SI UNITS AND SOME CONVERSION FACTORS

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1. Introduction

Throughout the centuries, many measurement systems have been developed. Evolving from numerous origins, they have been modified by custom and local adaptations. Most therefore lack rational structure. The Imperial system, which uses measurements such as the yard, quart, and pound, is an example of poorly correlated units.

About 200 years ago, France invented the metric system to bring order to its measures. Although strongly opposed at first, this new system proved effective and gained popularity, so much so that 98 per cent of the world's population now lives in countries that have adopted or are changing to the metric system. These countries include the USA, where conversion to SI is further advanced than is superficially apparent

Finally, in 1960, the International System of Units was established as a result of a long series of international discussions. This modernized metric system, called SI from the French name *le Systeme International d'unites* replaced all former systems of measurement, including former versions of the metric system. Canada, too, decided to adopt SI.

SI includes familiar metric units such as the metre and kilogram. There are, however, a number of changes from former metric systems. For instance, the centigrade temperature scale is called the Celsius scale This is a change in name only, so that 20°C, formerly read as "twenty degrees centigrade" is now read as "twenty degrees Celsius". No change occurs in the scale, only in the name. Water still freezes at 0°C and boils at

100°C. This kind of change is not difficult for those who are familiar with older metric systems. Other changes which are of a more specialized nature will be examined later.

Before universal approval of SI, the Imperial and various metric systems were the prevalent expressions of measurement in the world.
The use of SI has eliminated confusion by:

1. Providing a coherent system of units.
2. Ensuring that quantities and units are uniform in concept and style.
3. Minimizing the number of multiples and submultiples in use.

2. Names and symbols for basic SI units

SI has three types of units:

- Base units;
- Derived units;
- Supplementary units.

2.1. SI base units

SI is founded on seven units called "base units". All derived units are a variation of these seven units. ANY PHYSICAL QUANTITY CAN BE EXPRESSED IN SI BY APPROPRIATE COMBINATIONS OF THE BASE UNITS; as given in Table 1.

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

Table 1. SI base units.

2.2. SI derived units

Other quantities, called derived quantities, are defined in terms of the seven base quantities via a system of quantity equations. The SI derived units for these derived quantities are obtained from these equations and the seven SI base units. Examples of such SI derived units are given in Table 2, where it should be noted that the symbol 1 for quantities of dimension 1 such as mass fraction is generally omitted.

Derived quantity	**SI derived unit**	
	Name	**Symbol**

Area	square meter	m^2
Volume	cubic meter	m^3
Speed, velocity	meter per second	$m\ s^{-1}$
Acceleration	meter per second squared	$m\ s^{-2}$
Wave number	reciprocal meter	m^{-1}
Mass density	kilogram per cubic meter	$kg\ m^{-3}$
Specific volume	cubic meter per kilogram	$m^3\ kg^{-1}$
Current density	ampere per square meter	$A\ m^{-2}$
Magnetic field strength	ampere per meter	$A\ m^{-1}$
Amount-of-substance concentration	mole per cubic meter	$mol\ m^{-3}$
Luminance	candela per square meter	$cd\ m^{-2}$
Mass fraction	kilogram per kilogram, which may be represented by the number 1	$kg\ kg^{-1} = 1$

Table 2. SI derived units.

2.3. Supplementary Units

For ease of understanding and convenience, 21 SI derived units have been given special names and symbols, as shown in Table 3.

Derived quantity	**SI derived unit**			
	Name	**Symbol**	**Expression in terms of other SI units**	**Expression in terms of SI base units**
Plane angle	radian[a]	rad	-	$m\ m^{-1} = 1$[b]
Solid angle	steradian[a]	sr[c]	-	$m^2\ m^{-2} = 1$[b]
Frequency	hertz	Hz	-	s^{-1}
Force	newton	N	-	$m\ kg\ s^{-2}$
Pressure, stress	pascal	Pa	$N\ m^{-2}$	$m^{-1}\ kg\ s^{-2}$
Energy, work, quantity of heat	joule	J	N-m	$m^2\ kg\ s^{-2}$
Power, radiant flux	watt	W	$J\ s^{-1}$	$m^2\ kg\ s^{-3}$
Electric charge, quantity of electricity	coulomb	C	-	s A
Electric potential difference, electromotive force	volt	V	$W\ A^{-1}$	$m^2\ kg\ s^{-3}\ A^{-1}$
Electrical capacitance	farad	F	$C\ V^{-1}$	$m^{-2}\ kg^{-1}\ s^4\ A^2$
Electric resistance	ohm	Ω	$V\ A^{-1}$	$m^2\ kg\ s^{-3}\ A^{-2}$
Electric conductance	siemens	S	$A\ V^{-1}$	$m^{-2}\ kg^{-1}\ s^{-3}\ A^2$
Magnetic flux	weber	Wb	V s	$m^2\ kg\ s^{-2}\ A^{-1}$
Magnetic flux density	tesla	T	$Wb\ m^{-2}$	$kg\ s^{-2}\ A^{-1}$
Inductance	henry	H	Wb/A	$m^2\ kg\ s^{-2}\ A^{-2}$
Celsius temperature	degree Celsius	C	-	K
Luminous flux	lumen	Lm	cd sr[c]	$m^2\ m^{-2}\ cd = cd\ sr$
Illumination	lux	lx	$lm\ m^{-2}$	$m^2\ m^{-4}\ cd = m^{-2}\ sr\ cd$
Activity (of a radionuclide)	becquerel	Bq	-	s^{-1}

Derived quantity	**SI derived unit**			
	Name	**Symbol**	**Expression in terms of other SI units**	**Expression in terms of SI base units**
Absorbed dose, specific energy (imparted), kerma	gray	Gy	$J\ kg^{-1}$	$m^2\ s^{-2}$
Dose equivalent[d]	sievert	Sv	$J^{-1} kg$	$m^2\ s^{-2}$

Table 3. SI derived units with special names and symbols.

[a] The radian and steradian may be used advantageously in expressions for derived units to distinguish between quantities of a different nature but of the same dimension; some examples are given in Table 4.

[b] In practice, the symbols rad and sr are used where appropriate, but the derived unit "1" is generally omitted.

[c] In photometry, the unit name steradian and the unit symbol sr are usually retained in expressions for derived units.

[d] Other quantities expressed in sieverts are ambient dose equivalent, directional dose equivalent, personal dose equivalent, and organ equivalent dose.

3. Special names and symbols for derived SI units

Derived quantity	**SI derived unit**	
	Name	**Symbol**
Dynamic viscosity	pascal second	Pa s
Moment of force	newton meter	N m
Surface tension	newton per meter	$N\ m^{-1}$
Angular velocity	radian per second	$rad\ s^{-1}$
Angular acceleration	radian per second squared	$rad\ s^{-2}$
Heat flux density, irradiance	watt per square meter	$W\ m^{-2}$
Heat capacity, entropy	joule per Kelvin	J K
Specific heat capacity, specific entropy	joule per kilogram Kelvin	$J\ kg^{-1}\ K^{-1}$
Specific energy	joule per kilogram	$J\ kg^{-1}$
Thermal conductivity	watt per meter Kelvin	$W\ m^{-1}\ K^{-1}$
Energy density	joule per cubic meter	$J\ m^{-3}$
Electric field strength	volt per meter	$V\ m^{-1}$
Electric charge density	coulomb per cubic meter	$C\ m^{-3}$
Electric flux density	coulomb per square meter	$C\ m^{-2}$
Permittivity	farad per meter	$F\ m^{-1}$
Permeability	henry per meter	$H\ m^{-1}$
Molar energy	joule per mole	$J\ mol^{-1}$
Molar entropy, molar heat capacity	joule per mole kelvin	$J\ mol^{-1}\ K^{-1}$
Exposure (X and γ rays)	coulomb per kilogram	$C\ kg^{-1}$
Absorbed dose rate	gray per second	$G\ s^{-1}$
Radiant intensity	watt per steradian	$W\ sr^{-1}$
Radiance	watt per square meter steradian	$W\ m^{-2}\ sr^{-1}$

Table 4. Examples of SI derived units whose names and symbols include SI derived units with special names and symbols.

4. Prefixes for SI units

The 20 SI prefixes used to form multiples and submultiples of SI units are given in Table 5.

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

Table 5. SI prefixes.

It is important to note that the kilogram is the only SI unit with a prefix as part of its name and symbol. Because multiple prefixes may not be used, in the case of kilogram the prefix names of Table 5 are used with the unit name "gram" and the prefix symbols are used with the unit symbol "g". With this exception, any SI prefix may be used with any SI unit, including the degree Celsius and its symbol C.

Example 1: 10^{-6} kg = 1 mg (one milligram),
But not10^{-6} kg = 1 µkg (one microkilogram)

Because the SI prefixes strictly represent powers of 10, they should not be used to represent powers of 2. Thus, one kilobit, or 1 kbit, is 1000 bits and not 2^{10} = 1024 bit. New prefixes for binary multiples have been proposed by Technical Committee 25 of the international Electrotechnical Commission (IEC) for use in information technology to alleviate this ambiguity, and they are currently under consideration internationally.

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Bibliography and Suggestions for further study

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