Units of Measure

The Systeme International [S I]

Le Systeme international d'Unites officially came into being in October 1960 and has been adopted by nearly all countries, though the amount of actual usage varies considerably.

It is based upon 7 principal units, 1 in each of 7 different categories -

Category	Name	Abbreviation
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Definitions of these basic units are given. Each of these units may take a prefix. From these basic units many other units are derived and named.

Definitions of the Seven Basic SI Units

metre [m] The metre is the basic unit of length. It is the distance light travels, in a vacuum, in 1/299792458th of a second.

kilogram [kg] The kilogram is the basic unit of mass. It is the mass of an international prototype in the form of a platinum-iridium cylinder kept at Sevres in France. It is now the only basic unit still defined in terms of a material object, and also the only one with a prefix[kilo] already in place.

second [s] The second is the basic unit of time. It is the length of time taken for 9192631770 periods of vibration of the caesium-133 atom to occur.

ampere [A] The ampere is the basic unit of electric current. It is that current which produces a specified force between two parallel wires which are 1 metre apart in a vacuum. It is named after the French physicist Andre Ampere (1775-1836).

kelvin [K] The kelvin is the basic unit of temperature. It is 1/273.16th of the thermodynamic temperature of the triple point of water. It is named after the Scottish mathematician and physicist William Thomson 1st Lord Kelvin (1824-1907).

mole [mol] The mole is the basic unit of substance. It is the amount of substance that contains as many elementary units as there are atoms in 0.012 kg of carbon-12.

candela [cd] The candela is the basic unit of luminous intensity. It is the intensity of a source of light of a specified frequency, which gives a specified amount of power in a given direction.

Derived Units of the S I

From the 7 basic units of the SI many other units are derived for a variety of purposes. Only some of them are explained here. The units printed in bold are either basic units or else, in some cases, are themselves derived.

farad [F] The farad is the SI unit of the capacitance of an electrical system, that is, its capacity to store electricity. It is a rather large unit as defined and is more often used as a microfarad. It is named after the English chemist and physicist Michael Faraday (1791-1867).

hertz [Hz] The hertz is the SI unit of the frequency of a periodic phenomenon. One hertz indicates that 1 cycle of the phenomenon occurs every second. For most work much higher frequencies are needed such as the kiloherz [kHz] and megaherz [MHz]. It is named after the German physicist Heinrich Rudolph Herz (1857-94).

joule [J] The joule is the SI unit of work or energy. One joule is the amount of work done when an applied force of 1 newton moves through a distance of 1 metre in the direction of the force.It is named after the English physicist James Prescott Joule (1818-89).

newton [N] The newton is the SI unit of force. One newton is the force required to give a mass of 1 kilogram an acceleration of 1 metre per second per second. It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727).

ohm [*] The ohm is the SI unit of resistance of an electrical conductor. Its symbol, shown here as [*] is the Greek letter known as 'omega'. It is named after the German physicist Georg Simon Ohm (1789-1854).

pascal [Pa] The pascal is the SI unit of pressure. One pascal is the pressure generated by a force of 1 newton acting on an area of 1 square metre. It is a rather small unit as defined and is more often used as a kilopascal [kP]. It is named after the French mathematician, physicist and philosopher Blaise Pascal (1623-62).

volt [V] The volt is the SI unit of electric potential. One volt is the difference of potential between two points of an electical conductor when a current of 1 ampere flowing between those points dissipates a power of 1 watt. It is named after the Italian physicist Count Alessandro Giuseppe Anastasio Volta (1745-1827).

watt [W] The watt is used to measure power or the rate of doing work. One watt is a power of 1 joule per second. It is named after the Scottish engineer James Watt (1736-1819).

Note that prefixes may be used in conjunction with any of the above units.

The Prefixes of the S I

The SI allows the sizes of units to be made bigger or smaller by the use of appropriate prefixes. For example, the electrical unit of a watt is not a big unit even in terms of ordinary household use, so it is generally used in terms of 1000 watts at a time. The prefix for 1000 is kilo so we use kilowatts[kW] as our unit of measurement. For makers of electricity, or bigger users such as industry, it is common to use megawatts[MW] or even gigawatts[GW]. The full range of prefixes with their [symbols or abbreviations] and their multiplying factors which are also given in other forms is

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	(a billion)
mega	[M]	1 000 000	(a million)
kilo	[k]	1 000	(a thousand)
		1	
milli	[m]	0.001	(a thousandth)
micro	[μ]	0.000 001	(a millionth)
nano	[n]	0.000 000 001	(a thousand millionth)
pico	[p]	0.000 000 000 001	$= 10^{-12}$
femto	[f]	0.000 000 000 000 001	$= 10^{-15}$
atto	[a]	0.000 000 000 000 000 001	$= 10^{-18}$
zepto	[z]	0.000 000 000 000 000 000 001	$= 10^{-21}$
yocto	[y]	0.000 000 000 000 000 000 000 001	$= 10^{-24}$

All of the SI prefixes are multiples or sub-multiples of 1000. However, these are inconvenient for many purposes and so centi (x 0.01), hecta (x 100), deca (x 10) and deci (x 0.1) are also used.

Conventions of Usage in the S I

There are various rules laid down for the use of the SI and its units as well as some observations to be made that will help in its correct use.

Any unit may take only ONE prefix. For example 'millimillimetre' is incorrect and should be written as 'micrometre'.

Prefixes which make a unit bigger are written in capital letters (M G T etc.), but when they make a unit smaller then lower case (m n p etc.) is used. The one exception to this is kilo [k] to avoid any possible confusion with kelvin [K].

A unit which is named after a person is written all in lower case (newton, volt, pascal etc.) when named in full, but using a capital letter (N V P etc.) when abbreviated. An exception to this rule is the litre which, if written as a lower case 'l' could be mistaken for a '1' (one) and so a capital 'L' is allowed as an alternative.

Units written in abbreviated form are never pluralised. So 'm' could always be either 'metre' or 'metres'. 'ms' would represent 'metre second'.

To make numbers easier to read they may be divided into groups of 3 separated by spaces (or half-spaces) but NOT commas.

The SI preferred way of showing a decimal fraction is to use a comma (123,456) to separate the whole number from its fractional part. The practice of using a point, as is common in English-

speaking countries, is acceptable providing only that the point is placed ON the line of the bottom edge of the numbers (123.456).

It will be noted that many units are eponymous, that is they are named after persons. This is always someone who was prominent in the early work done within the field in which the unit is used.

A Brief History of Measurement

One of the earliest types of measurement concerned that of length. These measurements were usually based on parts of the body. A well documented example (the first) is the Egyptian cubit which was derived from the length of the arm from the elbow to the outstretched finger tips. By 2500 BC this had been standardised in a royal master cubit made of black marble (about 52 cm). This cubit was divided into 28 digits (roughly a finger width) which could be further divided into fractional parts, the smallest of these being only just over a millimetre.

In England units of measurement were not properly standardised until the 13th century, though variations (and abuses) continued until long after that. For example, there were three different gallons (ale, wine and corn) up until 1824 when the gallon was standardised.

In the US A the system of weights and measured first adopted was that of the English, though a few differences came in when decisions were made at the time of standardisation in 1836. For instance, the wine-gallon of 231 cubic inches was used instead of the English one (as defined in 1824) of about 277 cubic inches. The US A also defined a separate dry gallon of about 269 cubic inches.

Even as late as the middle of the 20th century there were some differences in UK and US measures which were nominally the same. The UK inch measured 2.53998 cm while the US inch was 2.540005 cm. Both were standardised at 2.54 cm in July 1959.

In France the metric system officially started in June 1799 with the declared intent of being 'For all people, for all time'. The unit of length was the metre which was defined as being one ten-millionth part of a quarter of the earth's circumference. The production of this standard required a very careful survey to be done which took several years. However, as more accurate instruments became available so the 'exactness' of the standard was called into question. Later efforts were directed at finding some absolute standard based on an observable physical phenomenon. Over two centuries this developed into the S I. So maybe their original slogan was more correct than anyone could have foreseen then.

Metric System of Measurements

Length		**Area**	
10 millimetres	= 1 centimetre	100 sq. mm	= 1 sq. cm
10 centimetres	= 1 decimeter	10 000 sq. cm	= 1 sq. metre
10 decimetres	= 1 metre	100 sq. metres	= 1 are
10 metres	= 1 dekametre	100 ares	= 1 hectare
10 dekametres	= 1 hectometre	10 000 sq. metres	= 1 hectare
10 hectometres	= 1 kilometre	100 hectares	= 1 sq. kilometre
1000 metres	= 1 kilometre	1 000 000 sq. metres	= 1 sq. kilometre

Capacity

10 millilitres	= 1 centilitre

Volume

10 centilitree	= 1 decilitre		
1000 cu. mm	= 1 cu. cm	10 decilitres	= 1 litre
1 000 000 cu. cm	= 1 cu. metre	1000 litres	= 1 cu. metre

Mass

1000 grams	= 1 kilogram
1000 kilograms	= 1 tonne

The UK (Imperial) System of Measurements

Length

12 inches	= 1 foot		
3 feet	= 1 yard		
22 yards	= 1 chain		
10 chains	= 1 furlong		
8 furlongs	= 1 mile		
5280 feet	= 1 mile		
1760 yards	= 1 mile	Capacity	
20 fluid ounces	= 1 pint		

Area

144 sq. inches	= 1 square foot		
9 sq. feet	= 1 square yard		
4840 sq. yards	= 1 acre		
640 acres	= 1 square mile		

Volume

4 gills	= 1 pint		
1728 cu. inches	= 1 cubic foot	2 pints	= 1 quart
27 cu. feet	= 1 cubic yard	4 quarts	= 1 gallon (8 pints)

Mass

437.5 grains = 1 ounce

Troy Weights

16 ounces	= 1 pound	24 grains	= 1 pennyweight
14 pounds	= 1 stone	20 pennyweights	= 1 ounce
8 stones	= 1 hundredweight [cwt]	12 ounces	= 1 pound
20 cwt	= 1 ton (2240 pounds)		

Apothecaries' Measures		**Apothecaries' Weights**	
20 minims	= 1 fl.scruple	20 grains	= 1 scruple
3 fl.scruples	= 1 fl.drachm	3 scruples	= 1 drachm
8 fl.drachms	= 1 fl.ounce	8 drachms	= 1 ounce
20 fl.ounces	= 1 pint	12 ounces	= 1 pound

The old Imperial (now UK) system was originally defined by three standard measures - the yard, the pound and the gallon which were held in London. They are now defined by reference to the SI measures of the metre, the kilogram and the litre. These equivalent measures are exact.

1 yard = 0.9144 metres - same as US
1 pound = 0.453 592 37 kilograms - same as US
1 gallon = 4.546 09 litres

Note particularly that the UK gallon is a different size to the US gallon so that NO liquid measures of the same name are the same size in the UK and US systems.

Also that the ton(UK) is 2240 pounds while a ton(US) is 2000 pounds. These are also referred to as a long ton and short ton respectively.

The US System of Measurements

Most of the US system of measurements is the same as that for the UK. The biggest differences to be noted are in Capacity which has both liquid and dry measures as well as being based on a different standard - the US liquid gallon is smaller than the UK gallon. There is also a measurement known at the US survey foot. It is gradually being phased out as the maps and land plans are re-drawn under metrication. (The changeover is being made by putting 39.37 US survey feet = 12 metres)

Length	**Area**
12 inches = 1 foot	144 sq. inches = 1 square foot
3 feet = 1 yard	9 sq. feet = 1 square yard
220 yards = 1 furlong	4840 sq. yards = 1 acre
8 furlongs = 1 mile	640 acres = 1 square mile
5280 feet = 1 mile	1 sq.mile = 1 section
1760 yards = 1 mile	36 sections = 1 township

Volume
1728 cu. inches = 1 cubic foot
27 cu. feet = 1 cubic yard

Capacity (Dry)	**Capacity (Liquid)**
16 fluid ounces = 1 pint	
2 pints = 1 quart	4 gills = 1 pint
8 quarts = 1 peck	2 pints = 1 quart
4 pecks = 1 bushel	4 quarts = 1 gallon (8 pints)

Mass
437.5 grains = 1 ounce Troy Weights
16 ounces = 1 pound (7000 grains) 24 grains = 1 pennyweight
14 pounds = 1 stone 20 pennyweights = 1 ounce (480 grains)
100 pounds = 1 hundredweight [cwt] 12 ounces = 1 pound (5760 grains)
20 cwt = 1 ton (2000 pounds)

Apothecaries' Measures	**Apothecaries' Weights**
60 minims = 1 fl.dram	20 grains = 1 scruple
8 fl.drams = 1 fl.ounce	3 scruples = 1 dram
16 fl.ounces = 1 pint	8 drams = 1 ounce (480 grains)
12 ounces = 1 pound (5760 grains)	

As with the UK system these measures were originally defined by physical standard measures - the yard, the pound, the gallon and the bushel.They are now all defined by reference to the SI measures of the metre, the kilogram and the litre. These equivalent measures are exact.

1 yard = 0.9144 metres - same as UK
1 pound = 0.453 592 37 kilograms - same as UK
1 gallon (liquid) = 3.785 411 784 litres
1 bushel (dry) = 35.239 070 166 88 litres

Note particularly that the US gallon is a different size to the UK gallon so that NO liquid measures of the same name are the same size in the US and UK systems.

Also that the ton(US) is 2000 pounds while a ton(UK) is 2240 pounds. These are also referred to as a short ton and long ton respectively.

Knots

A nautical mile is a unit of distance equal to 1,852 metres. This value was adopted by the International Hydrographic Conference in 1929 and has subsequently been adopted by the International Bureau of Weights and Measures.

It is also the unit adopted for the purposes of Australian Maritime Legislation. Refer to Schedule 1.(1) of the Seas and Submerged Lands Act 1973 as published in the Commonwealth of Australia gazette No. S29, 9 February 1983.

The length of the nautical mile is very close to the mean value of the length of 1 minute of latitude, which varies from approximately 1,843 metres at the equator to 1,861.6 metres at the pole.

Hypertext Webster Gateway:
11. (Naut.) (a) A division of the log line, serving to measure the rate of the vessel's motion. Each knot on the line bears the same proportion to a mile that thirty seconds do to an hour. The number of knots which run off from the reel in half a minute, therefore, shows the number of miles the vessel sails in an hour. Hence: (b) A nautical mile, or 6080.27 feet; as, when a ship goes eight miles an hour, her speed is said to be eight knots.