'll need to round the answer to the right number of significant figures!

Convert 4.45 m to in, assuming that $2.54 \text{ cm} = 1 \text{ in}$

EXACT!

$$2.54 \text{ cm} = 1 \text{ in} \quad 1 \text{ cm} = 10^{-2} \text{ m}$$

$$4.45 \text{ m} \times \frac{1 \text{ cm}}{10^{-2} \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 175.1968504 \text{ in}$$

$$= \boxed{175 \text{ in}}$$

Significant figures analysis:
 - 4.45 m: 3 significant figures (indicated by an upward arrow and the number 3)
 - 10^{-2} m : infinite significant figures (indicated by an upward arrow and the symbol ∞)
 - 2.54 cm: infinite significant figures (indicated by an upward arrow and the symbol ∞)

Usually, in unit conversions the answer will have the same number of significant figures as the original measurement did.

EXCEPTION: Temperature conversions, since these often involve ADDITION (different rule!)

A note on rounding: If possible, try to round only at the END of a multiple-step calculations. Avoid rounding intermediate numbers if possible, since extra rounding introduces ERROR into your calculations.