SCIENCE & PLANTS FOR SCHOOLS

SAPS STUDY SUPPORT

Symbols and Units

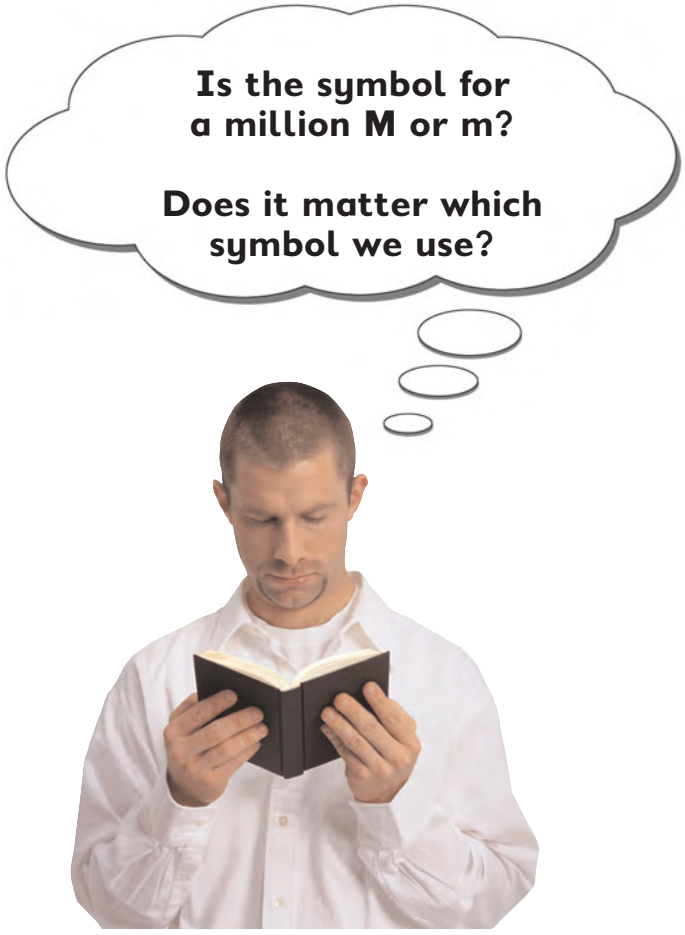
$J\ s^{-1}$ N Bq

$kg\ m\ s^{-2}$ °C Hz

$1\ tonne = 10^{3}\ kg$

December 2003
Version 1.0

Symbols and Units:
A survival guide



Why not read this Guide to find out the answer to the first question?

Find out if you agree with us that the answer to the second question is yes!

Introduction

In science, it is important that we are able to present results in a way that minimises confusion. Scientists therefore adopt a common system for presenting data that is widely used and understood.

This guide will:

- help you remember the units and symbols that you may meet in your science courses
- remind you of the importance of using units correctly.

We recommend that you work your way through the guide section by section.
There are six sections:

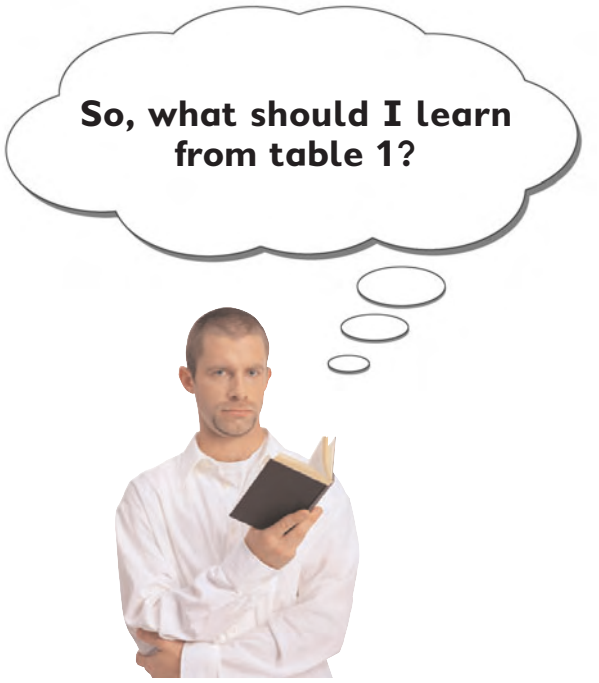
1. SI base units

For many years in the UK, teaching in schools and colleges has encouraged the use of SI units. (SI stands for *Système International d'Unités* or *International System of Units*) SI units are a coherent system of units comprising seven *base units* **on which all other units are based**.

Table 1 SI base units

Physical quantity	*Name*	*Symbol*
Length	metre	m
Mass	kilogram*	kg
Time	second	s
Amount of substance	mole	mol
Thermodynamic temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd

*Note the spelling of gram rather than gramme.



Well, there are 2 main points

1. The name for a unit always starts with a small (or lower case) letter even though they may have been named after a person e.g. the kelvin is named after Lord Kelvin.

2. The symbol for a unit starts with a capital letter only if it is named after a person e.g. A is the symbol for ampere. If the symbol for a unit is not named after a person it always starts with a small (or lower case) letter - for example, the symbol for second is s (**not S!**).

There is one exception to the rule about symbols not starting with a capital letter (unless they are named after a person). This exception involves the symbol for the litre. The symbol for the litre is not named after a person and technically its correct symbol should be the letter l (lower case). But you can see how easily this can be confused with the number 1, depending on the typeface used. So we can use the capital letter L as the symbol for the 'litre'. This means that the symbol for the litre can either be l or L and both forms are acceptable.

2. Derived units

In addition to the SI base units there are a number of units that are derived from these. They are obtained by appropriate combination of these basic units. For convenience, these derived units are given special names and some of those that you may meet are listed below.

Table 2 Some SI derived units

Physical quantity	*Units*	*Name*	*Symbol*
Rate of activity of radioactive source	s^{-1}	becquerel	Bq
Electric charge	A s	coulomb	C
Frequency	s^{-1}	hertz	Hz
Energy or work	N m	joule	J
Force	kg m s^{-2}	newton	N
Pressure	N m^{-2}	pascal	Pa
Potential difference	J C^{-1}	volt	V
Power	J s^{-1}	watt	W

3. Secondary units and prefixes

Sometimes, base and derived SI units are too large or too small to be handled easily. When this happens, modified units (known as secondary units) often prove useful. The size of any secondary unit is defined as a multiple of the base or derived unit. In order to obtain a suitable range for the secondary unit, the base or derived unit may be multiplied by a power of 10. The size of the secondary unit is then indicated by attaching a modifying prefix to the name of the base or derived unit. These prefixes indicate the power of 10 by which the base or derived unit has been multiplied (Table 3).

Table 3 Prefixes and their values

Prefix	*Symbol*	*Multiple*	*Standard*
yotta	Y	1 000 000 000 000 000 000 000 000	10^{24}
zetta	Z	1 000 000 000 000 000 000 000	10^{21}
exa	E	1 000 000 000 000 000 000	10^{18}
peta	P	1 000 000 000 000 000	10^{15}
tera	T	1 000 000 000 000	10^{12}
giga	G	1 000 000 000	10^{9}
mega	M	1 000 000	10^{6}
kilo	k	1 000	10^{3}
hecto	h	100	10^{2}
deca	da	10	10^{1}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}
zetto	z	0.000000000000000000001	10^{-21}
yocto	y	0.000000000000000000000001	10^{-24}

Common examples involving the use of prefixes include:

km (kilometre = 1000 m), cm (centimetre 0.01 m), mm (millimetre = 0.001 m) and μm (micrometre = 0.000001 m)
mL or ml (1 millilitre = 0.001 L), μL or μl (1 microlitre = 0.000001 L)

How big is a billion?
Can I use it in scientific writing?

We recommend that you avoid the use of the word billion since it can lead to confusion.

Until recently, the UK definition was one million million (or 10^{12}). But in the USA, the billion is defined as one thousand million (or 10^{9}) and this is becoming increasingly the accepted value in the UK.

Some sources (e.g. Whitaker's 2003 Almanac) still define the billion as 10^{12}. The Times Online Style Guide defines a billion 'as one thousand million not a million million' (see http://www.timesonline.co.uk). Dictionary definitions often do not offer any more clarity! The 1995 edition of the Concise Oxford Dictionary defines the billion 'as one thousand million and now, less often as one million million' whereas the Shorter Oxford English Dictionary (published in 2002) defines the billion as both one million million and also one thousand million!

In most European countries (other than the UK) the billion continues to be defined as one million million.

I have read somewhere that the prefixes k and M have different meanings when they are used in computing. Is that right?

This can lead to misunderstandings!

It is common for the size of computer files to be given in units of kb, Mb or Gb (representing kilobytes, megabytes or gigabytes of information). The k, M and G when used in relation to computing actually represent 1024, 1048576 and 1073741824 rather than 1000, 1 000 000 and 1 000 000 000. The reasons for the (relatively) small differences arise from numbers in so-called binary form and are beyond the scope of this booklet. You just need to recognise, though, that there are occasions when the misuse of prefixes can lead to confusion.

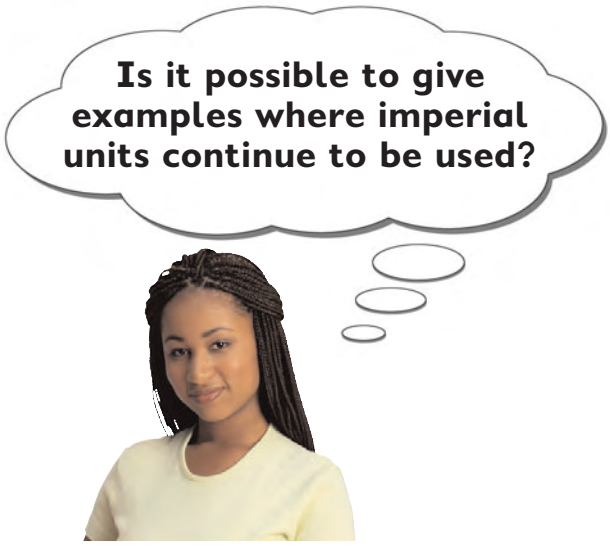
4. Units outside the SI

Certain units are not part of the SI, but are so widely used that they are generally accepted within scientific writing. A few of the units in this category are shown in Table 4.

Table 4 Units accepted for use with the SI

Physical quantity	*Name*	*Symbol*	*Value*
Time	minute	min (**NOT mins**)	1 min = 60 s
Time	hour	h	1 h = 3600 s
Time	day	d	1 d = 86 400 s
Temperature	degree celsius	°C	°C = K-273.15
Mass	tonne	t is often used	1 tonne = 10^3 kg

Note that so-called 'imperial units' (e.g. inch, foot, yard, gallon) are no longer acceptable in scientific writings or reports although you might still come across such units in 'everyday life'. See Appendix 1 for more examples of common units and their SI equivalents.



Well you probably only need to look in the newspaper or listen to radio or TV to find examples of 'incorrect' use of units and symbols.

Below we reproduce part of a form that is used by organisations wishing to book exhibition space at a conference. Suppose that you were asked to change this form and correct any errors in terms of units and symbols that are used. How many changes would you make?

Spot the errors!

Space requirements – please specify area required

Length or area required (in Metres) _____ width of area required (in Metres) _____

Price is for space only, and is priced at £52.00 per square metre excluding VAT. There is a minimum take up of 2 square metres at £104.00 excluding VAT.

Trestle tables approx. 6 ft by 2 ft 6 ins can be supplied. Please supply ____ tables.

Chairs can be supplied. Please supply ____ chairs.

Electrical points (5 amp) can be supplied. Please supply ____ points.

You might be surprised to learn that the form is used for a science education conference! How many errors did you spot? Click here to compare your answer with ours.

5. Using SI units and their symbols

In an attempt to avoid confusion, a number of rules or conventions are followed when using units and symbols. This section deals with some of these conventions and you will see that we list 12 different points that you should consider.

1. Symbols consist of capital letters when the units that they represent are named after a person. For example, the joule (symbol J) is named after James Joule – but note the unit name does not have an initial capital letter.

   Example An energy content of 40 joule = 40 J (**not** 40 j)
   A force of 50 newton = 50 N (**not** 50 n)

2. Insert a space between the number and unit.

   Example 75 kg (**not** 75kg)

   The exception to this is when a percentage is being expressed.

   Example 75% (**not** 75 %)

3. Temperature

   The symbol for temperature in celsius (°C) is preceded by a space when expressing values for celsius temperatures.

   Example 30.4 °C (**not** 30.4°C **or** 30.4° C)

   The degree sign is omitted when recording temperatures in the SI unit (kelvin)

   Example The melting point of water is 273.15 K (**not** 273.15 °K)

4. Symbols must be written in their singular form. In some cases it may not be possible to avoid the use of the 's' after the unit especially in written text. However, there should **never** be an 's' after the symbol unless it stands for second!

   Example 2.4 mm (**not** 2.4 mms); 50 W (**not** 50 Ws); 50 kg (**not** 50 kgs)

5. No full stop should be inserted after the symbol (except at the end of a sentence!)

   Example six milligram of aspirin = 6 mg aspirin (**not** 6 mg. aspirin)

6. When two or more unit symbols are combined to create a derived unit symbol they should be separated by a space.

   Example 1 L min^{-1} (**not** 1 $Lmin^{-1}$)

7. No space is left between a prefix (that indicates a power of 10) and the symbol to which it applies. This rule is particularly important in avoiding confusion between m (meaning milli) and m (meaning metre).

   Example One millisecond = 1 ms
   One metre per second = 1 m s^{-1}

8. Compound prefixes should not be used - use only one multiplying prefix.

   Example 10^{-9} m = 1 nm (**not** 1mμm)

9. A combination of prefix and symbol for a unit is regarded as a single symbol. This is often a source of confusion. In mathematics, if we were to come across the expression I dm^3 we might assume that it means 1 x d x m x m x m whereas in the sense of a unit 1 dm^3 is the same as 1 $(dm)^3$.

This might become clearer if we look at the following:

Example 1 litre = 1 dm^3 = 1 $(dm)^3$ = 10^{-3} m^3 (**not** 10^{-1} m^3)

1 cm^3 = 1 $(cm)^3$ = 10^{-6} m^3 (**not** 10^{-2} m^3)
1 cm^3 = 10^{-3} dm^3

(See Appendix 2 for more information on units of volume in common usage).

10. To help with the reading of numbers it is better not to use commas. This avoids confusion with the (occasional) use of the comma to denote a decimal point. Internationally the comma is often used in place of a decimal point and this can lead to confusion.

Examples
a. The number 123456789.23 may be written as 123 456 789.23 i.e. with a space separating groups of three digits (but should **not** be written as 123,456,789.23)
b. When writing a four-digit number the inclusion of a space is optional e.g. 1 000 or 1000.

11. The solidus (/) is discouraged in favour of the negative index when writing symbols of reciprocal units.

Example It is preferable to write N m^{-2} rather than N/m^2

The solidus must never be used more than once in any unit.

Example The molar gas constant, R = 8.314 J K^{-1} mol^{-1} (**not** 8.314 J/K/mol)

12. Symbols are used only when they are preceded by a numerical value. Symbols should not be used as abbreviations within a sentence.

Examples
a. It is sold by the cubic metre (**not** it is sold by the m^3)
b. There are 10^6 mm in 1 km (**but not** there are many mm in a km)

Spot the errors!

Let's look at an example of text and see if we can spot any errors in the way that units and symbols have been used. If you were asked to re-write the following piece of text (shown in italics below) how many changes would you make?

…In the United States, energy production from natural gas released about 5.5 billion tonnes of waste in 1994. Natural gas fires and explosions are also significant risks. A single mile of pipeline three feet in diameter at a pressure of 1000 pounds per square inch (psi) contains the equivalent of two-thirds of a kiloton of explosive energy; a million miles of such pipelines lace the earth.

(The above passage was taken from an article, 'The need for nuclear power: viewpoint on the world's challenging energy future', by Richard Rhodes and Denis Beller published in 2000 in volume 42 (part 2) of the International Atomic Energy Agency Bulletin, pages 43-50).

Compare your answers with the suggestions given in Answers 2 Published article

Further information on the correct use of units is available (see Appendix 3).

6. Some useful physical constants

Some of the universal constants that you are likely to meet are given in Table 5.

Table 5 Some universal constants

Constant	*Symbol*	*Value*	*Units*
Gravitational constant	g	9.81	$m\ s^{-2}$
Velocity of light in a vacuum	c	2.998×10^{8}	$m\ s^{-1}$

7. Acknowledgements

I am grateful to those individuals who have read early drafts of this guide and given freely of their time, advice and expertise. Particular thanks go to Dean Madden (National Centre for Biotechnology Education, University of Reading), Debbie Eldridge (King Ecgbert School, Sheffield), Kath Crawford (Scottish Schools Equipment Research Centre (SSERC) and SAPS Biotechnology Scotland Project), Jaquie Burt (Portobello High School, Edinburgh), John Adds (Abbey Tutorial College), John Gray (University of Cambridge), Stephen Tomkins (University of Cambridge) and Erica Clark (SAPS). Any errors or omissions that remain are, of course, the sole responsibility of the author.

It is our intention to issue updates to this Guide on a regular basis and so further comments on content and other areas that might be covered are welcomed. Please send your comments and suggestions to: saps@botanic.cam.ac.uk

Appendix 1 Conversion table for translation of common units into their SI equivalents

Unit and Symbol	*SI Equivalent*	*Unit and Symbol*	*SI Equivalent*
ångstrom, Å	100 pm = 10^{-10} m	millibar, mbar	100 Pa
atmosphere, atm	101 300 Pa	millimetre of Hg, mm Hg	133.3 Pa
calorie, cal	4.184 J	molar, M	1 mol dm^{-3} or 1 mol L^{-1}
cubic foot, ft^3	0.0283 m^3	ounce, oz	28.35 g
cubic inch, in^3	16.39 cm^3	pint, pt	0.5683 dm^3
fluid ounce, fl oz	28.41 cm^3	pound, lb	0.4536 kg
foot, ft	0.3048 m	pound-force, lbf	4.448 N
gallon	4.546 dm^3	pound per square inch,lb in^{-2}	703.07 kg m^{-2}
inch, in	25.4 mm	square foot, ft^2	0.0929 m^2
kilowatt hour, kW h	3.6 MJ	square inch, in^2	645.2 mm^2

Appendix 2 Conversion table for some additional volumes and units

Volume	*Equivalent*	*Notes*
1 microlitre (1 μl or 1 μL)	0.000001 dm^3	Also equivalent to 1 mm^3 but mm^3 rarely used and μl is preferred
1 millilitre (1 ml or 1 mL)	0.001 dm^3 or 1 cm^3	1 cm^3 preferred but ml is commonly used
1 decilitre (dl)	100 cm^3 = 100 ml	Not in common usage
1 litre (1 l or 1 L)	1.0 dm^3	1 dm^3 preferred but both l and L are acceptable

Appendix 3 Sources of Information

If you would like further information on the correct use of units and symbols you might want to have a look at the following publications.

1. Biological Nomenclature: Standard terms and expressions used in the teaching of biology (2000), edited by A Cadogan. Published by the Institute of Biology, London, UK.

2. Signs, Symbols and Systematics: The ASE companion to 16-19 science (2000), edited by T C Swinfen. Published by the Association for Science Education, Hatfield, UK.

3. Brown, B. (2003), Musings on measurements, Biological Sciences Review, 16, 30-32.

Answers 1 Application for Exhibition Space

Space requirements – please specify area required

Length or area required (in Metres) _____ width of area required (in Metres) _____

Price is for space only, and is priced at £52.00 per square metre excluding VAT. There is a minimum take up of 2 square metres at £104.00 excluding VAT.

Trestle tables approx. 6 ft by 2 ft 6 ins can be supplied	Please supply ____ tables.
Chairs can be supplied	Please supply ____ chairs.
Electrical points (5 amp) can be supplied	Please supply ____ points

How many 'errors' did you spot? We found the following:

- the correct term for length is the metre not the Metre – this error occurred twice
- the use of imperial units (foot, inch etc) should be discouraged. The use of the symbol 'ins' as opposed to 'in' is also doubtful
- the correct unit for electrical current is the ampere not the amp

It is doubtful that any misunderstanding would be caused by the 'errors' in the above box although that may not always be the case.

Answers 2 Published article

The article that was chosen contains a number of areas where we could make suggestions for improvement especially since it is an article written for a scientific audience. Let's have another look at what was written:

…In the United States, energy production from natural gas released about 5.5 billion tonnes of waste in 1994. Natural gas fires and explosions are also significant risks. A single mile* of pipeline three feet* in diameter at a pressure of 1000 pounds per square inch* (psi) contains the equivalent of two-thirds of a kiloton* of explosive energy; a million miles* of such pipelines lace the earth.*

How many 'errors' did you spot? We found the following:

* *5.5 billion tonnes* – this would be better written as 5.5 x 10^9 tonne. The word billion is confusing and the plural form of tonne is discouraged. As an alternative, 5.5 Gtonne could have been used.
* *A single mile* – the use of the unit mile is discouraged and conversion to km would be preferable.
* *three feet* – the use of feet and inches is discouraged and conversion to metre would be preferable.
* *pounds per square inch* – this is a non-SI unit and should be converted to Pa or kPa.
* *kiloton* – the authors have introduced a new unit here which seems to be based on the 'old' or imperial unit the ton rather than the SI derived unit the tonne.
* *miles* – the use of miles is discouraged and conversion to km would be preferable.

So, in just some 70 words of text we have managed to find no less than 6 opportunities to criticise the authors for their use of units!