# Maths skills – M0.1 Recognise and make use of appropriate units in calculations

### Tutorials

Learners may be tested on their ability to:

* convert between units e.g. mm3 to cm3 as part of volumetric calculations
* work out the unit for a rate e.g. breathing rate.

### Units

Units indicate what a given quantity is measured in. Generally, a measured quantity without units is meaningless, although there are some exceptions, like pH for example.

In an exam, you would be expected to be able to convert between different metric units, such as between mm and cm without being given the information about how many mm there are in a cm.

Converting between units involves multiplying or dividing by an appropriate factor. The factor is determined by how many of one unit there are in the other unit. For example, there are 1000 m in a km, so in this case, converting between metres and km your conversion factor would be 1000.

If your measurement is getting larger, for example from mm to m, then you need to divide by your factor. If your measurement is getting smaller, for example from m to mm then you need to multiply by your factor.

Just remember that if the unit gets bigger the number should get smaller, and if the unit gets smaller then the number should get bigger.

For example, say we are converting 7 µm to mm. There are 1000 µm in one mm, so the conversion factor is 1000 or 103.

As the measurement is getting larger, you divide your number by the factor.

Therefore, we divide 7 µm by 103 which equals 0.007 mm which in standard form (see section M0.2 for this) is 7 x 10-3 mm.

Let’s look at units of length you may encounter and how they relate to the metre.

We have kilometres which are 1000 m, decimetres are a tenth of a metre, centimetres a hundredth, millimetres a thousandth of a metre, micrometres are 10-6 metres and nanometres are 10-9 metres.

| **Units of length** | **Abbreviation** | **Number of metres** | |
| --- | --- | --- | --- |
| **kilometre** | km | 1000 m | 103 m |
| **metre** | m | m | m |
| **decimetre** | dm | 1/10 m | 10-1 m |
| **centimetre** | cm | 1/100 m | 10-2 m |
| **millimetre** | mm | 1/1000 m | 10-3 m |
| **micrometre** | μm | 1/1000000 m | 10-6 m |
| **nanometre** | nm | 1/1000000000 m | 10-9 m |

These units of length are also used when dealing with area and volume.

Area is expressed as length squared, such as square centimetres.

You may need to work out how many square centimetres there are in a square metre. There are 100 cm in a metre, so if you were to convert cm to metres the conversion factor would be 100. But you are dealing with squares, so there are 100 **times** 100 cm2 in a m2. So here your conversion factor would be 100 times 100, which is 10,000, or 104.

So 4 m2 expressed in square centimetres would be 4 x 10,000 cm2. Remember that here the units are getting smaller – metres to centimetres – so the number gets bigger – you multiply by your factor.

Likewise, volume is expressed as length cubed.

So 4 m3 expressed in cm3 would have a conversion factor of 100 x 100 x 100, which is 106. So there are 106 cm3 in one m3 and 4 m3 expressed in cm3 would be 4 x 106 cm3.

The main units of volume are mm3, cm3 and dm3. However, if we are dealing with liquids we often use the unit 'litre' (*l*) instead. Here are the more commonly used units of volume for liquids. Note that a litre is equivalent to dm3 and a millilitre is equivalent to cm3.

| **Units of volume** | **Abbreviation** | **How it relates to the litre** | | **Equivalence in length measurements** |
| --- | --- | --- | --- | --- |
| **litre** | *l* | *l* | *l* | dm3 |
| **millilitre** | m*l* | 10-3 *l* | 1/1000 *l* | cm3 |
| **microlitre** | μ*l* | 10-6 *l* | 1/1000000 *l* | mm3 |
| **nanolitre** | n*l* | 10-9 *l* | 1/1000000000 *l* |  |

You will encounter units of mass and here are common units of mass and how they relate to the gram. For example the microgram is a millionth of a gram.

| **Units of mass** | **Abbreviation** | **How it relates to the gram** | |
| --- | --- | --- | --- |
| **kilogram** | kg | 103 g | 1000 g |
| **gram** | g | g | g |
| **milligram** | mg | 10-3 g | 1/1000 g |
| **microgram** | μg | 10-6 g | 1/1000000 g |
| **nanogram** | ng | 10-9 g | 1/1000000000 g |

And here are units of time and how they relate to the standard unit of the second.

| **Units of time** | **Abbreviation** | **How they relate to the second** | |
| --- | --- | --- | --- |
| **second** | s | s | s |
| **millisecond** | ms | 10-3 s | 1/1000 s |
| **microsecond** | μs | 10-6 s | 1/1000000 s |
| **nanosecond** | ns | 10-9 s | 1/1000000000 s |

If we are dealing with times greater than a second, we use minutes, hours, days, etc.

You must always think about which unit you are using when communicating a measurement. For example, although it is true that an average mitochondrion has a length of 0.0000055 m, it is more appropriate to state the measurement as 5.5 μm. Likewise, if the volume of a liquid is 56000 m*l* it would be better to refer to it as 56 *l* or 56 dm3.

It is the clear communication of the number and its unit which is the most important thing to consider.

### Rates of change

A rate of change is the quantity being measured per unit of time. Now this **per** means ‘divided by’. So quantity measured divided by the unit of time equals the rate of change.

An important mathematical notation to remember is that whatever is underneath the division line (the denominator) can also be written to the negative power. So the rate of change would be equal to the quantity being measured times the unit of time to the minus one.

So remember, whenever you see the term ‘per’ it means ‘divided by’ and you need to write the units with the correct mathematical notation, with the denominator expressed to its negative power.

For example, a woodlouse might crawl at 10 cm per second.   
This would be written as 10 cm s-1.

If a patient is on a drip, the number of drips per minute would be drips min-1.

There are other examples where the rate of change is measured as quantity per length, area or volume. Here the same principle applies, with, for example, the unit volume being made into its negative power:

For example, as a slime mould develops the number of cells per unit volume might increase, so you would be looking at the number of cells per mm3 or cells mm-3. The power stays the same, but the negative sign in front of it tells you that you divide by mm3. So the rate of change of the slime mould colony would be measured in number of cells per cubic mm per s, written as cells mm-3 s-1.

There are other examples where you would need to combine two or more units, for example, light energy is measured in photons per square metre per second – the number of photons that hit a square metre every second and you would express your data in photons m-2 s-1. The rate of change would be measured in a change in the number of these photons hitting a square metre every second over a period of time. So if you were to measure the rate of *change* in light intensity you would express your data in photons per square metre per second per second: photons m-2 s-1 s-1 which is written as photons m-2 s-2

Rates of change are used in many areas of biology: For example:

Bacterial growth rates are measured as the number of bacteria per hour expressed as bacteria h-1

Breathing rate would be expressed as breaths min-1

Rate of change in temperature would be oC s-1.

You just need to remember that the minus sign is simply a notation that tells you the unit is the denominator.

So if we return to the example of light energy, measured in photons m-2 s-2, this tells you that you take the change in the number of photons hitting each square metre each second and divide that by the time over which the change took place.

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