Guide to Units

2008 Edition

Cambridge University Engineering Department

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Guide to Units, Unit Symbols and Abbreviations

The units used in the Department will be basically those of the Système International (SI units) listed below. Additional non-SI and British units may be encountered. Of these, only those marked with an asterisk * can be expected to be used regularly; the others may be used in teaching courses for purposes of familiarisation. If they are used, conversion into the equivalent SI units should generally be made as the first step in any calculation.

Definitions and conversion factors can be found in the Appendices (which are based on R.W. Haywood's "Thermodynamic Tables in SI (metric) Units", CUP, 3rd edition, 1990).

Basic Physical Quantities and Units

Quantity	SI		Additional (non-SI)		
	Name	Symbol	Name	Symbol	Definition
Length	metre	m	* ångstrom micron inch foot	Å μm " '	10^{-10} m 10^{-6} m
Area		m^2	hectare	ha	10^4 m^2
Volume		m^3	litre	L or l	10^{-3} m^3
Mass†	kilogram	kg	* gram * tonne	g t	10^{-3} kg 10^3 kg
Amount of substance	kilomole (mole)	kmol (mol)			
Time	second	s	* minute * hour year	min h a or yr	60 s 3600 s
Plane angle	radian	rad	* degree minute second	° ' "	
Solid angle	steradian	sr			
Speed‡		$m\,s^{-1}$		$km\,h^{-1}$	
Angular speed		$rad\,s^{-1}$	*	$rev\,min^{-1}$	

† The kilogram is the SI unit of mass and only this unit gives a coherent system. Care must be taken when other multiples are used since it is not practical to use the logical "millikilogram" for gram. Calculations should always be made in terms of kilograms to obtain maximum benefit from the coherence of the SI scheme.

‡ Note that the term *speed* should be used for a *scalar* and the term *velocity* for a *vector*.

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Prefixes for Multiples and Sub-multiples

Name	Prefix	Value
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}

Name	Prefix	Value
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Also in frequent use		
Name	Prefix	Value
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}

Great care should be exercised when using these prefixes:

- The prefix is written adjacent to the abbreviation of the unit. Unit abbreviations should be separated with a space or a point, e.g. mK is a millikelvin but m K or m.K is metre kelvin.
- When a multiple of a basic unit is raised to a power, the power applies to the *whole multiple* and not to the basic unit alone, e.g. $1\,\text{mm}^3$ means $1\,(\text{mm})^3 = 10^{-9}\,\text{m}^3$, *not* $1\,\text{m}(\text{m})^3 = 10^{-3}\,\text{m}^3$.

System Variables and Properties

Mechanical

Quantity	SI			Additional (non-SI)		
	Name	Symbol	Definition	Name	Symbol	Definition
Force	newton†	N	kg m s^{-2}	dyne	dyn	g cm s^{-2}
Torque		N m				
Work, Energy	joule	J	N m	erg	erg	dyn cm
Power	watt	W	J s^{-1}			
Pressure	pascal	Pa	N m^{-2}	* bar	bar	10^5 Pa
Stress	pascal	Pa			N mm^{-2}	MN m^{-2}
Dynamic viscosity		Pa s	$\text{kg m}^{-1}\,\text{s}^{-1}$	poise	P	$\text{g cm}^{-1}\,\text{s}^{-1}$
Kinematic viscosity		$\text{m}^2\,\text{s}^{-1}$		stokes	St	$\text{cm}^2\,\text{s}^{-1}$

† Units named for an historical figure nevertheless start with a lower case letter; their symbols with an upper case letter.

Thermal

Quantity	SI			Additional (non-SI)		
	Name	Symbol	Definition	Name	Symbol	Definition
Temperature[‡]	kelvin	K		rankine	R	$T_R = 1.8T_K$
Energy, Work, Heat	joule	J	N m	* kilowatt-hour	kW h	3.6 MJ
Specific heat capacity		$\mathrm{J\,kg^{-1}\,K^{-1}}$				
Specific entropy		$\mathrm{J\,kg^{-1}\,K^{-1}}$				
Thermal conductivity		$\mathrm{W\,m^{-1}\,K^{-1}}$				
Heat transfer coefficient		$\mathrm{W\,m^{-2}\,K^{-1}}$				
Surface tension		$\mathrm{N\,m^{-1}}$				

‡ The Celcius temperature scale (°C) is defined as $T - 273.15$, written as t °C. *Differences* of Celcius temperatures should be shown as kelvin, K, but are commonly seen as °C.

Illumination

Quantity	SI			Additional (non-SI)		
	Name	Symbol	Definition	Name	Symbol	Definition
Luminous intensity	candela	cd				
Luminance		$\mathrm{cd\,m^{-2}}$				
Luminous flux	lumen	lm	cd sr			
Illumination	lux	lx	$\mathrm{lm\,m^{-2}}$			

Atomic Physics

(named units significant to health and safety)

Quantity	SI			Additional (non-SI)		
	Name	Symbol	Definition	Name	Symbol	Definition
Radioactivity	becquerel	Bq	disintegration $\mathrm{s^{-1}}$	curie	Ci	37 GBq
Absorbed dose	gray	Gy	$\mathrm{J\,kg^{-1}}$	rad	rad	10^{-2} Gy
Effective dose, Equivalent dose	sievert	Sv	$\mathrm{J\,kg^{-1}}$	rem	rem	10^{-2} Sv

Electrical

Quantity	SI			Additional (non-SI)		
	Name	Symbol	Definition	Name	Symbol	Definition
Energy	joule	J	N m	* kilowatt-hour * electronvolt	kW h eV	3.6 MJ 0.1602 aJ
Power	watt	W	$J\,s^{-1}$			
Current	ampere	A				
Charge	coulomb	C	A s			
Potential, e.m.f.	volt	V				
Resistance	ohm	Ω	$V\,A^{-1}$			
Conductance	siemens	S	Ω^{-1}	mho	S	
Capacitance	farad	F	$C\,V^{-1}$			
Inductance	henry	H	$V\,s\,A^{-1}$			
Magnetising force		$A\,m^{-1}$		oersted	Oe	$10^3/4\pi$ H
Magnetic flux	weber	Wb	V s			
Magnetic flux density	tesla	T	$Wb\,m^{-2}$	gauss	Gs	10^{-4} T
Frequency	hertz	Hz	s^{-1}	cycles per second	s^{-1}	

Abbreviations for some Electrical terms

Direct current	d.c.	Alternating current	a.c.
Root mean square	r.m.s.	Potential difference	p.d.
Electromotive force	e.m.f.	Magnetomotive force	m.m.f.
Apparent power	VA	Reactive power	var

G.T. Parks, September 2001
Adapted from R.J.R., October 1994
Modified from J.D.L., October 1992

Appendix A

Definitions of SI Units

The units quoted below are the basic units to the *Système International d'Unités.* The abbreviation CGPM refers to the *Conférence Générale des Poids et Mesures.*

Length: The unit of length called the *metre* is the length of the path travelled by light in vacuum during a time interval of **1/299 792 458** of a second (17^{th} CGPM, 1983).

Mass: The unit of mass called the *kilogram* is the mass of the international prototype which is the in the custody of the *bureau International des Poids et Mesures* (BIPM) at Sèvres, near Paris, France (3^{rd} CGPM, 1901).

Time: The unit is time called 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 caesium 133 atom (13^{th} CBPM, 1967).

Thermodynamic temperature: The unit of thermodynamic temperature called the *kelvin* is the fraction **1/273.16** of the thermodynamic temperature of the triple point of water (13^{th} CGPM, 1967).

Electric current: The unit of electric current called 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** metre apart in a vacuum, would produce between these conductors a force equal to $\mathbf{2 \times 10^{-7}}$ newton per metre of length (9^{th} CGPM, 1948).

Luminous intensity: The unit of luminous intensity called the *candela* is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $\mathbf{540 \times 10^{12}}$ hertz and that has a radiant intensity in that direction of **(1/683)** watt per steradian (16^{th} CGPM, 1979).

Amount of substance: The *mole* is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12 (14^{th} CGPM, 1971).

Note: When the *mole* is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.

Appendix B

Definitions of Some Derived SI Units

Force: The unit of force called the *newton* is that force which, when applied to a body having a mass of 1 kilogram, gives it an acceleration of 1 metre per second per second. (Thus 1 N = 1 kg m/s^2.)

Pressure: The unit of pressure called the *pascal* is equal to 1 newton per square metre. (Thus 1 Pa = 1 N/m^2.)

Energy: The unit of energy call the *joule* is the work done when the point of application of a force of 1 newton is displaced through a distance of 1 metre in the direction of the force. (Thus 1 J = 1 N m.)

Power: The unit of power called the *watt* is equal to 1 joule per second.

Electric charge: The unit of electric charge called the *coulomb* is the quantity of electricity transported in 1 second by a current of 1 ampere.

Electric potential: The unit of electric potential call the *volt* is the difference of 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.

Appendix C

Definitions of Some Non-SI Metric Units

Each equation serves to define **exactly** the unit appearing on the left-hand side of the equation.

Length:

1 micron $= 10^{-6}$ m $= 1\mu$m
1 ångström (Å) $= 10^{-10}$ m

Volume:

1 litre (l) $= 1000$ cm^3 $= 1$ dm^3 $= 10^{-3}$ m^3

Note: this is the litre of the 12th CGPM, 1964. It is not identical to that previously defined by the 3rd CGPM, 1901, as the volume occupied by a mass of 1 kg of pure water at its temperature of maximum density and under pressure of 1 standard atmosphere.
1 litre (1901) $\approx 1.000\,028 \times 10^{-3}$ m^3. (Up to 1976, the 1901 litre was used in the definition of the UK gallon. To the number of significant figures quoted in Appendix D, this redefinition involved no change in magnitude.)

Mass:

1 tonne, or metric ton (t) $= 10^3$ kg

Force:

1 dyne (dyn) $= 1$ g cm/s^2 $= 10^{-5}$ N
1 kilogram force (kgf) $= 9.806\,65$ N

Note: This is that force which, when applied to a body having a mass of 1 kg, given an acceleration equal to the international standard acceleration of 9.806 65 m/s^2. In Germany, the *kilogram force* is also given the name *kilopond* (kp).

Pressure, stress:

1 bar (bar) $= 10^5$ N/m^2
1 std. atmosphere (atm) $= 1.013\,25$ bar $= 0.101\,325$ MN/m^2
1 tech. atmosphere (at) $= 1$ kgf/cm^2
$= 0.980\,665$ bar $= 0.098\,0665$ MN/m^2

Note: This unit is also sometimes given the unit symbol *ata.*

1 torr $= 1/760$ atm ≈ 133.0 N/m^2
≈ 1 mmHg to within 1 part in 7 million
1 mmHg $= 13.5951 \times 9.806\,65$ N/m^2
≈ 133.0 N/m^2

Note: This is the pressure that would be exerted by a 1mm column of mercury of density 13.5951 g/cm^3 under a gravitational acceleration equal to the international standard acceleration of 9.806 65 m/s^2.

Energy:

1 erg $= 1$ dyn cm $= 10^{-7}$ N m $= 10^{-7}$ J
1 calorie (cal) $= 4.1868$ J

Note: This is the *International Table calorie*, defined by the Fifth International Conference on the Properties of Steam, 1956.

1 thermochemical calorie $= 4.184$ J

Dynamic viscosity:

1 poise (P) $= 1$ g/cm s $= 1$ dyn s/cm^2
$= 0.1$ kg/m s $= 0.1$ N s/m^2

Kinematic viscosity:

1 stokes (St) $= 1$ cm^2/s $= 10^{-4}$ m^2/s

Appendix D

British Units — Definitions and Conversion Factors

Definitions of Some Basic Units

Each equation serves to define **exactly** the unit appearing on the left-hand side of the equation.

Length:	1 yard (yd) = 0.9144 m
Mass:	1 pound (lb) = 0.453 592 37 kg
Force:	1 poundal (pdl) = 1 lb ft/s^2
	1 pound force (lbf) = $\frac{9.806\ 65}{0.3048}$ pdl (≈ 32.2 pdl)

Note: This is the force which, when applied to a body having a mass of 1 lb, gives it an acceleration equal to the international standard acceleration of 9.806 65 m/s^2.

Specific energy: 1 Btu/lb = 5/9 cal/g

Note: This equation serves to define the *British Thermal Unit* (Btu). The calorie here is the *International Table calorie* defined in Appendix C.

Conversion Factors for Mechanical Units

Quantity	British Unit	Conversion Factor		SI Unit
Length	1 inch (in)	$= \frac{0.9144 \times 100}{36}$	= 2.54	cm
	1 foot (ft)	$= \frac{0.9144}{3}$	= 0.3048	m
	1 mile (mile)	$= \frac{0.9144 \times 1760}{1000}$	≈ 1.61	km
Mass	1 ounce (oz)	$= \frac{0.453\ 592\ 37 \times 1000}{16}$	≈ 28.35	g
	1 pound (lb)	= 0.453 592 37	≈ 0.4536	kg
	1 hundredweight (cwt)	$= 0.453\ 592\ 37 \times 112$	≈ 50.8	kg
	1 ton (ton)	$= 0.453\ 592\ 37 \times 2240$	≈ 1016	kg
	(1 US short ton	$= 0.453\ 592\ 37 \times 2000$	≈ 907	kg)
Force	1 poundal (pdl)	$= 0.453\ 592\ 37 \times 0.3048$	≈ 0.1383	N
	1 ounce force (ozf)	$= \frac{0.453\ 592\ 37 \times 9.806\ 65}{16}$	≈ 0.278	N
	1 pound force (lbf)	$= 0.453\ 592\ 37 \times 9.806\ 65$	≈ 4.45	N
	1 ton force (tonf)	$= 0.453\ 592\ 37 \times 9.806\ 65 \times 2240$	≈ 9.96	kN
Volume	1 UK gallon (gal)* * Redefined in 1976	= 4.546 091 6	≈ 4.546	dm^3
	(1 US gallon	$= 231 \times (2.54)^3 \times 10^{-3}$	≈ 3.785	dm^3)

Quantity	British Unit	Conversion Factor		SI Unit
Specific volume	1 ft^3/lb	$= \dfrac{(0.3048)^3}{0.453\ 592\ 37} \times 10^3$	≈ 62.43	dm^3/kg
Pressure, stress	1 $tonf/in^2$	$= \dfrac{0.453\ 592\ 37 \times 9.806\ 65}{10^6}\left(\dfrac{12}{0.3048}\right)^2 \times 2240$	≈ 15.44	MN/m^2
	1 lbf/in^2	$= \dfrac{0.453\ 592\ 37 \times 9.806\ 65}{10^3}\left(\dfrac{12}{0.3048}\right)^2$	≈ 6.895	kN/m^2
	1 inHg*	$= 25.4 \times 13.5951 \times 9.806\ 65 \times 10^{-3}$	≈ 3.39	kN/m^2
	1 ftH_2O*	$= 0.3048 \times 9.806\ 65$	≈ 2.99	kN/m^2
Dynamic viscosity	1 lb/ft s = 1 pdl s/ft^2	$= \dfrac{0.453\ 592\ 37}{0.3048}$	≈ 1.488	kg/m s N s/m^2
Kinematic viscosity	1 ft^2/s	$= (0.3048)^2$	≈ 0.0929	m^2/s
Energy	1 ft lbf	$= 0.3048 \times 0.453\ 592\ 37 \times 9.806\ 65$	≈ 1.356	J
Power	1 horsepower (hp)	$= 550 \times 0.3048 \times 0.453\ 592\ 37 \times 9.806\ 65$	≈ 746	W
Specific fuel consumption	1 lb/hp h	$= \dfrac{10^6}{550 \times 0.3048 \times 9.806\ 65 \times 3600}$	≈ 0.169	kg/MJ

* *Note*: These are equal respectively to the pressures that would be exerted by a 1 in column of mercury of density 13.5951 g/cm^3, and by a 1 ft column of water density 1 g/cm^3, under the international standard acceleration of 9.806 65 m/s^2.

Conversion Factors for Thermal Units

Quantity	British Unit	Conversion Factor		SI Unit
Energy	1 Btu	$= \frac{4.1868 \times 0.453\,592\,37}{1.8}$	≈ 1.055	kJ
	1 therm (≡ 10^5 Btu)	$= \frac{4.1868 \times 0.453\,592\,37}{1.8} \times 10^2$	≈ 105.5	MJ
Specific energy	1 Btu/lb	$= \frac{4.1868}{1.8}$	= 2.326	kJ/kg
Specific heat capacity **Specific entropy**	1 Btu/lb R	= 4.1868	≈ 4.19	kJ/kg K
Gas constant	1 ft lbf/lb R	$= 0.3048 \times 9.806\,65 \times 1.8$	≈ 5.38	J/kg K
Thermal conductivity	1 Btu/h ft R	$= \frac{4.1868 \times 0.453\,592\,37}{3.6 \times 0.3048}$	≈ 1.73	W/m K
Heat transfer coefficient	1 Btu/h ft^2 R	$= \frac{4.1868 \times 0.453\,592\,37}{3.6 \times (0.3048)^2}$	≈ 5.68	W/m^2 K

Note: R is here the *rankine* unit of *thermodynamic temperature*, here defined in terms of the *kelvin* by the relation 1 R = (1/1.8) K.