

Converting from one unit to another

We will use the method of dimensional analysis, sometimes called the factor-label method.
... or, the "drag and drop" method!

Dimensional analysis uses conversion factors to change between one unit and another

What's a conversion factor? A simple equality.

Example

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

Conversion factors in metric

In the metric system, conversion factors between units may always be made from the metric prefixes!

For example, "kilo-" means 10^3

$$k = 10^3$$

so

$$k m = 10^3 m$$

$$k L = 10^3 L$$

$$k g = 10^3 g$$

$$k s = 10^3 s$$

Just apply the prefix to the base unit!

How do we actually USE a conversion factor?

Convert 15.75 m to cm

$$15.75 \cancel{\text{m}} \times \frac{\text{cm}}{10^{-2} \cancel{\text{m}}} = 1575 \text{ cm}$$

$\text{cm} = 10^{-2} \text{ m}$

* Similar to...

If $X = 2$, then

$$\frac{X}{2} = 1$$

$15.75 / \boxed{\text{EE}}^{-2}$.. on TI-83

* This fraction equals one, so multiplying by it does not change the VALUE of the number, only its UNITS!

Convert 0.01893 kg to g

$$\text{kg} = 10^3 \text{ g}$$

$$0.01893 \cancel{\text{kg}} \times \frac{10^3 \text{ g}}{\cancel{\text{kg}}} = 18.93 \text{ g}$$

DRAG AND DROP

- Drag the part of the factor that you want to cancel out to the BOTTOM.

- Then, drag the other half of the factor to the TOP

Convert 14500 mg to kg $\text{mg} = 10^{-3} \text{g}$ $\text{kg} = 10^3 \text{g}$

$$14500 \text{ mg} \times \frac{10^{-3} \text{ g}}{\text{mg}} \times \frac{\text{kg}}{10^3 \text{ g}} = \boxed{0.0145 \text{ kg}}$$

Convert 0.147 cm² to m² $\text{cm} = 10^{-2} \text{m}$

$$0.147 \text{ cm}^2 \times \frac{10^{-2} \text{ m}}{\text{cm}} \times \frac{10^{-2} \text{ m}}{\text{cm}} = \boxed{1.47 \times 10^{-5} \text{ m}^2}$$

0.0000147 m^2

For squared units, we have to convert BOTH PARTS of the squared unit, so we must use each conversion factor TWICE. It makes sense when you remember what a squared unit is:

$$\text{cm}^2 = \underline{\text{cm}} \times \underline{\text{cm}}$$

For CUBED units, use each factor THREE times!

8.45 kg to μg kg = 10³g μg = 10⁻⁶g

$$8.45 \cancel{\text{kg}} \times \frac{10^3 \cancel{\text{g}}}{\cancel{\text{kg}}} \times \frac{\mu\text{g}}{10^{-6} \cancel{\text{g}}} = \boxed{8450000000 \mu\text{g}}$$

$8.45 \times 10^9 \mu\text{g}$

88100 kHz to MHz kHz = 10³Hz

MHz = 10⁶Hz

Hz = 1/s (frequency)

$$88100 \cancel{\text{kHz}} \times \frac{10^3 \cancel{\text{Hz}}}{\cancel{\text{kHz}}} \times \frac{\text{MHz}}{10^6 \cancel{\text{Hz}}} = \boxed{88.1 \text{ MHz}}$$

Convert 38.47 in to m, assuming 2.54 cm = 1 in

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

$$38.47 \cancel{\text{ in}} \times \frac{2.54 \cancel{\text{ cm}}}{\cancel{\text{ in}}} \times \frac{10^{-2} \cancel{\text{ m}}}{\cancel{\text{ cm}}} = \boxed{0.97771 \text{ m}}$$

Convert 12.48 km to in

$$2.54 \text{ cm} = 1 \text{ in} \quad \text{cm} = 10^{-2} \text{ m} \quad \text{km} = 10^3 \text{ m}$$

$$12.48 \cancel{\text{ km}} \times \frac{10^3 \cancel{\text{ m}}}{\cancel{\text{ km}}} \times \frac{\cancel{\text{ cm}}}{10^{-2} \cancel{\text{ m}}} \times \frac{\text{in}}{2.54 \cancel{\text{ cm}}} = \boxed{491300 \text{ in}}$$

Accuracy and Precision

- two related concepts that you must understand when working with measured numbers!

Accuracy

- how close a measured number is to the CORRECT (or "true") value of what you are measuring
- "Is it right?"
- checked by comparing measurements against a STANDARD (a substance or object with known properties)

Precision

- how close a SET of measured numbers are to EACH OTHER
- "Can I reproduce this?"
- checked by repeated measurements

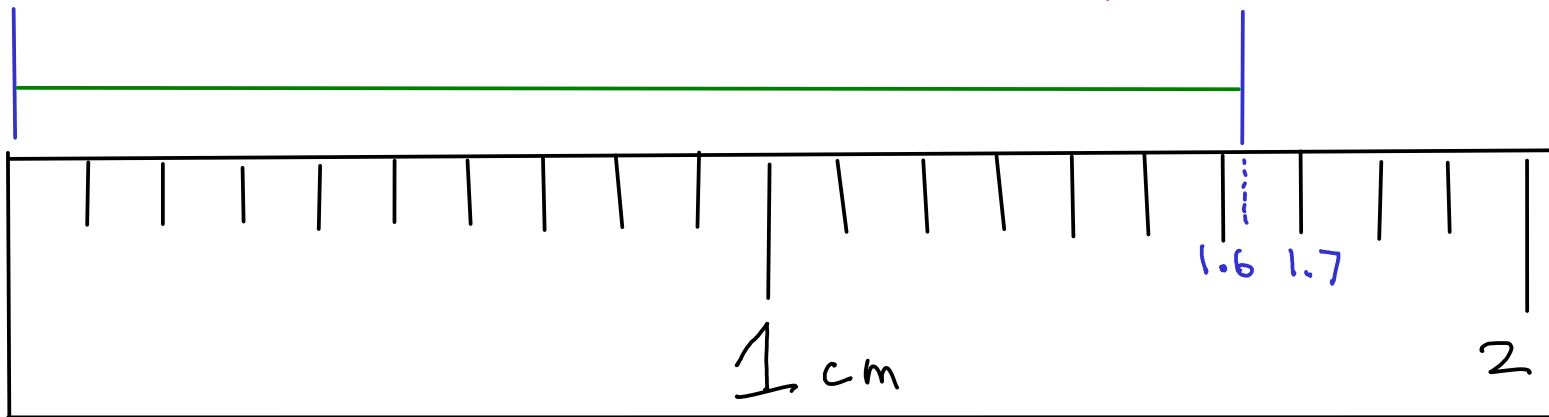
More on precision

Every measurement contains some amount of ERROR, or some amount of deviation from the true value of what is being measured.

RANDOM ERROR is the variability in a measurement that cannot be traced back to a single cause. Random errors cause measurements to fluctuate around the true value, but can be averaged out given enough measurements.

When reporting measurements, we want to indicate how much random error we think is present. How?

Write your measurements in this form: $X.XX$ cm



How long is the green line?

Write your answer on the card, then pass the card up to the front!

Our classroom experiment: Results

After throwing away obvious mistakes in reading the scale, we had:

Value	# students
1.61	1
1.62	11
1.63	13

25 measurements

Overall average

$$\bar{x} = 1.6248 \text{ cm (unrounded)}$$

$$= \underbrace{1.62}_{\text{CERTAIN DIGITS}} \pm \underbrace{0.01}_{\text{UNCERTAIN DIGITS}} \text{ cm}$$

CERTAIN DIGITS: Appear in nearly all repeats of the measurement

UNCERTAIN DIGITS: Vary.. Variation caused by estimation or other sources of random error.

When reading measurements from a scale, record all CERTAIN digits and one UNCERTAIN (or estimated) digit.

When using a digital device, record all the displayed digits.

Significant figures


SIGNIFICANT FIGURES are a way to indicate the amount of uncertainty in a measurement.

The significant figures in a measurement are all of the CERTAIN DIGITS plus one and only one UNCERTAIN (or estimated) DIGIT

Example:

From our classroom experiment,

1.62 cm



We estimated the last digit, It's uncertain

These digits were obtained in all measurements. They are certain

THIS MEASUREMENT HAS "THREE SIGNIFICANT FIGURES"!

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

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

uncertain digits!

$$27.3 \text{ m} \pm 0.1 \text{ m}$$

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
5

85000. mm (± 1 mm)
5 decimal point

0.001030 kg
4

156.0002 g
7

0.10 s
2

17000000 mg
2

120000 km (± 100 km) 1350 ms (± 10 ms)
4 3