# 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!

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

Round so that there's only one uncertain digit in the answer!

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

**170.7**

- 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!

4 3 3

$15.62 \times 0.0667 \times 35.0 = 36.46489$

How should we report this answer?

36.5

3 2 5

$25.4 \times 0.00023 \times 15.201 = 0.088804242$

How should we report this answer?

0.089

# A few more math with significant figures examples:

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

~~16~~

160000

$(1.6 \times 10^5)$

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

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

2692

DENSITY CALCULATION

$$\frac{14.7068\ g}{2.7\ mL}$$

(6 sig figs / 2 sig figs)

$$= 5.446962963\ g/mL$$

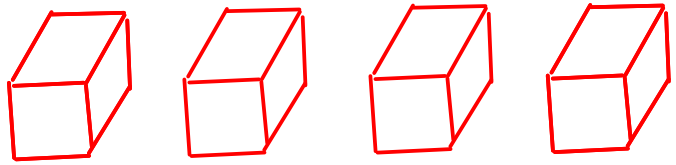
5.4 g/mL

To improve (make more precise) this calculated density, we must improve the poorest measurement. We must use a more precise device to measure the VOLUME (which only has two significant figures in this example)!

# 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

$12\ in = 1\ ft$

$Km = 10^3\ m$

*All metric prefixes are exact!

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

# 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 cm = 1 in *

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

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

3 ← 4.45 m; ∞ ← $10^{-2}$ m; ∞ ← 2.54 cm

Round the answer so that it has three SIGNIFICANT FIGURES, just like you do with any other multiplication/division using measurements!

$= \boxed{175\ in}$

*An inch is defined as EXACTLY 2.54 cm !

When merely converting the units of a measurement, you almost always have the same number of significant figures in the answer as you did in the original measurement. (EXCEPTION: Temperature conversions, since they involve addition and subtraction)

# Scientific Notation

-a way to represent large and small numbers

-a way to indicate significant figures

Form:

$a.aaa\ldots \times 10^{a}$

(always ONE nonzero digit before the decimal)

$3.6 \times 10^{4}$

means

$3.6 \times 10 \times 10 \times 10 \times 10$

OR

36000

$6.21 \times 10^{-3}$

means

$6.21 \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10}$

OR

0.00621

Scientific notation removes the need for placeholder zeros, and that's good when you're dealing with very large and very small numbers!

$4.70 \times 10^{-6} = 0.00000470$

Scientific notation indicates significant figures without extra decimal points or lines. All numbers in front of the power of ten are significant!

$3700 = 3.70 \times 10^{3}$

To write a number in scientific notation, move the decimal point so that it is behind the first nonzero number. The power of ten will be the number of places you moved the decimal. If the number is less than 1, the power of ten is negative. If it's greater than one, the power of ten is positive.

$0.00765$ (3)

$7.65 \times 10^{-3}$

$14000$ (4)

$1.4000 \times 10^{4}$

$6.38 \times 10^{5}$

6.3800000000 ← Big number!

638000

$4.20 \times 10^{-6}$

0.000004.20 ← Small number!

0.00000420

Using scientific notation on a calculator:

$6.38 \times 10^{5}$

on a TI-8x:

enter

6.38 [EE] 5

calculator displays:

6.38 E 5

this E means "x10 raised to"

$4.20 \times 10^{-6}$

enter:

4.20 [EE] [(-)] 6

calculator displays:

4.2 E⁻6

means "$\times 10^{-6}$"