Converting the Gateway Arch to SI Units

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by João Roque Dias
Lisbon - Portugal
jrdias@mail.telepac.pt

The *Système International* [SI]

The *Système International d'Unités* (abbreviated **SI**, even in the English language) was officialy born in October 1960 and has been adopted by nearly all countries. The amount of actual usage, though, varies considerably. The SI is based upon 7 principal units (called *base units,* NOT *"basic units"*), one in each of seven different categories:

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

Definitions of the Seven Base SI Units

meter [m]

The **meter** is the base unit of length. It is the distance light travels, in vacuum, in 1/299792458*th* of a second.

kilogram [kg]

The **kilogram** is the base unit of mass. It is the mass of an international prototype in the form of a platinum-10% iridium cylinder kept at Sèvres in France. *It is now the only base unit still defined in terms of a material object and also the only one with a prefix [kilo] included in its name.*

second [s]

The **second** is the base unit of time. It is the length of time taken for 9 192 631 770 periods of vibration of the caesium-133 atom to occur.

ampere [A]

The **ampere** is the base unit of electric current. It is the current which produces a specified force (0.2 μN/m) between two parallel wires, which are 1 meter apart in a vacuum. A widely used unit is the *milliampere* [mA]. *It is named after the French physicist André Ampère (1775-1836).*

kelvin [K]

The **kelvin** is the base unit of temperature. It is 1/273.16*th* 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). The form °K (degree Kelvin) is now deprecated.*

mole [mol]

The **mole** is the base 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 base 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 SI

From the 7 base units of the SI many other units are **derived** for a variety of purposes. Only some of them (those with **special names**) are explained here. The units printed in **bold** are either base 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* [μF] or *picofarad* [pF]. *It is named after the English chemist and physicist Michael Faraday (1791-1867).*

hertz [Hz]

The **hertz** is the SI unit of 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 *kilohertz* [kHz] and *megahertz* [MHz]. *It is named after the German physicist Heinrich Rudolph Hertz (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 **meter** 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 **meter** per **second** in each **second** [m/s^2]**.** *It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727).*

ohm [Ω]

The **ohm** is the SI unit of electrical resistance. Its symbol [Ω] 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 meter** [N/m^2]. It is a rather small unit as defined and is more often used as *kilopascal* [kPa] or *megapascal* [MPa]. *It is named after the French mathematician, physicist and philosopher Blaise Pascal (1623-1662).*

volt [V]

The **volt** is the SI unit of electric potential. One volt is the difference of potential between two points of an electrical 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 the power of 1 **joule** per **second** [J/s]. *It is named after the Scottish engineer James Watt (1736-1819).*

The SI Prefixes

The SI allows the sizes of units to be made bigger or smaller by the use of appropriate prefixes. For example, the SI electrical unit (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 daily unit of measurement. For makers of electricity, or bigger users such as industrial plants, it is common to use *megawatts* [MW] or even *gigawatts* [GW]. Countries use *terawatts* (TW). Below is the full range of SI prefixes with their symbols and multiplying factors:

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**	***(1000 millions = a billion)***
mega	**[M]**	**1 000 000**	***(a million)***
kilo	**[k]**	**1 000**	***(a thousand)***
hecto	**[h]**	**100**	
deca	**[da]**	**10**	
		1	
deci	**[d]**	**0.1**	
centi	**[c]**	**0.01**	
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**	**$= 10^{-24}$**

(μ) - the symbol used for **micro** is the Greek letter known as 'mu'.
Nearly all of the SI prefixes are multiples or sub-multiples of 1000. However, these are inconvenient for many purposes and so **hecto**, **deca**, **deci**, and **centi** are also used. **deca** also appears as **deka [da]** or **[dk]** in the USA and Continental Europe. Even standards can have deviations…

Speak right, write right: rules of usage for SI units

1. Units may take only **ONE** prefix. For example, 'millimillimeter' is incorrect and should be written as 'micrometer'.
2. Prefixes that make a unit bigger are written in capital letters (M, G, T, etc.), but when they make a unit smaller, lower case (m, n, p, etc.) must be used. Exceptions to this are the *kilo* [k] to avoid any possible confusion with *kelvin* [K]; also, note the usage: *hecto* [h] and *deca* [da] or [dk].
3. Units named after a person are written **all in lower case** (newton, volt, pascal etc.) **when named in full**, **but starting with a capital letter** (N, V, Pa, etc.) **when the symbol is used**. An exception to this rule is the liter 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. It is intended that a single letter will be decided upon some time in the future by the BIPM when it becomes clear which letter is being favored most in use.
4. Units written with their symbols are **NEVER** pluralized. Therefore, 'm' can always be either 'meter' or 'meters'. Note that 'ms' could represent 'meter x second' (whatever that is!!!) or, more correctly, 'millisecond'.
5. The symbols of units (such as J, N, g, Pa, kg, Pa, etc.) are **NEVER** followed by a period [.], unless in the **end of a sentence**.
6. To make numbers easier to read, they may be divided **into groups of 3 separated by spaces** (or half-spaces) in numbers with 5 or more digits, but NOT commas. **Note:** 2000, but 20 000.
7. The SI **preferred** way of showing a decimal fraction is to use a comma (123,456) to separate the whole part of the number from its fractional part. The practice of using a period, as it is common in English-speaking countries, is acceptable, providing only that the period is placed **ON** the line of the bottom edge of the numbers (123.456).

Pitfalls checklist

NO! NEVER! PLEASE, DON'T! WHAT?	YES! ALWAYS!
megagram	ton
kiloday, megasecond, millidegree, decadegree	SI prefixes are **NOT** used with units of time or angle
millimillimeter	micrometer
M or G (without units)	Prefixes can **ONLY** be used with units
M (meter), Km, cM (centimeter), KW, KV. KWH	m, km, cm, kW, kV, kW.h
Pascal, Newton, Volt, hectoPascal	pascal, newton, volt, hectopascal
(used as symbols of units)	(**ALWAYS** lowercase, when unit name is written in full)
10m, 50Kw, 20kPa	10 m, 50 kW, 20 kPa (**ALWAYS** with a space)
50C, 50F, 120°C, 212°F, °K, 10 degC	50 °C, 50 °F, 120 °C, 212 °F, K, 10 °C
m2	m^2, whenever possible, this is the preferred spelling
ms (as plural of "meter")	m (either 1 m or 1 000 000 m)
Bake cake at 123.54 °C	Come on! Make it easy on your reader: 125 °C.
Mjoule	MJ (do not use prefixes with unit names spelled in full)
kinch (???)	1000 inches (**DO NOT** use SI prefixes with non SI units)
kW/h	kW.h (isn't this what you want to say?)
kg. (period after the symbol)	kg (in the SI, symbols **ARE NOT** abbreviations)
cc, CC, cu.cm	cm^3

Learn how to read units right…

CORRECT SPELLING	MEANING
500 kW.h	500 kilowatts TIMES 1 hour
200 km/h	200 quilometers PER (DIVIDED) 1 hour
g.CV/h (e.g., specific consumption of Diesel engines)	grams TIMES CV PER hour
$kW.m^2.m/h$	kW TIMES 1 square meter TIMES 1 meter PER 1 hour

Note: All these sites have been tested and found to be in perfect working condition on 22 September, 1999.

- ***BIPM - Bureau International des Poids et Mesures***
  They're the ones who tell the world how to measure things correctly.
  Download and print the SI Brochure (PDF format). It's the Bible!

  http://www.bipm.fr

- Conversion of temperatures

  http://www.cchem.berkeley.edu/ChemResources/temperature.html

- Conversion to and from U.S. fluid to metric measures and U.S. dry to metric measures

  http://hbd.org/brewery/cm3/recs/convert.html

- Great software. Requires free on-line registration before downloading.

  http://www.daat.com/coolcalc.htm

- A great site about units for the medical translator. Very precise info about the SI.

  http://www.healthlab.org/siunits.htm

- Go ahead, just print these pages!

  http://www.asi.org/adb/f/conversion-factors.html

- Not for the faint of heart! 2,800 units in 80 categories. Probably the best units program I've seen on the NET. Costs a mere $32.00, plus some extra pennies for shipping.

  http://www.pro-techsoftware.com/unitsprohome.html

- Start here! Click on the unit you want to convert and enter the number.

  http://www.entisoft.com/ESUnits/Units_A.HTM

- Just print the 5 files: mass1 thru mass5. Makes a great starter for your Units Binder.

  http://www.ceramics.com/mass1.html

- Homepage of Sergei Gershtein. From Russia with Units…

  http://www.mplik.ru/~sg/transl/index.html

- A great pocket calculator for units conversion. Costs about $60.00.

  http://mdmetric.com/ciumm1.htm

Units on your bookshelf

Conversion Tables of Units for Science and Engineering *by Ari L Horvath*
Macmillan Reference Books, London, 1986 (147 pages) ISBN 0 333 40857 8
Probably the most comprehensive set of conversion factors in book form, covering both old and modern units. There are 77 tables covering categories from Length to Radiation dosage. The Length table alone lists 107 units, together with the conversion factors needed to change each one into meters.

The Macmillan Dictionary of Measurement *by Darton and Clark*
Macmillan, New York, 1994 (538 pages)
ISBN 0 460 861379
Very comprehensive coverage of all kinds of units (including currencies), sorted in conventional dictionary form, and giving several conversion factors. A must! Guaranteed to be one of the most looked-up reference books in your library. Try any Barnes & Noble store.

The Economist Desk Companion
Random Century, London, 1992 (272 pages)
ISBN 0 7126 9816 7
A handy compendium of units used in Science, Medicine, Engineering, Industry, Commerce, Finance and many other fields, together with all the necessary conversion factors. There is also much other incidental (but related) information.

World Weights and Measures
Statistical Office of the United Nations, New York 1955 (225 pages)
A very comprehensive survey of each country in the world (as it was then) from Aden to Zanzibar, giving the units used in each for Length, Area and Capacity with their British and Metric equivalents. Includes an appendix on the measures used for commodities.
Currencies are also given. The indexes are very thorough. Given its age, it may be hard to find.

The World of Measurements *by H Arthur Klein*
Allen and Unwin, London, 1975 (736 pages)
ISBN 0 04 500024 7
A very readable and comprehensive account of the history of units used in measuring, from the earliest known beginnings and around the world.

Scientific Unit Conversion *by François Cardarelli*
Springer-Verlag, London, 1997 (456 pages)
ISBN 3-540-76022-9
It claims: "This practical manual aims to be the most comprehensive work on the subject of unit conversion. It contains more than 10 000 precise conversion factors ..."
With its very wide coverage, both historical and modern, it should certainly satisfy nearly all users.

Your own Units Binder *by yourself*
Any 2 or 3-ring binder will do. Fill it with as many information about units and conversion factors as you can. Possible sources: files downloaded from the Internet, last pages of dictionaries, university manuals, technical brochures. Units are everywhere. You just have to collect them.