CONDENSED GUIDE TO SI UNITS AND ASSOCIATED TYPOGRAPHICAL STANDARDS

This condensed guide to SI units and their standard usage is provided for the benefit of those who use units of measure. This document is intended as a reference and review of the world standard for expressing the terms of quantity we use, to aid consistency, simplify communication and reduce jargon. Widespread disregard for technical literacy in labeling, signage, literary and verbal communication standards, creates confusion and ambiguity and can be life-threatening in medical, structural and other physical circumstances.

The Metric System of units was legalized by the U.S. Congress for trade in the United States in the year 1866. In the intervening five generations of American life, vanishingly little to barely sufficient attention has been paid to learning—much less integrating—the world standard into American life and business, with varying notorious results ranging from acquiescence for use in the Olympic Games, to loss of multi-million dollar spacecraft due to bad English-to-metric conversions. There have also been perhaps hundreds of thousands of unnoticed "accidental" military and civilian deaths directly caused by America's provincial chauvinist attitude toward the world standard SI system of units widely called "the metric system."

In 1960 the international "General Conference on Weights and Measures" met in Paris and named the Metric System of units (based on the **meter**, **kilogram**, **second**, **ampere**, **kelvin** and **candela**) the "International System of Units." The Conference also established the abbreviation "SI" as the official abbreviation, to be used in all languages.

The SI units are used to derive units of measurement for all physical quantities and phenomena.

There are seven SI "base units," from which most other units are derived.

These are:

NAME	*SYMBOL*	*QUANTITY*
ampere	A	electric current
candela	cd	luminous intensity
meter	m	length
kelvin	K	thermodynamic temperature
kilogram	kg	mass
mole	mol	amount of substance
second	s	time

The ***derived units*** with their derivative equations:

NAME	***SYMBOL***	***QUANTITY***	***DERIVED BY***
coulomb	**C**	**quantity of electricity**	**A•s**
farad	**F**	**capacitance**	**A•s/V**
henry	**H**	**inductance**	**V•s/A**
hertz	**Hz**	**frequency**	**s^{-1}**
joule	**J**	**energy or work**	**N•m**
lumen	**lm**	**luminous flux**	**cd•sr**
lux	**lx**	**illuminance**	**lm/m^2**
newton	**N**	**force**	**$kg•m/s^2$**
ohm	Ω (upper case omega)	**electric resistance**	**V/A**
pascal	**Pa**	**pressure**	**N/m^2**
radian	**rad**	**plane angle**	**arc length = radius**
siemens	**S**	**conductance**	**Ω^{-1}**
steradian	**sr**	**solid angle**	**square on the surface of a sphere whose sides = arc length=radius**
tesla	**T**	**magnetic flux density**	**Wb/m^2**
voltampere	**VA**	**apparent power**	**V•A**
volt	**V**	**potential difference**	**W/A**
watt	**W**	**power**	**J/s**
weber	**Wb**	**magnetic flux**	**V•s**

***Supplementary units*:**

NAME	***SYMBOL***	***QUANTITY***
ampere turn	**At**	**magnetomotive force**
ampere per meter	**A/m**	**magnetic field strength**
candela per square meter	**cd/m^2**	**luminance**
joule per kelvin	**J/K**	**entropy**
joule per kilogram kelvin	**J/(kg•K)**	**specific heat capacity**
kilogram per cubic meter	**kg/m^3**	**mass density (density)**
lumen per watt	**lm/W**	**luminous efficacy**
lumen second	**lm/s**	**quantity of light**
meter per second	**m/s**	**speed, velocity**
meter per second per second	**m/s^2**	**acceleration**
square meter	**m^2**	**area**
cubic meter	**m^3**	**volume**
square meter per second	**m^2/s**	**kinematic viscosity**
newton-second per square meter	**$N•s/m^2$**	**dynamic viscosity**
1 per second	**s-**	**radioactivity**
radian per second	**rad/s**	**angular velocity**
radian per second per second	**rad/s^2**	**angular acceleration**
volt per meter	**V/m**	**electric field strength**
watt per meter kelvin	**W/(m•K)**	**thermal conductivity**
watt per steradian	**W/sr**	**radiant intensity**
watt per steradian square meter	**$W/(sr•m^2)$**	**radiance**

DEFINITIONS OF SI UNITS

Note: the wording used by the Conference may seem stilted, but it is carefully chosen for semantic clarity to make the definitions unambiguous.

The **ampere** is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.

The **candela** is the luminous intensity, in the perpendicular direction, of a surface of 1/600,000 square meter of a blackbody at the temperature of freezing platinum under a pressure of 101,325 newtons per square meter.

The **coulomb** is the quantity of electricity transported in 1 second by the current of 1 ampere.

The **farad** is the capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

The **henry** is the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

The **joule** is the work done when the point of application of 1 newton is displaced a distance of 1 meter in the direction of the force.

The **kelvin**, the unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

The **kilogram** is the unit of mass; it is equal to the mass of the international prototype of the kilogram. (The international prototype of the kilogram is a particular cylinder of platinum-iridium alloy which is preserved in a vault at Sevres, France, by the International Bureau of Weights and Measures.)

The **lumen** is the luminous flux emitted in a solid angle of 1 steradian by a uniform point source having an intensity of 1 candela.

The **meter** is the length equal to 1,650,763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

The **mole** is the amount of substance of a system which contains as many elementary entities as there are carbon atoms in 12 grams of carbon 12. The elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.

The **newton** is that force which gives to a mass of 1 kilogram an acceleration of 1 meter per second per second.

The **ohm** is the electric resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

The **radian** is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

The **second** is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

The **steradian** is the solid angle which, having its vertex in the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

The **volt** is the difference of electric potential between two points of a conducting wire carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

The **watt** is the power which gives rise to the production of energy at the rate of 1 joule per second.

The **weber** is the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.

SI PREFIXES: The names of multiples and sub-multiples of any SI unit are formed by application of the prefixes:

MULTIPLIER	PREFIX	SYMBOL	×1 is equal to:	spoken magnitude
10^{24}	yotta	Y	1 000 000 000 000 000 000 000 000	septillion
10^{21}	zetta	Z	1 000 000 000 000 000 000 000	sextillion
10^{18}	exa	E	1 000 000 000 000 000 000	quintillion
10^{15}	peta	P	1 000 000 000 000 000	quadrillion
10^{12}	tera	T	1 000 000 000 000	trillion
10^{9}	giga	G	1 000 000 000	billion
10^{6}	mega	M	1 000 000	million
10^{3}	kilo	k	1 000	thousand
10^{2}	hecto	h	100	hundred
10^{1}	deka	da	10	ten
10^{0}	*(unity)*	*(none)*	1	one
10^{-1}	deci	d	.1	tenth
10^{-2}	centi	c	.01	hundredth
10^{-3}	milli	m	.001	thousandth
10^{-6}	micro	µ	.000 001	millionth
10^{-9}	nano	n	.000 000 001	billionth
10^{-12}	pico	p	.000 000 000 001	trillionth
10^{-15}	femto	f	.000 000 000 000 001	quadrillionth
10^{-18}	atto	a	.000 000 000 000 000 001	quintillionth
10^{-21}	zepto	z	.000 000 000 000 000 000 001	sextillionth
10^{-24}	yocto	y	.000 000 000 000 000 000 000 001	septillionth

Some examples:

Ten-thousand grams is written **10 kg**

20,000 cycles per second is written **20 kHz**

Ten million hertz is written **10 MHz**

250 billionths weber per meter of magnetic flux is written **250 nWb/m**

30 millionths of a gram is written 30 µg — **never use mcg or mcgs**.

(NOTE: the 'micro' symbol **µ** is ASCII 181 in most fonts. To insert **µ** in text, press and hold the ALT key while typing 0181.

The term **Mcg**, is not only an old depricated term, but could be misinterpreted as a million grams (1 metric ton). Used in medicines for an amount that should have been micrograms of chemicals in a pill, this represents a mass that would squash the patient.

There is never any need to pluralize unit numerators by adding an 's' (e.g. mcgs), which can be easily confused with seconds. Never mix terms such as msec for milliseconds (ms), and spell out terms such as megadollars, but not Mdollars – for obvious reasons.

Always use fewer than 1000 units with SI prefixes; "1000MGS" is advertising hyperbole, as well as being both incorrectly spaced and spelled in this example. 1000 milligrams is one gram, and is properly written **1 g** only. One megagram equals one metric ton (2205 pounds). A long way, in any case, from one gram.

SI prefixes and units should be written together and then set off by a single space from their numerators. For example; use the form **35 mm** but not ~~35mm~~. Use **1 kHz** but not ~~1k Hz~~. Use **47 kΩ** but not ~~47k Ω~~**.** Use **120 GB** but not ~~120GB~~, and so on.

Always separate the numerator of a unit from its prefix and/or unit name, but do not separate the prefix and name.

In any ambiguous cases, SI units and numerators <u>may be spelled out longhand</u>, e.g., "gigabytes" or "nanometers."

When writing use standard SI formats and be consistent. Consult National Bureau of Standards (now N.I.S.T.) publication 330, (1977) for details on usage.

Never combine SI prefixes directly, that is, write 10^{-10} farads as 100 pF but never ~~0.1 micro-microfarads (μμF)~~.

The rule for unit names written longhand is that the name is always lower case, but when abbreviating, ***the first letter is upper case if the unit is named after a person and lower case if it is not.***

Examples:

V = volt for Volta

F = farad for Faraday

T = tesla for Tesla

and so on.

m = meter

s = second

rad = radian

l = liter,

and so on.

Revolutions per minute should be written as r/min. or rev./min., miles per hour should be written as mi./hr., and inches per second should be written as in./s and so on.

Note: the proper name for the non-SI term liter is dm^3 (cubic decimeter). The liter designation should always be **l** rather than **L** as upper case use violates the naming convention for abbreviations. There was no one named Liter, and the use of **L** could be confused with the electrical inductance term used for coils.)

A pamphlet describing SI units, conversions between SI units, older CGS and MKS units and units outside the SI system of units is available in the form of NASA Publication SP-7012, (1973). Inquire to the U.S. Government Printing Office in Pueblo, Colorado for this and other publications about SI units, their use and history, and to the National Bureau of Standards (now, National Institute of Standards and Technology [N.I.S.T.]) for publication 330, (1977) for details on usage.

COMPUTER RELATED EXCEPTIONS:

The computer industry and most tangential organizations notoriously disregard standard terms usage.

The same rules apply to bits, bytes, speeds and such.

Computer terms:

Digital computers manipulate on and off states (voltage present and no voltage present) in processor chips, circuit boards and cables. A single switch state of on or off is called a digital bit. Because there are only two state possibilities, this type of operation is "binary" [Middle English *binarie*, from Late Latin *binarius*, from Latin *bini*, two by two.]

byte = B = eight binary bits (digits, or switch states)

bit = b = one 0 or 1 switch state (on or off)

nybble = four binary digits or half of an eight-bit byte.

hertz (clock frequency) = Hz = state changes or operations per second

mickey = mouse movements = smallest movement handled by a mouse (typically 8 pixels per horizontal mickey)

Thousands, millions, billions and trillions still take their origins from the scientific world community, thus megabytes are properly written **MB** while kilobytes are properly written **kB**, but not "~~KB~~" as is frequently seen. Text spacing rules ALWAYS apply: **500 GB** but not "~~500GB~~," **300 MHz** but not "~~300MH~~" and **never** "~~300mHz~~" or "~~300 mHz~~" —which would signify 300 millihertz or one event every 0.3 second rather than 300 million events per second — a billion-to-one error.

1000 bits per second = **kb/s**

1000 bytes per second = **kB/s**

1,000,000 bits per second = **Mb/s**

1,000,000 bytes per second = **MB/s**

250 gigabytes hard disk storage = **250 GB**

300 gigahertz CPU speed = **300 GHz**

And so on.