# How do we actually USE a conversion factor?

Convert 15.75 m to cm

$cm = 10^{-2} m$

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

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

* Similar to...

If X = 2, then

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

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

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Convert 0.01893 kg to g

$Kg = 10^{3} g$

$$0.01893\,K\cancel{g} \times \frac{10^{3}\,g}{K\cancel{g}} = \boxed{18.93\ g}$$

DRAG AND DROP

- Drag the part of the factor that contains the unit you want to get rid of (cancel out) to the BOTTOM.

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

Convert 14500 mg to kg

$mg = 10^{-3} g \qquad Kg = 10^{3} g$

$$14500\,m\cancel{g} \times \frac{10^{-3}\,\cancel{g}}{m\cancel{g}} \times \frac{Kg}{10^{3}\,\cancel{g}} = \boxed{0.0145\ Kg}$$

Convert 0.147 $cm^2$ to $m^2$

$cm = 10^{-2} m$

$$0.147\,c\cancel{m}^{\cancel{2}} \times \frac{10^{-2}\,m}{c\cancel{m}} \times \frac{10^{-2}\,m}{c\cancel{m}} = \boxed{1.47 \times 10^{-5}\ m^2}$$

$(0.0000147\ m^2)$

Tip: When making conversion factors with prefixes, you can only use units WITHOUT their own exponents!

To handle squared or cubed units, apply each factor two (squared) or three (cubed) times. It makes sense if you remember:

$cm^2 = cm \cdot cm \qquad cm^3 = cm \cdot cm \cdot cm$

8.45 kg to $\mu g$

$kg = 10^3 g$ $\quad$ $\mu g = 10^{-6} g$

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

$(8.45 \times 10^9\ \mu g)$

88100 kHz to MHz

$\boxed{Hz = s^{-1}\ (\text{frequency})}$

$kHz = 10^3 Hz$

$MHz = 10^6 Hz$

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

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

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

$$38.47\,\cancel{in} \times \frac{2.54\,\cancel{cm}}{1\,\cancel{in}} \times \frac{10^{-2}\,m}{\cancel{cm}} = \boxed{0.9771\,m}$$

Convert 12.48 km to in

$2.54\, cm = in \qquad cm = 10^{-2} m \qquad Km = 10^{3} m$

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

# 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

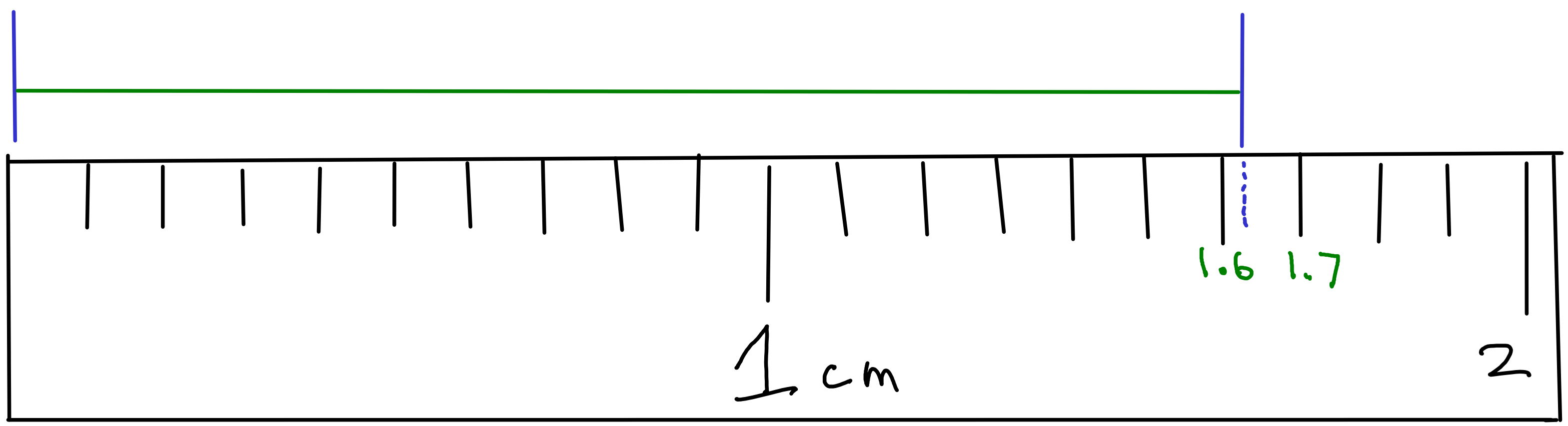
# More on precison

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?

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 | 7 |
| 1.63 | 8 |
| | |
| | |

16 measurements

Overall average

$\bar{x} = 1.624375$ cm (unrounded)

$= \underbrace{1.6}\underbrace{2}$ cm ($\pm$ 0.01 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 is a THREE SIGNIFICANT FIGURE average!

# 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.

1.473 g ± 0.001

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

21 m ± 1

37.26 kg ± 0.01

Some other examples

3.2076 g (± 0.0001 g)

27.3 m (± 0.1 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.

$0.\boxed{15}\ g$ $\quad .15\ g$

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

$0.0\boxed{15}\ m$ $\quad (1.5\ cm)$

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

$0.000\boxed{63}\ mm$

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!

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

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

$\boxed{15}00$ m $\pm$ 100 m

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

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

These zeros are not significant.

This zero IS significant. It's marked.

25

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

76.070 g (±0.001g)

5

85000. mm

5

decimal point

0.001030 kg

4

156.0002 g (±0.0001g)

7

0.10 s

2

17000000 mg (±1000000mg)

2

120000 km (±100km)

4

1350 ms

3

# 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!

$$
\begin{array}{rl}
14.20\underline{6} & \pm 0.001 \\
154.7\underline{2} & \pm 0.01 \\
1.\underline{6} & \pm 0.1 \\
+\quad 0.22\underline{2} & \pm 0.001 \\
\hline
170.748 &
\end{array}
$$

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

$\boxed{170.7}$

* 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!

$$\underbrace{15.62}_{4} \times 0.\underbrace{0667}_{3} \times \underbrace{35.0}_{3} \approx 36.46489$$

How should we report this answer?

$$\boxed{36.5}$$

$$\underbrace{25.4}_{3} \times 0.000\underbrace{23}_{2} \times \underbrace{15.201}_{5} \approx 0.088804242$$

How should we report this answer?

$$\boxed{0.089}$$

Note: Leading zeros are not significant, so our first significant digit is the leftmost "8"!