BRITISH STANDARD

BS 350:2004

Conversion factors for units

ICS 01.060; 17.020

Confirmed
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British Standards

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Committees responsible for this British Standard

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British Measurement and Testing Association

City University

Department of Trade and Industry, National Weights and Measures Laboratory

Federation of Small Businesses

Institute of Measurement and Control

Institution of Electrical Engineers

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Foreword

This British Standard has been prepared by Technical Committee SS/7.
It supersedes BS 350-1:1974 which is withdrawn.

BS 350 was first published in 1930, and has been revised on a number of occasions since. It was split into two parts in 1959, Part 1 dealing with the basis of tables and conversion factors, and Part 2, which first appeared in 1962, giving detailed conversion tables for the more frequently used conversions. In 1967 a Supplement (PD 6203) was issued to Part 2, giving additional detailed tables for SI conversions. BS 350-2 was withdrawn in 1981 since many of the tables included in it had become inconsistent with the International System of Units (SI) and the increasing use of pocket calculators was considered to have made such tables, which often required interpolation, obsolete. PD 6203 was withdrawn in 1998.

This revision provides a comprehensive list of conversion factors and notes on their use. The units in about fifty quantities of measurement are given, together with such definitions and information on the derivation of conversion factors as are considered necessary for the purpose. However, as it is now the only part of the standard, it has been returned to its original numbering, BS 350.

In this revision, while interconversion factors between all the important units treated are given, the standpoint from which the various units and conversion factors are discussed is the SI. Very few imperial units remain in official use in the UK. Furthermore, the SI, under the custody of the General Conference of Weights and Measures (CGPM), forms the precise and natural basis for conversion information on units, and offers firm prospects of an international harmonization in unit practice, after which conversion factors will no longer be required. However, it is recognized that many older documents refer to units which are not recommended now, so conversion factors have been retained for many of these.

The standardization function of this standard lies in the provision of conversion factors reliable to a stated accuracy. Other important information is included to help the user to make conversions. BS 350 does not purport to define quantities or units, or to standardize the letter symbols or abbreviations used for units. These matters are dealt with elsewhere, but their mention is necessary here and has been updated with the latest international and national decisions.

Where conversion factors are given in bold type it is to show that they are exact; in general, factors have been rounded to include six significant figures, thus permitting accuracies satisfactory for most practical purposes. The computation of each factor has as far as possible been made from first principles, using eight or more significant figures to minimize the possibilities of errors in rounding. Six-figure factors are unnecessarily precise for many practical purposes, and may be rounded to fewer significant figures as appropriate. The Department of Trade and Industry has asked that users of these conversion factors be reminded that conversions for trade purposes have to be based on the statutory definitions of units in the Weights and Measures Act, 1985 [1].

Submission of additional units for inclusion in a future edition of the standard will be welcomed. These should be sent to the secretary of Technical Committee SS/7 at BSI, 389 Chiswick High Road, London W4 4AL.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

In particular, attention is drawn to the Weights and Measures Act 1985 [1] and associated Orders and Amendments.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 105 and a back cover.

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1 Scope

This standard provides conversion factors for units of measurement for a number of quantities, which are, or have been, in general use in engineering, industry and trade. The subjects covered are, broadly, metrology, mechanics and heat; the standard does not deal with purely electrical units.

NOTE 1 SI units are normally recommended. However, in certain circumstances use of particular units is required by legislation.

NOTE 2 Electrical and light units are given in BS 5775-5 and in BS 5775-6, respectively.

NOTE 3 A commentary on imperial and metric systems of measurement and units is given in Annex A.

2 Number

2.1 The following prefixes, with meaning, name and symbol as shown in Table 1, are used to denote decimal multiples or submultiples of (metric) units. These prefixes developed in conjunction with the metric system, and are authorized as "SI prefixes".

Table 1 — Prefixes denoting decimal multiples or submultiples

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

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2.2 The scientific convention is now to use the system shown in Table 2.

Table 2 — Meaning of million, billion, trillion, etc.

Term	Meaning	Corresponding decimal factor
million	thousand × thousand	10^6
billion	thousand × million	10^9
trillion	million × million	10^{12}
quadrillion	million × billion	10^{15}

2.3 The former convention in the UK was that one billion was 10^{12}, one trillion 10^{18}, one quadrillion 10^{24} etc. Some people still use this convention. In view of the differences between the former and the current practice, ambiguities can easily arise with the words "billion", "trillion" and "quadrillion", etc., therefore their use should be avoided.

3 Length

3.1 The SI unit of length is the metre (symbol m). It is one of the base units of the SI and is the length of the path travelled by light in vacuum during a time interval of **1/299 792 458** of a second.

3.2 Multiples and submultiples of the metre are formed by using any of the SI prefixes given in **2.1**; kilometre (km), decimetre (dm), centimetre (cm), millimetre (mm) and micrometre (µm) are common examples. An alternative term for the micrometre, abrogated by the CGPM but still in common use, is "micron". The symbol µ, associated in the past with the micron, is incorrect; µm should be used.

3.3 Some units of length having associations with the metric system but not forming part of the SI are:

			Refer to note
1 ångström (Å)	=	10^{-10} m	—
1 fermi (f, fm)	=	10^{-15} m	—
1 nautical mile (international) (n mile)	=	**1 852** m	—
1 astronomical unit (AU)	=	$1.496\ 00 \times 10^{11}$ m	1
1 parsec (pc)	=	$3.085\ 68 \times 10^{16}$ m	2
	=	3.262 l.y.	
1 light year (l.y.)	=	$9.460\ 528 \times 10^{15}$ m	3

3.4 The definitive UK (or imperial) and US unit of length is the yard, legally defined (since 1959 in the USA and since 1963 in the UK) as follows:

1 yard = **0.914 4** m

3.5 The connection between multiples and submultiples of the yard is indicated in the following table of named UK and US units of length.

						Refer to note
			(1 in	=	**0.025 4** m)	—
1 foot (ft)	=	12 inches (in)	(1 ft	=	**0.304 8** m)	4
1 yard (yd)	=	3 feet (ft)	(1 yd	=	**0.914 4** m)	—
1 chain	=	22 yards (yd)	(1 chain	=	**20.116 8** m)	5
1 furlong	=	10 chains	(1 furlong	=	**201.168** m)	—
1 mile	=	8 furlongs	(1 mile	=	**1 609.344** m)	6

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3.6 Some less usual, or more specialized, UK and US named units of length, which are not recommended, are:

							Refer to note
1 micro-inch (µin)	=	10^{-6} in	=	**0.025 4** µm	=	**25.4** × 10^{-9} m	—
1 thou	=	10^{-3} in	=	**25.4** µm	=	**25.4** × 10^{-6} m	7
1 mil	=	10^{-3} in	=	**25.4** µm	=	**25.4** × 10^{-6} m	8
1 point	=	$\frac{1}{72}$ in (approx)			=	0.351 mm (approx.)	9
1 iron	=	$\frac{1}{48}$ in			=	0.529 167 mm	10
1 line	=	$\frac{1}{40}$ in			=	**0.635** mm	11
1 line or ligne	=	$\frac{1}{12}$ in			=	2.116 67 mm	12
1 em	=	$\frac{1}{6}$ in			=	4.233 33 mm	13
1 hand	=	4 in			=	**10.16** cm	14
1 link	=	$\frac{1}{100}$ chain	=	0.66 ft	=	**0.201 168** m	—
1 US survey foot	=	$\frac{1}{0.999\,998}$ ft	=	$\frac{12}{39.37}$ m	=	0.304 801 m	—
1 fathom	=	6 ft			=	**1.828 8** m	—
1 rod, pole, or perch	=	5½ yd			=	**5.029 2** m	15
1 engineer's chain	=	100 ft			=	**30.48** m	—
1 cable-length		—				—	16
1 nautical mile (UK)	=	6 080 ft			=	1 853.18 m	17
1 telegraph nautical mile	=	6 087 ft			=	1 855.32 m	—

Notes on Clause 3

NOTE 1 Approximately the mean distance between the Sun and the Earth.

NOTE 2 The distance at which 1 AU subtends an angle of 1 second (1″).

NOTE 3 Approximate distance travelled by light in 1 year.

NOTE 4 An exception is the US survey foot, shown in **3.6**.

NOTE 5 Commonly called Gunter's chain in the USA.

NOTE 6 Also known as a statute mile. There is no recognized abbreviation for mile and the complete word "mile" is used as the unit symbol.

NOTE 7 Colloquial, for one-thousandth of an inch.

NOTE 8 Colloquial, for one-thousandth of an inch. For other meanings of mil see **4.5**, **5.5** and Clause **8**, Note 2.

NOTE 9 Printing trade. (Originally defined by 83 picas = 83 × 12 points = 35 cm.)

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NOTE 10 Boot and shoe trade.

NOTE 11 Button trade.

NOTE 12 Watch trade.

NOTE 13 Printing trade.

NOTE 14 Height of horses.

NOTE 15 Obsolescent.

NOTE 16 A nautical term not precisely defined. In its most general concept it is equal to one-tenth of an unspecified nautical mile, but other values have been used, including the "US Navy" value 120 fathoms (720 ft), the "Ordinary" definition 100 fathoms (600 ft), and "Royal Navy" 608 ft. In view of the scope for confusion, the use of this term is deprecated.

NOTE 17 Also known as the "nautical mile (British)" or "Admiralty nautical mile". In 1995 The Units of Measurement Regulations [2] redefined the nautical mile (UK) in metric terms as 1 853 m exactly (approximately 6 079.4 ft). The nautical mile (UK) is now obsolete as the international nautical mile has been adopted in the UK.

For conversion factors for a number of units of length see Table 3.

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Table 3 — Length

Exact values are printed in bold type

	metre m	inch[a] in	foot ft	yard yd	chain	furlong	mile	fathom	nautical mile (UK)[b]	nautical mile (international) n mile
1 metre m =	**1**	39.370 1	3.280 84	1.093 61	0.049 709 7	$4.970\ 97 \times 10^{-3}$	$6.213\ 71 \times 10^{-4}$	0.546 807	$5.396\ 12 \times 10^{-4}$	$5.399\ 57 \times 10^{-4}$
1 inch in =	**0.025 4**	**1**	0.083 333 3	0.027 777 8	$1.262\ 63 \times 10^{-3}$	$1.262\ 63 \times 10^{-4}$	$1.578\ 28 \times 10^{-5}$	$1.388\ 89 \times 10^{-2}$	$1.370\ 61 \times 10^{-5}$	$1.371\ 49 \times 10^{-5}$
1 foot ft =	**0.304 8**	**12**	**1**	0.333 333	0.015 151 5	$1.515\ 15 \times 10^{-3}$	$1.893\ 94 \times 10^{-4}$	0.166 667	$1.644\ 74 \times 10^{-4}$	$1.645\ 79 \times 10^{-4}$
1 yard yd =	**0.914 4**	**36**	**3**	**1**	0.045 454 5	$4.545\ 45 \times 10^{-3}$	$5.681\ 82 \times 10^{-4}$	**0.5**	$4.934\ 21 \times 10^{-4}$	$4.937\ 37 \times 10^{-4}$
1 chain =	**20.116 8**	**792**	**66**	**22**	**1**	**0.1**	**0.012 5**	**11**	$1.085\ 53 \times 10^{-2}$	$1.086\ 22 \times 10^{-2}$
1 furlong =	**201.168**	**7 920**	**660**	**220**	**10**	**1**	**0.125**	**110**	0.108 553	0.108 622
1 mile =	**1 609.344**	**63 360**	**5 280**	**1 760**	**80**	**8**	**1**	**880**	0.868 421	0.868 976
1 fathom =	**1.828 8**	**72**	**6**	**2**	$9.090\ 91 \times 10^{-2}$	$9.090\ 91 \times 10^{-3}$	$1.136\ 36 \times 10^{-3}$	**1**	$9.868\ 42 \times 10^{-4}$	$9.874\ 73 \times 10^{-4}$
1 nautical mile (UK)[b] =	1 853.18	**72 960**	**6 080**	2 026.67	92.121 2	9.212 12	1.151 52	1 013.33	**1**	1.000 64
1 nautical mile (international) n mile =	**1 852**	72 913.4	6 076.12	2 025.37	92.062 4	9.206 24	1.150 78	1 012.69	0.999 361	**1**

[a] For a detailed table of conversions from inches to millimetres and vice versa, see BS 2856. The conversions to inches are there given to the nearest 10^{-7} in.
[b] The nautical mile (UK) is no longer used.

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4 Area (length squared)

4.1 The coherent SI unit of area is the square metre (symbol m^2), a derived unit.

4.2 Areas are also expressed in terms of the squares of any of the multiples and submultiples of the metre formed by the use of the SI prefixes, e.g. square millimetre (mm^2), square centimetre (cm^2), square decimetre (dm^2), square kilometre (km^2).

In accordance with the rule concerning prefixes attached to units raised to a power, the relationship between each of these and the square metre is as follows:

$$1\ \mathrm{mm}^2 = \left(\frac{\mathrm{m}}{1\,000}\right)^2 = 10^{-6}\ \mathrm{m}^2$$

$$1\ \mathrm{cm}^2 = \left(\frac{\mathrm{m}}{100}\right)^2 = 10^{-4}\ \mathrm{m}^2$$

$$1\ \mathrm{dm}^2 = \left(\frac{\mathrm{m}}{10}\right)^2 = 10^{-2}\ \mathrm{m}^2$$

$$1\ \mathrm{km}^2 = (1\,000\ \mathrm{m})^2 = 10^{6}\ \mathrm{m}^2$$

4.3 A metric unit with a special name is the are (symbol a).

$1\ \mathrm{a} = 100\ \mathrm{m}^2$

This, and more especially its multiple the hectare (symbol ha), are used for land measurement of area.

$1\ \mathrm{ha} = 100\ \mathrm{a} = 10\,000\ \mathrm{m}^2$

Another specially named metric unit (but not SI) is the barn, used in atomic physics in the measurement of cross sections.

$1\ \mathrm{barn} = 10^{-28}\ \mathrm{m}^2$

4.4 The connection between various traditional UK and US units of area, and their relationship to the square metre, are as follows:

						Refer to note
1 square foot (ft^2)	=	144 square inches (in^2)	(1 in^2	=	**6.451 6** $\times 10^{-4}$ m^2)	—
1 square yard (yd^2)	=	9 square feet	(1 ft^2	=	0.092 903 0 m^2)	—
1 rood	=	1 210 square yards	(1 yd^2	=	0.836 127 m^2)	1
1 acre = 4 roods	=	4 840 square yards	(1 rood	=	1 011.71 m^2)	—
			(1 acre	=	4 046.86 m^2)	—
1 square mile ($mile^2$)	=	640 acres	(1 $mile^2$	=	2.589 99 $\times 10^6$ m^2)	—
			(1 $mile^2$	=	258.999 ha)	—

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4.5 A specialized UK and US unit of area (used in connection with sections of wire) is the "circular mil".

	Refer to note
1 circular mil = $7.853\ 98 \times 10^{-7}\ \mathrm{in}^2 = 5.067\ 07 \times 10^{-10}\ \mathrm{m}^2$	2

Notes on Clause 4

NOTE 1 The rood is obsolete in the UK and rarely used in the USA.

NOTE 2 The circular mil has an area equal to that of a circle one-thousandth of an inch in diameter. For other meanings of mil see **3.6**, **5.5** and Clause **8**, Note 2.

For conversion factors for a number of units of area see Table 4 and Table 5.

Table 4 — Area

Exact values are printed in bold type

	square metre m^2	hectare ha	square inch in^2	square foot ft^2	square yard yd^2	rood	acre	square mile $mile^2$
1 square metre m^2 =	**1**	**1** × 10^{-4}	1 550.00	10.763 9	1.195 99	9.884 22 × 10^{-4}	2.471 05 × 10^{-4}	3.861 02 × 10^{-7}
1 hectare ha =	**10 000**	**1**	1 550.00 × 10^{4}	107 639	11 959.9	9.884 22	2.471 05	3.861 02 × 10^{-3}
1 square inch in^2 =	**6.451 6** × 10^{-4}	**6.451 6** × 10^{-8}	**1**	6.944 44 × 10^{-3}	7.716 05 × 10^{-4}	6.376 90 × 10^{-7}	1.594 23 × 10^{-7}	2.490 98 × 10^{-10}
1 square foot ft^2 =	0.092 903 0	9.290 30 × 10^{-6}	**144**	**1**	0.111 111	9.182 74 × 10^{-5}	2.295 68 × 10^{-5}	3.587 01 × 10^{-8}
1 square yard yd^2 =	0.836 127	8.361 27 × 10^{-5}	**1 296**	**9**	**1**	8.264 46 × 10^{-4}	2.066 12 × 10^{-4}	3.228 31 × 10^{-7}
1 rood =	1 011.71	0.101 171	**1 568 160**	**10 890**	**1 210**	**1**	**0.25**	**3.906 25** × 10^{-4}
1 acre =	4 046.86	0.404 686	**6 272 640**	**43 560**	**4 840**	**4**	**1**	**1.562 5** × 10^{-3}
1 square mile $mile^2$ =	2.589 99 × 10^{6}	258.999	4.014 49 × 10^{9}	**2.787 84** × 10^{7}	**3.097 6** × 10^{6}	**2 560**	**640**	**1**

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Table 5 — Area of section of wire

Exact values are printed in bold type

		circular mil	square millimetre mm^2	square inch in^2
1 circular mil[a]	=	**1**	$5.067\ 07 \times 10^{-4}$	$7.853\ 98 \times 10^{-7}$
1 square millimetre mm^2	=	1 973.53	**1**	$1.550\ 00 \times 10^{-3}$
1 square inch in^2	=	$1.273\ 24 \times 10^6$	**645.16**	**1**

[a] For definition of circular mil, see Clause **4**, Note 2.

5 Volume and capacity (length cubed)

5.1 The coherent SI unit of volume is the cubic metre (symbol m^3), a derived unit.

5.2 Volumes are also expressed in terms of the cubes of any of the multiples and submultiples of the metre formed by the use of the SI prefixes; of these the cubic decimetre (dm^3), the cubic centimetre (cm^3), and the cubic millimetre (mm^3) are common examples.

The relationship between each of these and the cubic metre is as follows:

$$1\ dm^3 = \left(\frac{m}{10}\right)^3 = 10^{-3}\ m^3$$

$$1\ cm^3 = \left(\frac{m}{100}\right)^3 = 10^{-6}\ m^3$$

$$1\ mm^3 = \left(\frac{m}{1\ 000}\right)^3 = 10^{-9}\ m^3$$

5.3 In the SI no distinction is drawn between units of volume and units of capacity. However, a metric unit with a special name, used in conjunction with the SI and commonly used for the measurement of liquids and fluids, is the litre (symbol l[1]).

$1\ \text{litre} = 1\ dm^3 = 10^{-3}\ m^3$

(This definition has applied in the SI since 1964, but see **5.4**.)

The SI prefixes are used with the litre, leading for example to the hectolitre (hl), centilitre (cl), millilitre (ml) and microlitre (µl).

$$1\ hl = 100\ \text{litre} = 10^{-1}\ m^3$$

$$1\ cl = \left(\frac{1}{100}\right)\text{litre} = 10^{-5}\ m^3$$

$$1\ ml = \left(\frac{1}{1\ 000}\right)\text{litre} = 10^{-6}\ m^3 = 1\ cm^3$$

$$1\ \mu l = \left(\frac{1}{10^6}\right)\text{litre} = 10^{-9}\ m^3 = 1\ mm^3$$

[1] Although in this standard the symbol used for the litre is the lower case letter "l", it has long been recognized that in some typefaces it was difficult to distinguish between the lower case letter "l" and numeral 1. The 16th General Conference on Weights and Measures (1979) accordingly recognized the use of the upper case letter "L" as an alternative symbol for the litre. In British Standards "l" is the preferred symbol, but "L" is preferred by some other organizations.

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5.4 Units of capacity for the measurement of liquids (and sometimes of dry goods also) have been treated as base units at various times in the past, and have been defined independently of length. Thus in the metric system from 1901 to 1964 the litre was defined as the volume occupied by a mass of one kilogram of water under specified conditions (at its temperature of maximum density and under a pressure of one standard atmosphere). Since 1964, however, the litre has been re-defined within the SI as a special name for the volume of one cubic decimetre (which is as it was before 1901). Since 1 November 1976, the 1964 definition has been embodied within the law of the United Kingdom. Because of these changes, where a very high degree of precision is called for, it is necessary to establish which definition of the litre is intended. In the tables which follow in this standard a litre as defined according to the 1901 definition is described as the "litre (1901)", and the litre as it is now defined according to the SI is described simply as the "litre".

1 litre (1901) = 1.000 028 litre

5.5 In the French timber trade the volume of one cubic metre goes under the obsolescent name "stère" (symbol st). Similarly, in the timber trade in Germany the cubic metre has been described as the "Festmeter" (Fm) or "Raummeter" (Rm), and these two special names are also obsolescent. Another obsolete metric-based volume unit is the "mil", once used in the UK in pharmaceutical work, particularly for prescriptions, to denote a millilitre. For other meanings of "mil" see **3.6**, **4.5**, and Clause **8**, Note 2.

5.6 The connection between the traditional UK and US units of volume and their relationship to the cubic metre are as follows:

Symbol	Unit				Metric equivalent
yd^3	1 cubic yard	=	27 cubic feet	=	0.764 555 m^3
ft^3	1 cubic foot	=	1 728 cubic inches	=	0.028 316 8 m^3
in^3	1 cubic inch			=	$1.638\ 71 \times 10^{-5}$ m^3

5.7 As with the litre in the metric system, it is customary to regard certain UK and US volumetric units as units of capacity. These include the UK gallon and its multiples and submultiples, and the US gallon and US bushel, with their multiples and submultiples. The UK and US units of capacity differ markedly from each other[2] and it is therefore important to avoid confusion in their use. The prefixes UK and US are used for purpose of their identification in this standard but the qualifications UK or US are frequently omitted in practice. Care is particularly necessary with conversions of the gallon in order to identify which gallon is concerned.

5.8 *UK-units of capacity*. These are all based on the UK gallon (UKgal), defined in Schedule 1 of the Weights and Measures Act, 1985 [1], as 4.546 09 cubic decimetres.

Key conversion factors are:

1 UKgal	=	4.546 09 dm^3 (Weights and Measures Act, 1985 [1])
	=	4.546 09 litre
	=	4.545 96 litre (1901)

2) For a direct comparison of UK and US units of capacity see Table 9.

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The connection between the UK gallon and its various multiples and submultiples is shown in the following list.

Symbol (if any)	Unit					Metric equivalent
UKmin	1 minim				=	0.059 193 9 cm^3
UK fl dr	1 fluid drachm	=	60 minim		=	3.551 63 cm^3
UK fl oz	1 fluid ounce	=	8 fluid drachms		=	28.413 1 cm^3
—	1 gill	=	5 fluid ounces		=	0.142 065 dm^3
UKpt	1 pint	=	4 gills	(= 20 fluid ounces)	=	0.568 261 dm^3
UKqt	1 quart	=	2 pints		=	1.136 52 dm^3
UKgal	1 gallon	=	4 quarts	(= 160 fluid ounces)	=	4.546 09 dm^3
—	1 peck	=	2 gallons		=	9.092 18 dm^3
—	1 bushel	=	4 pecks		=	36.368 7 dm^3

NOTE The minim, fluid drachm, peck and bushel were deleted from Schedule 1 to the UK Weights and Measures Act, 1963, and it is now illegal to use these units for trade purposes.

The following are, or have been, used in the brewing industry:

1 hogshead	=	54 gallons
1 barrel	=	36 gallons
1 kilderkin	=	18 gallons
1 firkin	=	9 gallons
1 pin	=	4.5 gallons

5.9 *US units of capacity*. The US units of capacity are defined in terms of a specified number of cubic inches. The US gallon is equal in volume to 231 cubic inches and is used for the measurement of liquids only. The US bushel is equal in volume to 2 150.42 cubic inches and is used for the measurement of dry commodities only.

5.10 *US units of capacity (liquid measure only)*. The connection between the US gallon and its various multiples and submultiples is shown in the following list.

Symbol (if any)	Unit					Metric equivalent
—	1 US minim				=	0.061 611 5 cm^3
fl dr	1 US fluid dram[3)]	=	60 minims		=	3.696 69 cm^3
US fl oz	1 US fluid ounce[4)]	=	8 fluid drams		=	29.573 5 cm^3
gi	1 US gill	=	4 fluid ounces		=	0.118 294 dm^3
liq pt	1 US liquid pint	=	4 gills	(= 16 fluid ounces)	=	0.473 176 dm^3
liq qt	1 US liquid quart	=	2 liquid pints		=	0.946 353 dm^3
USgal	1 US gallon	=	4 liquid quarts	(= 128 fluid ounces)	=	3.785 41 dm^3
bbl	1 US barrel (for petroleum)	=	42 gallons		=	158.987 dm^3

3) Sometimes also known as the liquid dram (liq dr) in the USA.
4) Sometimes also known as the liquid ounce (liq oz) in the USA.

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5.11 *US units of capacity (dry measure only)*. The connection between the US bushel and its various multiples and submultiples is shown in the following list.

Symbol (if any)	Unit				Metric equivalent
—	1 US dry pint			=	0.550 610 dm^3
dry qt	1 US dry quart	=	2 dry pints	=	1.101 22 dm^3
pk	1 US peck	=	8 dry quarts	=	8.809 76 dm^3
bu	1 US bushel	=	4 pecks	=	35.239 1 dm^3
bbl (dry)	1 US dry barrel	=	7 056 cubic inches	=	115.627 dm^3

Notes on Clause 5

NOTE 1 In the UK different values are used for the barrel for different purposes (e.g. the wine barrel is nominally 31½ UKgal and the beer barrel nominally 36 UKgal).

NOTE 2 The barrel (bbl) referred to in the list of US capacity units for dry measure only is the standard barrel in the US for fruits, vegetables and dried commodities, with the exception of cranberries. Cranberries are sold in the US by reference to a standard cranberry barrel containing 5 826 cubic inches.

NOTE 3 There are other bushels having different capacities from those mentioned in **5.8** and **5.11**.

NOTE 4 Other specialized units of volume used in the UK timber trade are:

1 board foot	=	144 in^3	(= 2.359 74 dm^3)
1 cord	=	128 ft^3	(= 3.624 56 m^3)
1 standard	=	165 ft^3	(= 4.672 28 m^3)

This last is sometimes known as the "Petrograd standard".

NOTE 5 The cran, once used in the UK fishing industry, is equal to 37½ UK gallons.

For conversion factors for a number of units of volume and units of capacity see Table 6, Table 7, Table 8 and Table 9.

6 Modulus of section, first moment of area

6.1 These quantities have the same dimensions as volume; the coherent SI unit is therefore the metre cubed (m^3).

6.2 They may also be expressed in terms of the cube of any suitable submultiple of the metre; the centimetre cubed (cm^3) and millimetre cubed (mm^3) are commonly used.

6.3 The imperial units are the foot cubed (ft^3) and the inch cubed (in^3).

The relationship between the above-mentioned units can be seen in or inferred from Table 6.

7 Second moment of area, or geometrical moment of inertia

The coherent SI unit for this quantity is the metre to the fourth (m^4). Other commonly used units are the centimetre to the fourth (cm^4) and millimetre to the fourth (mm^4). The imperial units are the foot to the fourth (ft^4) and the inch to the fourth (in^4). See Table 10 for conversion factors for these units.

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Table 6 — Volume and capacity

Exact values are printed in bold type

	cubic metre m^3	**cubic decimetre** dm^3 **litre**[a] l	**litre (1901)**[a]	**cubic inch** in^3	**cubic foot** ft^3	**cubic yard** yd^3	**UK bushel**	**US dry pint**	**US bushel**
1 cubic metre m^3 =	**1**	**1 000**	999.972	61 023.7	35.314 7	1.307 95	27.496 1	1 816.17	28.377 6
1 cubic decimetre dm^3 1 litre l[a] =	**0.001**	**1**	0.999 972	61.023 7	0.035 314 7	$1.307\ 95 \times 10^{-3}$	0.027 496 1	1.816 17	0.028 377 6
1 litre (1901)[a] =	$1.000\ 028 \times 10^{-3}$	1.000 028	**1**	61.025 5	0.035 315 7	$1.307\ 99 \times 10^{-3}$	0.027 496 9	1.816 22	0.028 378 4
1 cubic inch in^3 =	$1.638\ 71 \times 10^{-5}$	$1.638\ 71 \times 10^{-2}$	0.016 386 6	**1**	$5.787\ 04 \times 10^{-4}$	$2.143\ 35 \times 10^{-5}$	$4.505\ 81 \times 10^{-4}$	0.029 761 6	$4.650\ 25 \times 10^{-4}$
1 cubic foot ft^3 =	0.028 316 8	28.316 8	28.316 1	**1 728**	**1**	0.037 037 0	0.778 604	51.428 1	0.803 564
1 cubic yard yd^3 =	0.764 555	764.555	764.533	**46 656**	**27**	**1**	21.022 3	1 388.56	21.696 2
1 UK bushel =	0.036 368 7	36.368 7	36.367 7	2 219.36	1.284 35	0.047 568 5	**1**	66.051 7	1.032 06
1 US dry pint =	$5.506\ 10 \times 10^{-4}$	0.550 610	0.550 595	33.600 3	0.019 444 6	$7.201\ 71 \times 10^{-4}$	0.015 139 7	**1**	**0.015 625**
1 US bushel =	0.035 239 1	35.239 1	35.238 1	**2 150.42**	1.244 46	0.046 091 0	0.968 939	**64**	**1**

[a] For explanation of the litre and the litre (1901) see **5.3** and **5.4**.

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Table 7 — Volume and capacity *(continued)*

Exact values are printed in bold type

	cubic metre m^3	cubic decimetre dm^3 **litre**[a] l	litre (1901)[a]	cubic inch in^3	cubic foot ft^3	UK pint[b] UKpt	UK gallon[c] UKgal	US liquid pint US liq pt	US gallon USgal
1 cubic metre m^3 =	**1**	**1 000**	999.972	61 023.7	35.314 7	1 759.75	219.969	2 113.38	264.172
1 cubic decimetre dm^3 1 litre l[a] =	**0.001**	**1**	0.999 972	61.023 7	0.035 314 7	1.759 75	0.219 969	2.113 38	0.264 172
1 litre (1901)[a] =	$1.000\ 028 \times 10^{-3}$	1.000 028	**1**	61.025 5	0.035 315 7	1.759 80	0.219 975	2.113 44	0.264 179
1 cubic inch in^3 =	$1.638\ 71 \times 10^{-5}$	0.016 387 1	0.016 386 6	**1**	$5.787\ 04 \times 10^{-4}$	0.028 837 2	$3.604\ 65 \times 10^{-3}$	0.034 632 0	$4.329\ 00 \times 10^{-3}$
1 cubic foot ft^3 =	0.028 316 8	28.316 8	28.316 1	**1 728**	**1**	49.830 7	6.228 83	59.844 2	7.480 52
1 UK pint[b] UKpt =	$0.568\ 261 \times 10^{-3}$	0.568 261	0.568 246	34.677 4	0.020 068 0	**1**	**0.125**	1.200 95	0.150 119
1 UK gallon[c] UKgal =	$4.546\ 09 \times 10^{-3}$	4.546 09	4.545 96	277.420	0.160 544	**8**	**1**	9.607 60	1.200 95
1 US liquid pint US liq pt =	$4.731\ 76 \times 10^{-4}$	0.473 176	0.473 163	**28.875**	0.016 710 1	0.832 674	0.104 084	**1**	**0.125**
1 US gallon USgal =	$3.785\ 41 \times 10^{-3}$	3.785 41	3.785 31	**231**	0.133 681	6.661 39	0.832 674	**8**	**1**

[a] For explanation of the litre and the litre (1901) see **5.3** and **5.4**.
[b] Also called an "imperial pint".
[c] Also called an "imperial gallon".

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Table 8 — Volume and capacity *(continued)*

Exact values are printed in bold type

	cubic centimetre cm^3 **millilitre** ml	**millilitre (1901)**	**cubic inch** in^3	**UK minim** UKmin	**UK fluid drachm** UK fl dr	**UK fluid ounce** UK fl oz	**US fluid ounce** US fl oz
1 cubic centimetre cm^3 1 millilitre ml =	**1**	0.999 972	0.061 023 7	16.893 6	0.281 561	0.035 195 1	0.033 814 0
1 millilitre (1901)[a] =	1.000 028	**1**	0.061 025 5	16.894 1	0.281 568	0.035 196 1	0.033 815 0
1 cubic inch in^3 =	16.387 1	16.386 6	**1**	276.837	4.613 95	0.576 744	0.554 113
1 UK minim UKmin =	0.059 193 9	0.059 192 2	$3.612\ 23 \times 10^{-3}$	**1**	0.016 666 7	$2.083\ 33 \times 10^{-3}$	$2.001\ 58 \times 10^{-3}$
1 UK fluid drachm UK fl dr =	3.551 63	3.551 53	0.216 734	**60**	**1**	**0.125**	0.120 095
1 UK fluid ounce UK fl oz =	28.413 1	28.412 3	1.733 87	**480**	**8**	**1**	0.960 760
1 US fluid ounce US fl oz =	29.573 5	29.572 7	1.804 69	499.604	8.326 74	1.040 84	**1**

NOTE $1\ mm^3 = 10^{-3}\ cm^3 = 1\ \mu l$ (see also **5.2**).

[a] For explanation of the litre and the litre (1901) see **5.3** and **5.4**.

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Table 9 — Relationship between UK (imperial) and US units of capacity

1 UK minim	=	0.960 760 US minim
1 UK fluid drachm	=	0.960 760 US fluid[a] dram
1 UK fluid ounce	=	0.960 760 US fluid[b] ounce
1 UK gill	=	1.200 95 US gill
1 UK pint	=	1.200 95 US liquid pint
1 UK quart	=	1.200 95 US liquid quart
1 UK gallon	=	1.200 95 US gallon
1 UK pint	=	1.032 06 US dry pint
1 UK quart	=	1.032 06 US dry quart
1 UK peck	=	1.032 06 US peck
1 UK bushel	=	1.032 06 US bushel
1 US minim	=	1.040 84 UK minim
1 US fluid[a] dram	=	1.040 84 UK fluid drachm
1 US fluid[b] ounce	=	1.040 84 UK fluid ounce
1 US gill	=	0.832 674 UK gill
1 US liquid pint	=	0.832 674 UK pint
1 US liquid quart	=	0.832 674 UK quart
1 US gallon	=	0.832 674 UK gallon
1 US dry pint	=	0.968 939 UK pint
1 US dry quart	=	0.968 939 UK quart
1 US peck	=	0.968 939 UK peck
1 US bushel	=	0.968 939 UK bushel

[a] Sometimes also known as the liquid dram in the USA.
[b] Sometimes also known as the liquid ounce in the USA.

Table 10 — Second moment of area

Exact values are printed in bold type

		m^4	cm^4	ft^4	in^4
1 m^4	=	**1**	**1** × 10^{8}	115.862	2 402 510
1 cm^4	=	**1** × 10^{-8}	**1**	1.158 62 × 10^{-6}	0.024 025 1
1 ft^4	=	0.863 097 × 10^{-2}	863 097	**1**	**20 736**
1 in^4	=	41.623 1 × 10^{-8}	41.623 1	4.822 53 × 10^{-5}	**1**

NOTE 1 $mm^4 = 10^{-4}\ cm^4 = 10^{-12}\ m^4$.

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8 Plane angle

8.1 The coherent SI unit of plane angle is the radian (symbol rad), a coherent derived[5] unit. It is the angle between two radii of a circle, which cut an arc on the circumference equal in length to the radius.

Thus a complete circle subtends an angle of 2π rad at its centre, and a right angle (∟)

$$\text{equals} \quad \frac{2\pi}{4}\,\text{rad} \quad = \quad \frac{\pi}{2}\,\text{rad.}$$

8.2 Traditional angular units which are of such practical importance that they have been retained for general use in conjunction with the SI are the degree (°), minute (′) and second (″) of arc.

The full circle subtends an angle of 360 degrees (360°) at its centre, and thus the right angle (∟) = 90 degrees (90°).

$$1\text{ degree }(1^\circ) \quad = \quad 60\text{ minutes }(60') \quad = \quad \frac{\pi}{180}\,\text{rad}$$

$$1\text{ minute }(1') \quad = \quad 60\text{ seconds }(60'') \quad = \quad \frac{\pi}{60 \times 180}\,\text{rad}$$

$$1\text{ second }(1'') \quad = \quad \frac{\pi}{3\,600 \times 180}\,\text{rad}$$

It is often convenient to express sub-divisions of the degree in decimal form, rather than to use minutes and seconds. In navigation, it is now usual to quote degrees, minutes and decimals of minutes.

8.3 A unit of plane angle used in some mainland European countries is the grade (^{g}) or, as it is called in Germany, the gon. This is a one-hundredth of a right angle.

$$1^g\text{ (or 1 gon)} \quad = \quad 0.9^\circ \quad = \quad \frac{\pi}{200}\,\text{rad}$$

Notes on Clause 8

NOTE 1 Note the possibility of confusion between the hundredth part of a grade in angular measure and the term “Centigrade” (correctly called Celsius) in connection with temperature (see **39.2**).

NOTE 2 The unit “mil” is sometimes used in connection with angular measure. For some purposes the angular mil is taken to be one thousandth of a radian (10^{-3} rad), which is equivalent to 3′ 26.25″. There is, however, another concept in which an angular mil is equal to 360/6 400 degrees i.e. 3′ 22.5″. For other meanings of “mil” see **3.6**, **4.5**, and **5.5**.

NOTE 3 In English there is no commonly used expression for the “full angle” subtended by a circle. In German the term “Vollwinkel” is used.

For interconversion factors for the units mentioned in 8.1, 8.2 and 8.3 see Table 11.

[5] In October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary (now “coherent derived”) units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

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Table 11 — Plane angle

Exact values are printed in bold type

	radian rad	right angle ∟	degree °	minute ′	second ″	grade (or gon) ^{g} gon
1 radian = rad	**1**	0.636 620	57.295 8	3 437.75	206 265	63.662 0
1 right angle =	1.570 80	**1**	**90**	**5 400**	**324 000**	**100**
1 degree = °	0.017 453 3	0.011 111 1	**1**	**60**	**3 600**	1.111 11
1 minute = ′	$2.908\ 88 \times 10^{-4}$	$1.851\ 85 \times 10^{-4}$	0.016 666 7	**1**	**60**	$1.851\ 85 \times 10^{-2}$
1 second = ″	$4.848\ 14 \times 10^{-6}$	$3.086\ 42 \times 10^{-6}$	$2.777\ 78 \times 10^{-4}$	0.016 666 7	**1**	$3.086\ 42 \times 10^{-4}$
1 grade (or gon) = ^{g} gon	0.015 708 0	**0.01**	**0.9**	**54**	**3 240**	**1**

9 Solid angle

The coherent SI unit of solid angle, the only unit in common use for solid angle, is the steradian (symbol sr), a coherent derived[6] unit. It is the solid angle which, having its vertex at the centre 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.

A complete sphere subtends a solid angle of 4π sr at its centre.

10 Time

10.1 The SI unit of time is the second (symbol s), a base unit. It is now defined as 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, as stated in *The International System of Units (SI)* 1998 [3].

10.2 Prior to 1967 the second was defined as a specified fraction of the time taken by the Earth to complete a particular orbit of the Sun. (This second, the "ephemeris second", is retained for use as a special unit in astronomy, and is as nearly equal to the SI unit as the highest precision of measurement could permit in 1967.)

10.3 Other units of time of such practical importance that they are retained for general use in conjunction with the SI are:

minute (min)	1 min	=	60 s		
hour (h)	1 h	=	60 min	=	3 600 s
day (d)	1 d	=	24 h	=	86 400 s

10.4 Longer durations of time are conveniently expressed in terms of the week, month or year, but the last two of these cannot in general be explicitly related to the second (of time).

1 week	=	7 d = 604 800 s
1 month	=	28, 29, 30 or 31 days (according to calendar)
1 year[7]	=	12 months = 365 or 366 days (according to calendar) = 8 760 h or 8 784 h (according to calendar).

[6] In October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary (now "coherent derived") units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

[7] The year referred to here is the "calendar year". Calendar adjustments are based on the "tropical year", the time interval between two consecutive passages (in the same direction) of the Sun through the Earth's equatorial plane. In 1900 the duration of the "tropical year" was 365.242 198 78 d and it is decreasing at the rate of 6.14×10^{-6} days per century.

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Notes on Clause 10

NOTE 1 The only time unit commonly used in conjunction with the SI prefixes is the second, e.g. the submultiples millisecond (ms), microsecond (µs) and nanosecond (ns), which are in wide technological use.

NOTE 2 The symbol "a" is used for year.

NOTE 3 The scale of International Atomic Time (TAI), based directly on the atomic radiation defining the second, is maintained by the Bureau International de l'Heure (BIH) in Paris. Legal time in the UK, as in most countries, is based on a related scale, that of Co-ordinated Universal Time (UTC), broadcast by an international network of radio stations. UTC is defined in such a manner that it differs from TAI by a whole number of seconds. The difference UTC – TAI was set equal to −10 s on 1 January 1972, the date of application of the reformulation of UTC (which previously involved a frequency offset). On 1 January 1999 the difference had risen to −31 s.

This difference can be changed in steps of 1 s, by the use of a positive or negative leap second at the end of a month of UTC, either at the end of December or of June, to keep UTC in agreement with the time defined by the rotation of Earth with an approximation better than 0.9 s. The decision on whether to add or remove a second is made by the International Earth Rotation Service (IERS), and notices are distributed well in advance. So far, all leap seconds have been positive. The legal times of most countries are offset from UTC by a whole number of hours (because of time zones and "daylight saving" arrangements). Note that since 1995, all member states of the European Union (EU) have used a common date and time for the beginning and end of "summer time".

11 Linear velocity (speed) (length/time)

11.1 The coherent SI unit of linear velocity is the metre per second (symbol m/s), a coherent derived unit.

11.2 Multiples and submultiples of the metre per second are formed by using any of the SI prefixes in conjunction with the metre.

11.3 A metric unit often used for speed is the kilometre per hour (km/h).

1 km/h = 0.277 778 m/s

11.4 Various speed units used in the imperial system are:

foot per second	1 ft/s	=	**0.304 8** m/s
inch per second	1 in/s	=	**0.025 4** m/s
foot per minute	1 ft/min	=	**0.005 08** m/s
mile per hour[8)]	1 mile/h	=	**0.447 04** m/s

11.5 The knot, one nautical mile per hour, is a unit used for speed in nautical and aeronautical contexts. The international knot (kn) is metric-based, being equal to one international nautical mile per hour.

1 kn = **1 852** m/h = 0.514 444 m/s

The UK knot is imperial-based and obsolescent, being equal to one UK nautical mile per hour.

1 UK knot = **6 080** ft/h = 0.514 773 m/s

For interconversion factors for the above units see Table 12.

8) Traditionally indicated by the abbreviation m.p.h.

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12 Angular velocity[9] (angle/time)

12.1 The coherent SI unit of angular velocity is the radian per second (rad/s), a derived unit.

12.2 Other units used are:

radian per minute	(rad/min)
revolution per minute	(rev/min) or (r/min)
revolution per second	(rev/s) or (r/s)
degree per minute	(°/min)
degree per second	(°/s)

For interconversion factors for the above units see Table 13.

[9] The terms "rotational velocity", "rotational speed" and "speed of rotation" are commonly used as alternative terms for angular velocity, but are also often thought of as a frequency, particularly when being expressed in revolutions per minute, or per second. When frequency is meant, the revolution should not be identified with angle as it is so identified in Table 13 (1 revolution = 2π radians = 360°), but should be thought of as a number, and a clearer term for expressing this concept is "rotational frequency". (See also Clause **13**, Frequency.)

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Table 12 — Linear velocity

Exact values are printed in bold type

		metre per second m/s	**kilometre per hour** km/h	**foot per second** ft/s	**foot per minute** ft/min	**inch per second** in/s	**mile per hour** mile/h	**knot (international)** kn	**UK knot**
1 metre per second m/s	=	**1**	**3.6**	3.280 84	196.850	39.370 1	2.236 94	1.943 84	1.942 60
1 kilometre per hour km/h	=	0.277 778	**1**	0.911 344	54.680 7	10.936 1	0.621 371	0.539 957	0.539 612
1 foot per second ft/s	=	**0.304 8**	**1.097 28**	**1**	**60**	**12**	0.681 818	0.592 484	0.592 105
1 foot per minute ft/min	=	**0.005 08**	**0.018 288**	0.016 666 7	**1**	**0.2**	0.011 363 6	$9.874\ 73 \times 10^{-3}$	$9.868\ 42 \times 10^{-3}$
1 inch per second in/s	=	**0.025 4**	**0.091 44**	0.083 333 3	**5**	**1**	0.056 818 2	$4.937\ 37 \times 10^{-2}$	$4.934\ 21 \times 10^{-2}$
1 mile per hour mile/h	=	**0.447 04**	**1.609 344**	1.466 67	**88**	**17.6**	**1**	0.868 976	0.868 421
1 knot (international) kn	=	0.514 444	**1.852**	1.687 81	101.269	20.253 7	1.150 78	**1**	0.999 361
1 UK knot	=	0.514 773	1.853 18	1.688 89	101.333	20.266 7	1.151 52	1.000 64	**1**

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Table 13 — Angular velocity and velocity of rotation

Exact values are printed in bold type

	radian per second rad/s	radian per minute rad/min	revolution per second rev/s	revolution per minute rev/min	degree per second °/s	degree per minute °/min
1 radian per second rad/s =	**1**	**60**	0.159 155	9.549 30	57.295 8	3 437.75
1 radian per minute rad/min =	0.016 666 7	**1**	0.002 652 58	0.159 155	0.954 930	57.295 8
1 revolution per second rev/s =	6.283 19	376.991	**1**	**60**	**360**	**21 600**
1 revolution per minute rev/min =	0.104 720	6.283 19	0.016 666 7	**1**	**6**	**360**
1 degree per second °/s =	0.017 453 3	1.047 20	0.002 777 78	0.166 667	**1**	**60**
1 degree per minute °/min =	$2.908\ 88 \times 10^{-4}$	0.017 453 3	$4.629\ 63 \times 10^{-5}$	$2.777\ 78 \times 10^{-3}$	0.016 666 7	**1**

13 Frequency (number/time)

13.1 The coherent SI unit of frequency (of a wave or periodic phenomenon) is the hertz (symbol Hz), a derived unit with a special name. Formerly, in the UK, the hertz was called the cycle per second (c/s). Expressed in terms of base units of the SI both the hertz and the cycle per second are the inverse second,

i.e. $\frac{1}{\mathrm{s}}$ (or s^{-1}).

13.2 The coherent SI unit of rotational frequency (e.g. a frequency associated with the mechanical rotation of a shaft) is also the inverse second,

i.e. $\frac{1}{\mathrm{s}}$ (or s^{-1}).

It is commonly known as the revolution per second (rev/s or r/s).

13.3 Another very commonly used unit of rotational frequency is the revolution per minute (rev/min or r/min, but traditionally indicated by the abbreviation r.p.m.).

$$1\ \text{rev/min} = \frac{1}{60}\ \text{rev/s}$$

$$= \text{(in SI terms)} \quad \frac{1}{60\ \mathrm{s}} \quad \text{or} \quad \frac{1}{60}\ \mathrm{s}^{-1}$$

13.4 Corresponding angular velocities are obtainable from Table 13,

using 1 rev/s as corresponding to 1 Hz, $\frac{1}{\mathrm{s}}$ (or $1\ \mathrm{s}^{-1}$).

NOTE See also footnote to Clause **12**, Angular velocity.

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14 Acceleration (length/time squared)

14.1 The coherent SI unit of acceleration is the metre per second squared (symbol m/s^2), a derived unit.

14.2 The centimetre per second squared (cm/s^2), a submultiple of the above, is also called the galileo or gal (symbol Gal).

1 Gal = 1 cm/s^2 = 10^{-2} m/s^2

A unit that has been commonly used in geodesy is the milligal (mGal).

1 mGal = 10^{-3} Gal = 10^{-5} m/s^2

14.3 The unit in the imperial system for acceleration is the foot per second squared (ft/s^2).

1 ft/s^2 = **0.304 8** m/s^2

14.4 The standard acceleration of **9.806 65** m/s^2 plays an important part in the definition of certain units in the older technical systems. When the acceleration of free fall has this value, this is the standard acceleration due to gravity, also known as "standard gravity", the associated symbol for this quantity being g_n.

The acceleration due to gravity is sometimes used as a unit of acceleration, and called "g", particularly in aeronautical engineering and centrifuge technology. For the sake of precision the standard value **9.806 65** m/s^2 should be taken for this unit. A close approximation in imperial units is 32.174 0 ft/s^2. These are frequently rounded to 9.81 m/s^2 and 32.2 ft/s^2.

Interconversion factors for the above units can be seen in or inferred from Table 14.

Table 14 — Acceleration

Exact values are printed in bold type

	metre per second squared m/s^2	**foot per second squared** ft/s^2	**standard acceleration due to gravity (standard gravity)** g_n
1 metre per second squared m/s^2 =	**1**	3.280 84	0.101 972
1 foot per second squared ft/s^2 =	**0.304 8**	**1**	0.031 081 0
standard acceleration due to gravity ("standard gravity") g_n =	**9.806 65**	32.174 0	**1**
NOTE 1 Gal = 1 cm/s^2 = 10^{-2} m/s^2; 1 mGal = 10^{-5} m/s^2 (see **14.2**).			

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15 Mass

15.1 The coherent SI unit of mass is the kilogram (symbol kg), a base unit. It is defined as equal to the mass of the international prototype of the kilogram (which is in the custody of the International Bureau of Weights and Measures at Sèvres near Paris). In view of the variability of the standard kilogram, due to dirt, moisture etc., coupled with more accurate balances, it is planned to replace it with a theoretical, electronic kilogram.

15.2 Because the name of the base unit of mass already contains the SI prefix "kilo", multiples and submultiples are formed by adding SI prefixes to the word "gram". Examples are megagram (Mg), gram (g), milligram (mg) and microgram (μg), as follows:

			Refer to note
1 Mg	=	1 000 kg	—
1 g	=	$\frac{1}{1\,000}$ kg	—
1 mg	=	10^{-6} kg	—
1 μg	=	10^{-9} kg	1

In practice the megagram is usually referred to by the special name "tonne" (symbol t), and is often called the "metric ton" in the UK and in the USA.

15.3 Some other units of mass having associations with the metric system are:

			Refer to note
1 metric carat = 200 milligrams	=	2×10^{-4} kg	2
1 quintal (q)	=	100 kg	—
1 atomic mass unit (u)	=	$1.660\,53 \times 10^{-27}$ kg	—

15.4 The primary unit of mass in the imperial system and in the USA is the pound (lb). In the UK Weights and Measures Act 1985 [1], and in similar legislation in the USA, it is defined exactly as follows:

1 lb = **0.453 592 37** kg

15.5 The connection between multiples and submultiples of the pound is indicated in the following lists of named UK and US units of mass.

Avoirdupois units

a) UK *and* US units

1 pound	=	16 ounces (oz)	(1 oz	=	28.349 5 g)
	=	16 × 16 drams (dr)	(1 dr	=	1.771 85 g)
	=	7 000 grains (gr)	(1 gr	=	**0.064 798 91** g)

b) UK units only

1 stone	=	14 pounds	(= 6.350 29 kg)
1 quarter (qr)	=	28 pounds	(= 12.700 6 kg)
1 cental (ctl)	=	100 pounds	(= 45.359 2 kg)
1 hundredweight (cwt)	=	112 pounds	(= 50.802 3 kg)
1 ton (ton)	=	2 240 pounds	(= 1 016.05 kg)

c) US units only

1 short hundredweight (sh cwt)	=	100 pounds	(= 45.359 2 kg)
1 short ton (sh ton)	=	2 000 pounds	(= 907.185 kg)

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(In the USA the word ton refers to the "short ton" of 2 000 lb unless otherwise specified. The terms "long ton" or "gross ton" are sometimes used, referring to the ton of 2 240 lb. The hundredweight of 112 lb is often called the "long hundredweight". The use of the "long" units is decreasing in the USA.)

Apothecaries' units (formerly used in the UK[10] and the USA)

Both British and US Pharmacopoeias use SI units, but the following units may appear in older documents.

1 scruple[10]	=	20 grains	(= 1.295 98 gram)
1 drachm[10] (in UK)	=	3 scruples	(= 3.887 93 gram)
1 dram (in USA)	=	3 scruples	(= 3.887 93 gram)
1 ounce[10] = 24 scruples (oz apoth in UK oz ap in USA)	=	480 grains	(= 31.103 5 gram)

Troy units (used in the UK and the USA)

1 ounce troy (oz tr in UK oz t in USA)	=	1 apothecaries' ounce	=	480 grains	(= 31.103 5 gram)

(The apothecaries' ounce[10] and the ounce troy are identical in mass and differ from the avoirdupois ounce. Unless otherwise qualified, the term ounce and its abbreviation oz signify the avoirdupois ounce. The pound troy has no legal basis in the UK but was legalized in the USA, where it was defined as a mass equal to 5 760 grains.

1 pound troy (USA only) = 12 ounces troy = 5 760 grains (= 0.373 242 kg)

The grain has the same value in the avoirdupois, troy, and apothecaries' systems, and is abbreviated to gr in the UK.)

15.6 Some more specialized UK and/or USA named units of mass are:

				Refer to note
1 assay ton (UK)	=	32.667 g		3
1 assay ton (US)	=	29.166 g		4
1 slug	=	32.174 0 lb	(= 14.593 9 kg)	5
1 international corn bushel	=	60 lb	(= 27.215 5 kg)	6

For interconversion factors for many of the units of mass mentioned above see Table 15, Table 16 and Table 17.

[10] The apothecaries' units (scruple, drachm, and apothecaries' ounce) have been illegal since 1 January 1971 for use in the United Kingdom.

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Notes on Clause 15

NOTE 1 The alternative name “gamma” (symbol γ) is sometimes used to indicate a microgram.

NOTE 2 The metric carat has international sanction for use in trade in diamonds, fine pearls, and precious stones. In the UK the legal abbreviation for this unit is CM.

NOTE 3 The number of milligrams in a UK assay ton is equal to the number of ounces troy in a UK ton.

NOTE 4 The number of milligrams in a US assay ton is equal to the number of ounces troy in a US (short) ton.

NOTE 5 The slug is the British technical unit of mass. One pound-force acting on this mass produces an acceleration of 1 foot per second squared.

NOTE 6 Used for the sale of wheat under International Wheat Agreement, 1949. However, this was replaced by the International Grains Agreement in 1995, which uses only metric units.

Table 15 — Mass

Exact values are printed in bold type

		kilogram kg	**pound** lb	**slug**
1 kilogram kg	=	**1**	2.204 62	0.068 521 8
1 pound lb	=	**0.453 592 37**	**1**	0.031 081 0
1 slug	=	14.593 9	32.174 0	**1**

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Table 16 — Mass *(continued)*

Exact values are printed in bold type

		gram g (0.001 kg)	**metric carat**	**grain**[a] gr	**dram (avoirdupois)** dr	**drachm (apoth.)**	**ounce (avoirdupois)** oz	**ounce (troy or apoth.)** oz tr or oz apoth
1 gram (0.001 kg) g	=	**1**	**5**	15.432 4	0.564 383	0.257 206	0.035 274 0	0.032 150 7
1 metric carat	=	**0.2**	**1**	3.086 47	0.112 877	0.051 441 2	$7.054\ 79 \times 10^{-3}$	$6.430\ 15 \times 10^{-3}$
1 grain[a] gr	=	0.064 798 9	0.323 995	**1**	0.036 571 4	0.016 666 7	$2.285\ 71 \times 10^{-3}$	$2.083\ 33 \times 10^{-3}$
1 dram (avoirdupois) dr	=	1.771 85	8.859 23	**27.343 75**	**1**	0.455 729	**0.062 5**	0.056 966 1
1 drachm (apoth.)	=	3.887 93	19.439 7	**60**	2.194 29	**1**	0.137 143	**0.125**
1 ounce (avoirdupois) oz	=	28.349 5	141.748	**437.5**	**16**	7.291 67	**1**	0.911 458
1 ounce (troy or apoth.) oz tr or oz apoth	=	31.103 5	155.517	**480**	17.554 3	**8**	1.097 14	**1**

[a] The grain has the same value in the avoirdupois, troy and apothecaries' systems. The apothecaries' units (drachm and apothecaries' ounce) are no longer legal for use in the United Kingdom.

Table 17 — Mass *(continued)*

Exact values are printed in bold type

		tonne (1 000 kg) (megagram Mg)	**pound** lb	**UK hundredweight** cwt	**short hundredweight**[a] sh cwt	**UK ton** ton	**short ton**[a] sh ton
1 tonne (1 000 kg) (1 Mg) t	=	**1**	2 204.62	19.684 1	22.046 2	0.984 207	1.102 31
1 pound lb	=	$4.535\ 92 \times 10^{-4}$	**1**	$8.928\ 57 \times 10^{-3}$	**0.01**	$4.464\ 29 \times 10^{-4}$	**0.000 5**
1 hundredweight cwt	=	0.050 802 3	**112**	**1**	**1.12**	**0.05**	**0.056**
1 short hundredweight[a] sh cwt	=	0.045 359 2	**100**	0.892 857	**1**	0.044 642 9	**0.05**
1 UK ton ton	=	1.016 05	**2 240**	**20**	**22.4**	**1**	**1.12**
1 short ton[a] sh ton	=	0.907 185	**2 000**	17.857 1	**20**	0.892 857	**1**

[a] US units. The short hundredweight (of 100 lb) is, in the UK, sometimes called the "cental" (symbol ctl).

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16 Mass per unit length (or lineic mass) (formerly linear density) (mass/length)

16.1 The coherent SI unit of mass per unit length is the kilogram per metre (symbol kg/m), a derived unit. The term "lineic mass" is recommended by the International Organization for Standardization (ISO).

16.2 Two specialized units of linear density used in the textile industry and which have an association with the metric system are:

1 tex	=	1 gram per kilometre	=	10^{-6} kg/m
1 denier	=	1 gram per 9 kilometres	=	$0.111\ 112 \times 10^{-6}$ kg/m

16.3 A selection of imperial units used in industry, often for wires, rods etc. is:

1 pound per inch (lb/in)	(= 17.858 0 kg/m)
1 pound per foot (lb/ft)	(= 1.488 16 kg/m)
1 pound per yard (lb/yd)	(= 0.496 055 kg/m)
1 pound per mile (lb/mile)	(= $2.818\ 49 \times 10^{-4}$ kg/m)
1 UK ton per 1 000 yards (ton/1 000 yd)	(= 1.111 16 kg/m)
1 UK ton per mile (ton/mile)	(= 0.631 342 kg/m)

Interconversion factors for the units in 16.1 and 16.3 are given in Table 18.

For further information on **16.2** reference should be made to BS 947 which gives tables for calculating the tex values of numbers or counts in other systems, including denier.

Table 18 — Mass per unit length (lineic mass)
(applicable to wires, rods, etc.)

Exact values are printed in bold type

		kilogram per metre kg/m	pound per inch lb/in	pound per foot lb/ft	pound per yard lb/yd	pound per mile lb/mile	UK ton per 1 000 yards ton/1 000 yd	UK ton per mile ton/mile
1 kilogram per metre[a] kg/m	=	**1**	0.055 997 4	0.671 969	2.015 91	3 548.00	0.899 958	1.583 93
1 pound per inch lb/in	=	17.858 0	**1**	**12**	**36**	**63 360**	16.071 4	28.285 7
1 pound per foot lb/ft	=	1.488 16	0.083 333 3	**1**	**3**	**5 280**	1.339 29	2.357 14
1 pound per yard lb/yd	=	0.496 055	0.027 777 8	0.333 333	**1**	**1 760**	0.446 429	0.785 714
1 pound per mile lb/mile	=	$2.818\ 49 \times 10^{-4}$	$1.578\ 28 \times 10^{-5}$	$1.893\ 94 \times 10^{-4}$	$5.681\ 82 \times 10^{-4}$	**1**	$2.536\ 53 \times 10^{-4}$	$4.464\ 29 \times 10^{-4}$
1 UK ton per 1 000 yards ton/1 000 yd	=	1.111 16	0.062 222 2	0.746 667	**2.24**	**3 942.4**	**1**	**1.76**
1 UK ton per mile ton/mile	=	0.631 342	0.035 353 5	0.424 242	1.272 73	**2 240**	0.568 182	**1**

[a] 1 kilogram per metre (kg/m) = 1 tonne per kilometre (t/km).

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17 Mass per unit area (areic mass) (mass/length squared)

(applicable for example to sheet metal, plating etc., and in agriculture)

17.1 The coherent SI unit is the kilogram per square metre (kg/m^2), a derived unit. ISO recommend the term "areic mass".

17.2 Other commonly used metric units are:

gram per square metre (g/m^2)	(= 0.001 kg/m^2)
milligram per square centimetre (mg/cm^2)	(= 0.01 kg/m^2)
milligram per square millimetre (mg/mm^2)	(= 1 kg/m^2)
kilogram per hectare (kg/ha)	(= 0.000 1 kg/m^2)

17.3 A selection of imperial units is:

pound per thousand square feet (lb/1 000 ft^2)	(= 4.882 43 × 10^{-3} kg/m^2)
ounce per square yard (oz/yd^2)	(= 3.390 57 × 10^{-2} kg/m^2)
ounce per square foot (oz/ft^2)	(= 0.305 152 kg/m^2)
pound per acre (lb/acre)	(= 1.120 85 × 10^{-4} kg/m^2)
UK ton per square mile (ton/mile^2)	(= 3.922 98 × 10^{-4} kg/m^2)

For interconversion factors for the above see Table 19.

18 Specific surface, or area per unit mass

(applicable to sheet metal, plating, etc., and in agriculture)

18.1 The coherent SI unit is the square metre per kilogram (m^2/kg), a derived unit.

18.2 Other commonly used metric units are:

square metre per gram (m^2/g)	(= 1 000 m^2/kg)
square centimetre per milligram (cm^2/mg)	(= 100 m^2/kg)
square millimetre per milligram (mm^2/mg)	(= 1 m^2/kg)
hectare per kilogram (ha/kg)	(= 10 000 m^2/kg)

18.3 A selection of imperial units is:

thousand square feet per pound (1 000 ft^2/lb)	(= 204.816 m^2/kg)
square yard per ounce (yd^2/oz)	(= 29.493 5 m^2/kg)
square foot per ounce (ft^2/oz)	(= 3.277 06 m^2/kg)
acre per pound (acre/lb)	(= 8 921.79 m^2/kg)
square mile per UK ton (mile^2/ton)	(= 2 549.08 m^2/kg)

For interconversion factors for the above see Table 20.

Table 19 — Mass per unit area (areic mass)
(applicable to sheet metal, plating, etc., and in agriculture)

Exact values are printed in bold type

		kilogram per square metre[a] kg/m²	pound per thousand square feet lb/1 000 ft²	ounce per square yard oz/yd²	ounce per square foot oz/ft²	pound per acre lb/acre	UK ton per square mile ton/mile²	kilogram per hectare kg/ha
1 kilogram per square metre[a] kg/m²	=	**1**	204.816	29.493 5	3.277 06	8 921.79	2 549.08	**1** × 10⁴
1 pound per thousand square feet lb/1 000 ft²	=	$4.882\ 43 \times 10^{-3}$	**1**	**0.144**	**0.016**	**43.56**	12.445 7	48.824 3
1 ounce per square yard oz/yd²	=	0.033 905 7	6.944 44	**1**	0.111 111	**302.5**	86.428 6	339.057
1 ounce per square foot oz/ft²	=	0.305 152	**62.5**	**9**	**1**	**2 722.5**	777.857	3 051.52
1 pound per acre lb/acre	=	$1.120\ 85 \times 10^{-4}$	0.022 956 8	$3.305\ 79 \times 10^{-3}$	$3.673\ 09 \times 10^{-4}$	**1**	0.285 714	1.120 85
1 UK ton per square mile ton/mile²	=	$3.922\ 98 \times 10^{-4}$	0.080 348 9	0.011 570 2	$1.285\ 58 \times 10^{-3}$	**3.5**	**1**	3.922 98
1 kilogram per hectare kg/ha	=	**1** $\times 10^{-4}$	0.020 481 6	$2.949\ 35 \times 10^{-3}$	$3.277\ 06 \times 10^{-4}$	0.892 179	0.254 908	**1**

[a] 1 kilogram per square metre (kg/m^2) = 1 000 g/m^2 = 100 mg/cm^2 = 1 mg/mm^2.

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Table 20 — Specific surface, or area per unit mass
(applicable to sheet metal, plating, etc., and in agriculture)

Exact values are printed in bold type

		square metre per kilogram[a] m^2/kg	**thousand square feet per pound** $1\ 000\ ft^2/lb$	**square yard per ounce** yd^2/oz	**square foot per ounce** ft^2/oz	**acre per pound** acre/lb	**square mile per UK ton** $mile^2/ton$	**hectare per kilogram** ha/kg
1 square metre per kilogram[a] m^2/kg	=	**1**	$4.882\ 43 \times 10^{-3}$	0.033 905 7	0.305 152	$1.120\ 85 \times 10^{-4}$	$3.922\ 98 \times 10^{-4}$	**1** $\times 10^{-4}$
1 thousand square feet per pound $1\ 000\ ft^2/lb$	=	204.816	**1**	6.944 44	**62.5**	0.022 956 8	0.080 348 9	0.020 481 6
1 square yard per ounce yd^2/oz	=	29.493 5	**0.144**	**1**	**9**	$3.305\ 79 \times 10^{-3}$	0.011 570 2	$2.949\ 35 \times 10^{-3}$
1 square foot per ounce ft^2/oz	=	3.277 06	**0.016**	0.111 111	**1**	$3.673\ 09 \times 10^{-4}$	$1.285\ 58 \times 10^{-3}$	$3.277\ 06 \times 10^{-4}$
1 acre per pound acre/lb	=	8 921.79	**43.56**	**302.5**	**2 722.5**	**1**	**3.5**	0.892 179
1 square mile per UK ton $mile^2/ton$	=	2 549.08	12.445 7	86.428 6	777.857	0.285 714	**1**	0.254 908
1 hectare per kilogram ha/kg	=	**1** $\times 10^4$	48.824 3	339.057	3 051.52	1.120 85	3.922 98	**1**

[a] 1 square metre per kilogram (m^2/kg) = 10^{-3} m^2/g = 10^{-2} cm^2/mg = 1 mm^2/mg.

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19 Area per unit capacity

Another combination with somewhat similar application is "area per unit capacity" (used for the "covering power" of paints, etc.). Table 21 gives interconversion factors for square metres per litre, square yards per UK gallon, and square feet per UK gallon.

Table 21 — Area per unit capacity

Exact values are printed in bold type

		square metre per litre m^2/l	square yard per gallon yd^2/gal	square foot per gallon ft^2/gal
1 square metre per litre m^2/l	=	**1**	5.437 08	48.933 7
1 square yard per gallon yd^2/gal	=	0.183 992	**1**	**9**
1 square foot per gallon ft^2/gal	=	0.020 435 8	0.111 111	**1**

20 Density[11] (volumic mass), (mass/volume)

20.1 The coherent SI unit of density is the kilogram per cubic metre (kg/m^3), a derived unit. ISO now prefer the term "volumic mass" to density.

20.2 Other commonly used metric units are:

gram per cubic centimetre (g/cm^3)
or
gram per millilitre (g/ml)[12]
} (= 1 000 kg/m^3)

20.3 A selection of imperial units is:

pound per cubic inch (lb/in^3)	(= 27 679.9 kg/m^3)
pound per cubic foot (lb/ft^3)	(= 16.018 5 kg/m^3)
UK ton per cubic yard ($UKton/yd^3$)	(= 1 328.94 kg/m^3)
pound per UK gallon (lb/UKgal)	(= 99.776 3 kg/m^3)
pound per US gallon (lb/USgal)	(= 119.826 kg/m^3)

For interconversion factors for the above see Table 22. See also Clause 21, Mass concentration.

[11] It should be noted that "relative density" (i.e. density/reference density) is a dimensionless quantity. The relative density of a substance is defined as the ratio of the mass of a given volume of that substance to the mass of an equal volume of a reference substance, under conditions which should be specified for both substances. When the reference substance is water the term "specific gravity" is commonly used for relative density. For conversions of readings of hydrometers on different density and specific gravity bases see BS 718.

[12] 1 gram per millilitre (1901) = 999.972 kg/m^3. See **5.3** and **5.4**.

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Table 22 — Density (volumic mass) (mass/volume)

Exact values are printed in bold type

	kilogram per cubic metre kg/m³	**gram per cubic centimetre (or gram per millilitre)** g/cm³ (g/ml)	**gram per millilitre (1901)** g/ml (1901)	**pound per cubic inch** lb/in³	**pound per cubic foot** lb/ft³	**UK ton per cubic yard** UKton/yd³	**pound per UK gallon** lb/UKgal	**pound per US gallon** lb/USgal
1 kilogram per cubic metre = kg/m³	**1**	**0.001**	$1.000\ 028 \times 10^{-3}$	$3.612\ 73 \times 10^{-5}$	$6.242\ 80 \times 10^{-2}$	$7.524\ 80 \times 10^{-4}$	$1.002\ 24 \times 10^{-2}$	$0.834\ 540 \times 10^{-2}$
1 gram per cubic centimetre = g/cm³ = (g/ml)	**1 000**	**1**	1.000 028	0.036 127 3	62.428 0	0.752 480	10.022 4	8.345 40
1 gram per millilitre (1901) = g/ml (1901)	999.972	0.999 972	**1**	0.036 126 3	62.426 2	0.752 459	10.022 1	8.345 17
1 pound per cubic inch = lb/in³	27 679.9	27.679 9	27.680 7	**1**	**1 728**	20.828 6	277.420	**231**
1 pound per cubic foot = lb/ft³	16.018 5	0.016 018 5	0.016 018 9	$5.787\ 04 \times 10^{-4}$	**1**	0.012 053 6	0.160 544	0.133 681
1 UK ton per cubic yard = UKton/yd³	1 328.94	1.328 94	1.328 98	0.048 011 0	82.963 0	**1**	13.319 2	11.090 5
1 pound per UK gallon = lb/UKgal	99.776 3	0.099 776 3	0.099 779 1	$3.604\ 65 \times 10^{-3}$	6.228 83	0.075 079 7	**1**	0.832 674
1 pound per US gallon = lb/USgal	119.826	0.119 826	0.119 830	$4.329\ 00 \times 10^{-3}$	7.480 52	0.090 167 0	1.200 95	**1**

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21 Mass concentration (mass/volume)

21.1 In practice "concentration" is "amount of substance concentration", e.g. "mol/l". Following discussions between IUPAP (International Union of Pure and Applied Physics) and IUPAC (International Union of Pure and Applied Chemistry), agreement was reached to assign the value 12 exactly to the relative atomic mass (commonly and erroneously called the "atomic weight") of the isotope of carbon with mass number 12 (carbon 12, ^{12}C). This unified the scale of relative atomic masses. The amount of substance was then defined by fixing the mass of carbon 12 to 0.012 kg, and the "amount of substance" was given the name "mole" (symbol mol). After proposals by IUPAP, IUPAC and ISO, the CIPM (International Committee for Weights and Measures) defined the mole as follows.

1. 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; its symbol is "mol".

2. 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.

In 1980 the CIPM approved the report of the CCU (Consultative Committee for Units) (1980) which specified the following.

"In this definition, it is understood that unbound atoms of carbon 12, at rest and in their ground state, are referred to."

21.2 The coherent SI unit for the expression of mass concentration[13)] (in the sense of the mass of a substance per unit volume of a solution, or the like) is the kilogram per cubic metre (kg/m^3), a derived unit. This unit is equal to 1 gram per cubic decimetre, and is commonly expressed as 1 gram per litre[14)].

$1\ kg/m^3 = 1\ g/dm^3 = 1\ g/l$

21.3 Some imperial and US units for the statement of mass concentration are:

grain per cubic foot (gr/ft^3)	(= $0.228\ 835 \times 10^{-2}\ kg/m^3$)
grain per UK gallon (gr/UKgal)	(= $0.014\ 253\ 8\ kg/m^3$)
grain per US gallon (gr/USgal)	(= $0.017\ 118\ 1\ kg/m^3$)
ounce per UK gallon (oz/UKgal)	(= $6.236\ 02\ kg/m^3$)
ounce per US gallon (oz/USgal)	(= $7.489\ 15\ kg/m^3$)

For interconversion factors for the above see Table 23. See also Clause 20, Density (volumic mass).

13) Concentration is sometimes expressed in other ways, for example, mass (of a substance) per unit mass (of a solution), or, in physical chemistry, in terms of moles per unit volume.

14) 1 gram per litre (1901) = $0.999\ 972\ kg/m^3$. See **5.3** and **5.4**.

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Table 23 — Mass concentration

Exact values are printed in bold type

	kg/m³ g/dm³ g/l	g/l (1901)[a]	gr/ft³	gr/UKgal	gr/USgal	oz/UKgal	oz/USgal
1 kilogram per cubic metre kg/m³ 1 gram per cubic decimetre g/dm³ 1 gram per litre g/l =	**1**	1.000 028	436.996	70.156 9	58.417 8	0.160 359	0.133 526
1 gram per litre (1901)[a] g/l (1901) =	0.999 972	**1**	436.983	70.154 9	58.416 2	0.160 354	0.133 523
1 grain per cubic foot gr/ft³ =	$0.228\ 835 \times 10^{-2}$	$0.228\ 842 \times 10^{-2}$	**1**	0.160 544	0.133 681	$3.669\ 57 \times 10^{-4}$	$3.055\ 56 \times 10^{-4}$
1 grain per UK gallon gr/UKgal =	0.014 253 8	0.014 254 2	6.228 83	**1**	0.832 674	$2.285\ 71 \times 10^{-3}$	$1.903\ 25 \times 10^{-3}$
1 grain per US gallon gr/USgal =	0.017 118 1	0.017 118 5	7.480 52	1.200 95	**1**	$2.745\ 03 \times 10^{-3}$	$2.285\ 71 \times 10^{-3}$
1 ounce per UK gallon oz/UKgal =	6.236 02	6.236 20	2 725.11	**437.5**	364.295	**1**	0.832 674
1 ounce per US gallon oz/USgal =	7.489 15	7.489 36	3 272.73	525.416	**437.5**	1.200 95	**1**

NOTE 1 g indicates gram. gr indicates grain.

NOTE 2 See also Table 22, Density (volumic mass).

[a] 1 litre (1901) per kilogram = $1.000\ 028 \times 10^{-3}$ m³/kg. See **5.3** and **5.4**.

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22 Specific volume (volume/mass)

22.1 The coherent SI unit of specific volume (which is the reciprocal of density) is the cubic metre per kilogram (m^3/kg), a derived unit.

22.2 Another commonly used metric unit is:

litre[15] per kilogram (l/kg) = 0.001 m^3/kg.

22.3 A selection of imperial units is:

cubic foot per pound (ft^3/lb)	(= 0.062 428 0 m^3/kg)
cubic inch per pound (in^3/lb)	(= 3.612 73 × 10^{-5} m^3/kg)
cubic foot per UK ton (ft^3/UKton)	(= 2.786 96 × 10^{-5} m^3/kg)
UK gallon per pound (UKgal/lb)	(= 0.010 022 4 m^3/kg)

For interconversion factors for the above see Table 24.

23 Mass rate of flow (mass/time)

23.1 The coherent SI unit of mass rate of flow is the kilogram per second (kg/s), a derived unit.

23.2 Another commonly used metric unit is the kilogram per hour (kg/h).

1 kg/h = 2.777 78 × 10^{-4} kg/s

23.3 A selection of imperial units is:

pound per second (lb/s)	(= 0.453 592 kg/s)
pound per hour (lb/h)	(= 1.259 98 × 10^{-4} kg/s)
UK ton per hour (UKton/h)	(= 0.282 235 kg/s)

For interconversion factors for the above see Table 25.

[15] 1 litre (1901) per kilogram = 1.000 028 × 10^{-3} m^3/kg. See **5.3** and **5.4**.

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Table 24 — Specific volume

Exact values are printed in bold type

	cubic metre per kilogram m³/kg	**litre[a] per kilogram** l/kg	**cubic foot per pound** ft³/lb	**cubic inch per pound** in³/lb	**cubic foot per UK ton** ft³/ton	**UK gallon per pound** UKgal/lb
1 cubic metre per kilogram m³/kg =	**1**	**1 000**	16.018 5	27 679.9	35 881.4	99.776 3
1 litre[a] per kilogram l/kg =	**0.001**	**1**	0.016 018 5	27.679 9	35.881 4	0.099 776 3
1 cubic foot per pound ft³/lb =	0.062 428 0	62.428 0	**1**	**1 728**	**2 240**	6.228 83
1 cubic inch per pound in³/lb =	$3.612\ 73 \times 10^{-5}$	0.036 127 3	$5.787\ 04 \times 10^{-4}$	**1**	1.296 30	$3.604\ 65 \times 10^{-3}$
1 cubic foot per UK ton ft³/ton =	$2.786\ 96 \times 10^{-5}$	0.027 869 6	$4.464\ 29 \times 10^{-4}$	0.771 429	**1**	$2.780\ 73 \times 10^{-3}$
1 UK gallon per pound UKgal/lb =	0.010 022 4	10.022 4	0.160 544	277.420	359.618	**1**

[a] 1 litre (1901) = 1.000 028 litre. See **5.3** and **5.4**.

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Table 25 — Mass rate of flow

Exact values are printed in bold type

		kilogram per second kg/s	kilogram per hour kg/h	pound per second lb/s	pound per hour lb/h	UK ton per hour UKton/h
1 kilogram per second kg/s	=	**1**	**3 600**	2.204 62	7 936.64	3.543 14
1 kilogram per hour kg/h	=	$2.777\ 78 \times 10^{-4}$	**1**	$6.123\ 95 \times 10^{-4}$	2.204 62	$9.842\ 07 \times 10^{-4}$
1 pound per second lb/s	=	0.453 592	1 632.93	**1**	**3 600**	1.607 14
1 pound per hour lb/h	=	$1.259\ 98 \times 10^{-4}$	0.453 592	$2.777\ 78 \times 10^{-4}$	**1**	$4.464\ 29 \times 10^{-4}$
1 UK ton per hour UKton/h	=	0.282 235	1 016.05	0.622 222	**2 240**	**1**

24 Volume rate of flow[16] (volume/time)

24.1 The coherent SI unit of volume rate of flow is the cubic metre per second[17] (m^3/s), a derived unit.

24.2 Some other commonly used metric units are:

cubic metre per hour (m^3/h)	(= $2.777\ 78 \times 10^{-4}\ m^3/s$)
litre[18] per second (l/s)	(= $0.001\ m^3/s$)
litre[18] per minute (l/min)	(= $1.666\ 67 \times 10^{-5}\ m^3/s$)
litre[18] per hour (l/h)	(= $2.777\ 78 \times 10^{-7}\ m^3/s$)

24.3 A selection of imperial units is:

cubic foot per second[19] (ft^3/s)	(= $0.028\ 316\ 8\ m^3/s$)
cubic foot per hour (ft^3/h)	(= $7.865\ 79 \times 10^{-6}\ m^3/s$)
UK gallon per second (UKgal/s)	(= $4.546\ 09 \times 10^{-3}\ m^3/s$)
UK gallon per minute (UKgal/min)	(= $7.576\ 82 \times 10^{-5}\ m^3/s$)
UK gallon per hour (UKgal/h)	(= $1.262\ 80 \times 10^{-6}\ m^3/s$)

For interconversion factors for the above see Table 26.

16) For gases, the conversion factors given here are based on the assumption that the reference conditions of temperature, pressure and humidity remain unchanged.

17) The cubic metre per second is sometimes known as the "cumec".

18) The litre (1901) = 1.000 028 litre (see **5.3** and **5.4**).

19) The cubic foot per second is sometimes known as the "cusec".

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Table 26 — Volume rate of flow

Exact values are printed in bold type

	cubic metre per second m^3/s	cubic metre per minute m^3/min	cubic metre per hour m^3/h	litre[a] per second l/s	litre[a] per minute l/min	litre[a] per hour l/h	cubic foot per second ft^3/s	cubic foot per minute ft^3/min	cubic foot per hour ft^3/h	UK gallon per second UKgal/s	UK gallon per minute UKgal/min	UK gallon per hour UKgal/h
1 cubic metre per second m^3/s =	**1**	**60**	**3 600**	**1 000**	**60 000**	**3.6** $\times 10^{6}$	35.314 7	2.118 88 $\times 10^{3}$	127 133	219.969	13 198.2	791 889
1 cubic metre per minute m^3/min =	0.016 666 7	**1**	**60**	16.666 7	**1 000**	**60 000**	0.588 578	35.314 7	2.118 88 $\times 10^{3}$	3.666 15	219.969	13 198.2
1 cubic metre per hour m^3/h =	2.777 78 $\times 10^{-4}$	0.016 666 7	**1**	0.277 778	16.666 7	**1 000**	9.809 63 $\times 10^{-3}$	0.588 578	35.314 7	0.061 102 6	3.666 15	219.969
1 litre[a] per second l/s =	**0.001**	**0.06**	**3.6**	**1**	**60**	**3 600**	0.035 314 7	2.118 88	127.133	0.219 969	13.198 2	791.889
1 litre[a] per minute l/min =	1.666 67 $\times 10^{-5}$	**0.001**	**0.06**	0.016 667	**1**	**60**	5.885 78 $\times 10^{-4}$	0.035 314 7	2.118 88	3.666 15 $\times 10^{-3}$	0.219 969	13.198 2
1 litre[a] per hour l/h =	0.277 778 $\times 10^{-6}$	1.666 67 $\times 10^{-5}$	**0.001**	0.277 778 $\times 10^{-3}$	0.016 666 7	**1**	9.809 63 $\times 10^{-6}$	5.885 78 $\times 10^{-4}$	0.035 314 7	6.110 26 $\times 10^{-5}$	3.666 15 $\times 10^{-3}$	0.219 969
1 cubic foot per second ft^3/s =	0.028 316 8	1.699 01	101.941	28.316 8	1 699.01	101 941	**1**	**60**	**3 600**	6.228 84	373.730	2.242 38 $\times 10^{4}$
1 cubic foot per minute ft^3/min =	4.719 47 $\times 10^{-4}$	0.028 316 8	1.699 01	0.471 947	28.316 8	1.699 01 $\times 10^{3}$	0.016 666 7	**1**	**60**	0.103 814	6.228 84	373.730
1 cubic foot per hour ft^3/h =	7.865 79 $\times 10^{-6}$	4.719 47 $\times 10^{-4}$	0.028 316 8	7.865 79 $\times 10^{-3}$	0.471 947	28.316 8	0.277 778 $\times 10^{-3}$	0.016 666 7	**1**	1.730 23 $\times 10^{-3}$	0.103 814	6.228 84
1 UK gallon per second UKgal/s =	**4.546 09** $\times 10^{-3}$	0.272 765	16.365 9	**4.546 09**	272.765	16 365.9	0.160 544	9.632 62	577.957	**1**	**60**	**3 600**
1 UK gallon per minute UKgal/min =	7.576 82 $\times 10^{-5}$	**4.546 09** $\times 10^{-3}$	0.272 765	0.075 768 2	**4.546 09**	272.765	2.675 73 $\times 10^{-3}$	0.160 544	9.632 62	0.016 666 7	**1**	**60**
1 UK gallon per hour UKgal/h =	1.262 80 $\times 10^{-6}$	7.576 82 $\times 10^{-5}$	**4.546 09** $\times 10^{-3}$	1.262 80 $\times 10^{-3}$	0.075 768 2	**4.546 09**	4.459 55 $\times 10^{-5}$	2.675 73 $\times 10^{-3}$	0.160 544	0.277 778 $\times 10^{-3}$	0.016 666 7	**1**

NOTE For gases, the conversion factors given in this table are based on the assumption that the reference conditions of temperature, pressure and humidity remain unchanged.

[a] The litre used here is equal to 1 cubic decimetre. 1 litre (1901) = 1.000 028 dm^3 (see **5.3** and **5.4**).

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25 Traffic factors

(in connection with volume of fuel consumed, distance run and load carried)

It should be noted that in mainland European countries fuel consumptions are usually expressed in terms of litres per kilometre, or litres per 100 kilometres, i.e. volume of fuel per distance run (see Table 27). In the UK the reciprocal factor (distance/volume) in terms of miles per gallon is used (see Table 28). As fuel in the UK is now sold in litres, consumption is sometimes calculated in miles per litre.

Table 27 — Fuel consumption (volume/distance)

Exact values are printed in bold type

		litre per kilometre[a] l/km	**UK gallon per mile** UKgal/mile	**US gallon per mile** USgal/mile	**litre per mile** l/mile
1 litre per kilometre[a] l/km	=	**1**	0.354 006	0.425 144	1.609 344
1 UK gallon per mile UKgal/mile	=	2.824 81	**1**	1.200 95	4.546 09
1 US gallon per mile USgal/mile	=	2.352 15	0.832 674	**1**	3.785 41
1 litre per mile l/mile	=	0.621 371	0.219 969	0.264 172	**1**

[a] Several mainland European countries use the factor "litre per 100 kilometres".

Table 28 — Fuel consumption (distance/volume)

Exact values are printed in bold type

		kilometre per litre km/l	**mile per UK gallon** mile/UKgal	**mile per US gallon** mile/USgal	**mile per litre** mile/l
1 kilometre per litre km/l	=	**1**	2.824 81	2.352 15	0.621 371
1 mile per UK gallon mile/UKgal	=	0.354 006	**1**	0.832 674	0.219 969
1 mile per US gallon mile/USgal	=	0.425 144	1.200 95	**1**	0.264 172
1 mile per litre mile/l	=	1.609 344	4.546 09	3.785 41	**1**

Mass carried × distance

1 tonne kilometre = 0.611 558 UKton mile
1 UKton mile = 1.635 17 tonne kilometre

Mass carried × distance/volume

1 tonne kilometre per litre = 2.780 20 UKton mile per UK gallon
1 UKton mile per UK gallon = 0.359 687 tonne kilometre per litre

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26 Moment of inertia (mass × length squared)

26.1 The coherent SI unit of moment of inertia is the kilogram metre squared ($kg \cdot m^2$), a derived unit.

26.2 Some other metric units which have been used are:

kilogram millimetre squared ($kg \cdot mm^2$)	($1\ kg \cdot mm^2 = 10^{-6}\ kg \cdot m^2$)
gram centimetre squared ($g \cdot cm^2$)	($1\ g \cdot cm^2 = 10^{-7}\ kg \cdot m^2$)

26.3 A selection of imperial units is:

pound foot squared ($lb \cdot ft^2$)	(= 0.042 140 1 $kg \cdot m^2$)
pound inch squared ($lb \cdot in^2$)	(= 2.926 40 × 10^{-4} $kg \cdot m^2$)
ounce (avoir) inch squared ($oz \cdot in^2$)	(= 1.829 00 × 10^{-5} $kg \cdot m^2$)

For interconversion factors for the above see Table 29.

Table 29 — Moment of inertia

Exact values are printed in bold type

		kilogram metre squared $kg \cdot m^2$	**pound foot squared** $lb \cdot ft^2$	**pound inch squared** $lb \cdot in^2$	**ounce inch squared** $oz \cdot in^2$
1 kilogram metre squared $kg \cdot m^2$	=	**1**	23.730 4	3 417.17	54 674.8
1 pound foot squared $lb \cdot ft^2$	=	0.042 140 1	**1**	**144**	**2 304**
1 pound inch squared $lb \cdot in^2$	=	2.926 40 × 10^{-4}	6.944 44 × 10^{-3}	**1**	**16**
1 ounce inch squared $oz \cdot in^2$	=	1.829 00 × 10^{-5}	4.340 28 × 10^{-4}	**0.062 5**	**1**
NOTE 1 $kg \cdot m^2 = 10^6\ kg \cdot mm^2 = 10^7\ g \cdot cm^2$.					

27 Momentum (linear) (mass × velocity)

The coherent SI unit of momentum is the kilogram metre per second.

Some key conversion factors are:

1 kg·m/s	=	7.233 01 lb·ft/s
1 lb·ft/s	=	0.138 255 kg·m/s
(1 kg·m/s	=	10^5 g·cm/s)

28 Angular momentum (mass × velocity × length)

The coherent SI unit of angular momentum is the kilogram metre squared per second.

Some key conversion factors are:

1 $kg \cdot m^2/s$	=	23.730 4 $lb \cdot ft^2/s$
1 $lb \cdot ft^2/s$	=	0.042 140 l $kg \cdot m^2/s$

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29 Force (mass × acceleration)

29.1 The coherent SI unit of force is the newton (N), a derived unit with a special name. Expressed in terms of base units of the SI, the newton is the kilogram metre per second squared ($kg \cdot m/s^2$) and is that force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one metre per second squared.

29.2 Other metric units of force of historical or practical importance are:

the dyne (dyn), the force unit in the centimetre-gram-second system;

the sthène (sn), the force unit in the metre-tonne-second system; and

the kilogram-force (kgf), which is often described as the metric technical unit of force. In Germany and some other mainland European countries the kilogram-force is called the kilopond (symbol kp).

1 dyn	=	$1\ g \cdot cm/s^2$	($= 10^{-5}$ N)
1 sn	=	$1\ t \cdot m/s^2$	($= 10^3$ N)

The kilogram-force (or kilopond) is that force which, when applied to a body having a mass of one kilogram, gives it the standard acceleration[20] due to gravity (i.e. **9.806 65** m/s^2).

Thus:

1 kgf (or kp) = **9.806 65** $kg \cdot m/s^2$ (= **9.806 65** N)

29.3 In the foot-pound-second system the coherent force unit is the poundal (pdl).

1 pdl	=	$1\ lb \cdot ft/s^2$
	=	**0.453 592 37** × **0.304 8** $kg \cdot m/s^2$
	(=	0.138 255 N) (approximately)

The corresponding technical force unit in the UK and USA is the pound-force (lbf). It is that force which, when applied to a body having a mass of one pound, gives it the standard acceleration[20] due to gravity.

Thus:

$$1\ \text{lbf} = \frac{\mathbf{9.806\ 65}}{\mathbf{0.304\ 8}}\ \text{lb} \cdot \text{ft/s}^2$$

= 32.174 0 pdl (approximately)

(= 4.448 22 N)[21]

Further technical force units associated with the pound-force are the ounce-force (ozf), the UK ton-force (tonf) and the US ton-force. In the USA a unit of 1 000 lbf named the “kip” is often used.

1 ozf	=	$\frac{1}{16}$ lbf	(= 0.278 014 N)
1 tonf	=	2 240 lbf	(= 9 964.02 N)
1 US ton-force	=	2 000 lbf	(= 8 896.44 N)
1 kip (USA only)	=	1 000 lbf	(= 4 448.22 N)

29.4 The kilogram-force (kgf), and the pound-force (lbf) and its associated units, are both exactly defined in terms of the standard acceleration due to gravity. Because local acceleration due to gravity usually differs slightly from standard acceleration, it follows that the forces exerted by gravity on bodies having a mass of 1 kg or 1 lb are rarely exactly equal to 1 kgf or 1 lbf respectively, and account has to be taken of this when very high precision is required. See also Clause **30**, Weight.

Interconversion factors for the above units are given in, or can be readily inferred from, Table 30.

[20] See **14.4**

[21] In exact terms, 0.453 592 37 × 9.806 65 N.

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Table 30 — Force

Exact values are printed in bold type

	newton N	kilogram-force kgf	poundal pdl	pound-force lbf	UK ton-force tonf	ounce-force ozf
1 newton N =	**1**	0.101 972	7.233 01	0.224 809	$1.003\ 61 \times 10^{-4}$	3.596 94
1 kilogram-force kgf =	**9.806 65**	**1**	70.931 6	2.204 62	$9.842\ 07 \times 10^{-4}$	35.274 0
1 poundal pdl =	0.138 255	0.014 098 1	**1**	0.031 081 0	$1.387\ 54 \times 10^{-5}$	0.497 295
1 pound-force lbf =	4.448 22	0.453 592	32.174 0	**1**	$4.464\ 29 \times 10^{-4}$	**16**
1 UK ton-force tonf =	9 964.02	1 016.05	72 069.9	**2 240**	**1**	**35 840**
1 ounce-force ozf =	0.278 014	0.028 349 5	2.010 88	**0.062 5**	$2.790\ 18 \times 10^{-5}$	**1**

NOTE

1 dyne (dyn) = 10^{-5} N (see **29.2**)

1 sthène (sn) = 10^{3} N (see **29.2**)

1 kip (USA only) = 1 000 lbf (see **29.3**)

1 US ton-force = 2 000 lbf (see **29.3**)

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30 Weight

30.1 Meaning of "weight"

The term "weight" is commonly used to denote either mass or force, i.e. the mass of a body or the force of gravity acting upon it. It is used in the sense of "mass" in the UK Weights and Measures Act, 1985 [1] and in common parlance; it is used in the sense of force by the CGPM and in scientific and some technical work. *The International System of Units (SI)*, 7th edition 1998 [3] states that "the word 'weight' denotes a quantity of the same nature as a 'force': the weight of a body is the product of its mass and the acceleration due to gravity: in particular, the standard weight of a body is the product of its mass and the standard acceleration due to gravity." The UK Weights and Measures Act 1985 [1], refers to "measurement of mass or weight", but specifies that the kilogram is the unit of mass.

As weight values may be found quoted in either mass or force units both usages are accommodated in the conversion tables. To convert weight units when using weight in the mass sense Table 15, Table 16 or Table 17 should be used; to convert weight units when using weight as a force Table 30 should be used.

30.2 Relationship between force of gravity and mass

The force of gravity (for example, expressed in newtons) is equal to the mass (in kilograms) multiplied by the local gravitational acceleration (in metres per second squared). For most practical purposes variations in local gravitational acceleration can be ignored and the standard value of **9.806 65** m/s^2 is assumed (usually rounded to 9.81 m/s^2).

It is the standard value of **9.806 65** m/s^2 that is used in defining with precision the technical force units, the kilogram-force and the pound-force.

30.3 Accurate weight conversions

Conversions from one system of units to another on a mass to mass basis, or on a force to force basis, can be made with good accuracy by using the tables for Clause **15** (Table 15, Table 16 and Table 17) and Clause **29** (Table 30), respectively. However, to obtain the accurate relationship of a mass to its associated gravitational force account has to be taken of the exact local value of the earth's gravitational field. The downward force on the mass is also affected by the buoyancy of any displaced atmosphere.

31 Moment of force, or torque (force × length)

31.1 The coherent SI unit of moment (of force) is the newton metre (N·m), a derived unit. See Note on Clause **31** concerning the energy unit, which has a different physical significance.

31.2 A metric unit often used for moment, or torque, in mainland European countries is the kilogram-force metre (kgf·m).

1 kgf·m = **9.806 65** N·m

This unit is called the kilopond metre (kp·m) in Germany.

31.3 A selection of imperial units is:

poundal foot (pdl·ft)	(= 0.042 140 1 N·m)
pound-force foot (lbf·ft)	(= 1.355 82 N·m)
pound-force inch (lbf·in)	(= 0.112 985 N·m)
UK ton-force foot (tonf·ft)	(= 3 037.03 N·m)
ounce-force inch (ozf·in)	(= 7.061 55 × 10^{-3} N·m)

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Note on Clause 31

NOTE The product newton × metre (N·m) also expresses the SI unit for work done, or energy, a unit having the special name joule (J), (see Clause **37**, Energy). However, torque and energy are different physical quantities; both are dimensionally force × length but in the former the directions of the force and length components are perpendicular to each other while in the latter they are in line with each other.

With imperial units a distinction between torque units and energy units is made (by convention) by reversing the order of the units; e.g. the foot pound-force (ft·lbf) is an energy unit and the pound-force foot (lbf·ft) a torque unit. There is no similar convention used, or advisable, with metric (including SI) units; it can be seen for example that m·N (the reverse of N·m) would easily be mistaken for millinewton. However, in practice both ft·lb and N·m may be seen indicating torque.

Metric moment or torque units should be expressed as indicated in **31.1** and **31.2**.

It may be useful to point out that because both torque and energy are dimensionally the same (force × length) there is a numerical correspondence between energy conversion tables and torque conversion tables.

For interconversion factors for the above see Table 31.

Table 31 — Moment of force (torque)

Exact values are printed in bold type

	newton metre N·m	kilogram-force[a] metre kgf·m	poundal foot pdl·ft	pound-force foot lbf·ft	pound-force inch lbf·in	UK ton-force foot tonf·ft	ounce-force inch ozf·in
1 newton metre N·m =	**1**	0.101 972	23.730 4	0.737 562	8.850 75	$3.292\ 69 \times 10^{-4}$	141.612
1 kilogram-force[a] metre kgf·m =	**9.806 65**	**1**	232.715	7.233 01	86.796 2	$3.229\ 02 \times 10^{-3}$	1 388.74
1 poundal foot pdl·ft =	0.042 140 1	$4.297\ 10 \times 10^{-3}$	**1**	0.031 081 0	0.372 971	$1.387\ 54 \times 10^{-5}$	5.967 54
1 pound-force foot lbf·ft =	1.355 82	0.138 255	32.174 0	**1**	**12**	$4.464\ 29 \times 10^{-4}$	**192**
1 pound-force inch lbf·in =	0.112 985	0.011 521 2	2.681 17	0.083 333 3	**1**	$3.720\ 24 \times 10^{-5}$	**16**
1 UK ton-force foot tonf·ft =	3 037.03	309.691	72 069.9	**2 240**	**26 880**	**1**	**430 080**
1 ounce-force inch ozf·in =	$7.061\ 55 \times 10^{-3}$	$7.200\ 78 \times 10^{-4}$	0.167 573	$5.208\ 33 \times 10^{-3}$	**0.062 5**	$2.325\ 15 \times 10^{-6}$	**1**

NOTE 1 newton millimetre (N·mm) = 10^{-3} newton metre (N·m).
1 dyne centimetre (dyn·cm) = 10^{-7} newton metre (N·m).

[a] The kilogram-force is called the kilopond (kp) in Germany. 1 kgf·m = 1 kp·m

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32 Force per unit length[22] (force/length)

32.1 The coherent SI unit is the newton per metre (N/m).

32.2 Another metric unit that may still be encountered is the dyne per centimetre (dyn/cm).

1 dyn/cm = 10^{-3} N/m

No interconversion tables are provided for force per unit length. The main reason for mentioning it here is to show the distinction from torque.

33 Pressure (force/area)

33.1 General

33.1.1 The coherent SI unit of pressure is the newton per square metre, N/m^2, for which the special name pascal (symbol Pa) was approved by the CGPM in 1971.

One pascal represents a very small pressure, and its multiples kilopascal (kPa) (or kN/m^2) and megapascal (MPa) (or MN/m^2) are therefore frequently used.

33.1.2 Arising from the historical evolution of the SI from the CGS system, some pressure units have a decimal relationship with the pascal. These are the dyne per square centimetre (dyn/cm^2) (sometimes called the barye), the pièze (pz), and the bar (bar[23]). Only the last of these, with its multiples, persists in common use.

The dyne per square centimetre is also a very small pressure:

$$1\ \text{dyn/cm}^2 = \frac{1\times10^{-5}\ \text{N}}{(\text{m}/100)^2} = 0.1\ \text{N/m}^2 = 0.1\ \text{Pa}$$

The pièze is the coherent pressure unit in the metre-tonne-second system, being equal to one sthène per square metre:

1 pz = 1 sn/m^2 = 1 × 10^3 N/m^2 = 1 kN/m^2 = 1 kPa.

The bar, 10^6 dyn/cm^2, is legally recognized in EU countries and has a magnitude not far removed from that of usual atmospheric pressure at sea level.

1 bar = 10^6 dyn/cm^2 = 10^6 × 0.1 N/m^2 = 10^5 N/m^2 = 10^5 Pa.

One of its submultiples, the millibar, is widely used in the expression of barometric pressures.

33.1.3 Also in common use in mainland European countries are the technical pressure units, the kilogram-force per square metre, and, in particular, the kilogram-force per square centimetre:

1 kgf/m^2	=	9.806 65 N/m^2 (exactly)	=	9.806 65 Pa
1 kgf/cm^2	=	0.980 665 × 10^5 N/m^2 (exactly)	=	0.098 066 5 MPa

In Germany and some other mainland European countries the kilopond (kp) is used in place of the kilogram-force (kgf), e.g. 1 kp/cm^2 = 1 kgf/cm^2.

These technical units have a simple relationship with conventional columns of water expressed in metric terms (see **33.2**).

[22] For example, surface tension.

[23] The internationally recognized unit symbol for the bar is the same as the unit name. In meteorology, however, the commonly used symbol for the millibar is simply mb.

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33.1.4 Some imperial units that are expressed directly in terms of force per unit area, are as follows. All except the first are technical units.

poundal per square foot (pdl/ft^2), the coherent unit in the foot-pound-second system

pound-force per square foot (lbf/ft^2)

pound-force per square inch (lbf/in^2)

UK ton-force per square foot ($tonf/ft^2$)

UK ton-force per square inch ($tonf/in^2$)

$$1\ \mathrm{pdl/ft^2} = \frac{\mathbf{0.453\ 592\ 37} \times (\mathbf{0.304\ 8})\ \mathrm{N}}{(\mathbf{0.304\ 8}\ \mathrm{m})^2}$$

$$= 1.488\ 16\ \mathrm{Pa\ (or\ N/m^2)} \quad \text{approx.}$$

$$1\ \mathrm{lbf/ft^2} = \frac{\mathbf{0.453\ 592\ 37} \times \mathbf{9.806\ 65}\ \mathrm{N}}{(\mathbf{0.304\ 8}\ \mathrm{m})^2}$$

$$= 47.880\ 3\ \mathrm{Pa\ (or\ N/m^2)} \quad \text{approx.}$$

1 lbf/in^2	= 144 lbf/ft^2	=	6 894.76 Pa (or N/m^2)	approx.
1 $UKtonf/ft^2$	= 2 240 lbf/ft^2	=	$1.072\ 52 \times 10^5$ Pa (or N/m^2)	approx.
1 $UKtonf/in^2$	= 2 240 lbf/in^2	=	$1.544\ 43 \times 10^7$ Pa (or N/m^2)	approx.

The pound-force per square inch (lbf/in^2) is often known and shown by the abbreviation p.s.i., but, although widely used in the UK and USA, this abbreviation is inconsistent with the internationally recognized symbology for units. In the USA, the expression "k.s.i." is often used to signify kips per square inch (i.e. 1 000 lbf/in^2).

33.2 Liquid columns

Pressures are often measured in terms of the height of a column of liquid, e.g. of mercury or of water. The pressure associated with a given height is dependent upon the density of the liquid and the local acceleration due to gravity. The following pressure units are based upon conventional density and gravity conditions:

the conventional millimetre of mercury (symbol mmHg);

the conventional inch of mercury (symbol inHg);

the conventional millimetre of water (symbol mmH_2O);

the conventional metre of water (symbol mH_2O);

the conventional inch of water (symbol inH_2O);

the conventional foot of water (symbol ftH_2O).

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$1\ \text{mmH}_2\text{O} = 0.001\ \text{m} \times 1\ 000\ \text{kg/m}^3 \times 9.806\ 65\ \text{m/s}^2 = 9.806\ 65\ \text{N/m}^2 = \mathbf{9.806\ 65}\ \text{Pa}$

(This is the pressure due to an ideal column of water of length 1 mm and of uniform density 1 g/cm^3, when under the standard condition g_n = **9.806 65** m/s^2)

1 mmHg	= 13.595 1 mmH$_2$O	= **13.595 1** × **9.806 65** Pa
		= 133.322 Pa (approx.)[24]
1 inH$_2$O	= 25.4 mmH$_2$O	= **9.806 65** × **25.4** Pa
		= 249.089 Pa (approx.)
1 inHg	= 25.4 mmHg	= **9.806 65** × **13.595 1** × **25.4** Pa
		= 3 386.39 Pa (approx.)
1 ftH$_2$O	= 304.8 mmH$_2$O	= **304.8** × **9.806 65** Pa
		= 2 989.07 Pa (approx.)

Another pressure unit in common use, known as the torr, is equal, within one part in 7 million, to the conventional millimetre of mercury (mmHg). It is, however, precisely defined in terms of the pascal as follows:

$$1\ \text{torr} = \frac{\mathbf{101\ 325.0}}{\mathbf{760}}\ \text{Pa}$$

$$= 133.322\ \text{Pa (approx.)}$$

Because of its size, the pascal is well-suited to vacuum technology. However, in addition to the millibar and torr and their submultiples, the term "micron" meaning micrometre of mercury (µmHg), is still common in this field. The symbol µmHg is sometimes (incorrectly) contracted to µ.

Following from its definition, the conventional millimetre of water is exactly equal to the kilogram-force per square metre:

1 mmH$_2$O = 1 kgf/m^2 (or kp/m^2)

Similarly, 10 mH$_2$O = 1 kgf/cm^2 (or kp/cm^2).

33.3 Atmospheres

Attention is called to the significance of the following terms and symbols.

Standard atmosphere (atm). This is an internationally established reference for pressure of 101 325 Pa, being equal to 760 mmHg within one part in 7 million. It should not be regarded or used as a unit, but it is of great importance and in widespread use as a reference.

Technical atmosphere (at). This unit, which is used in mainland European countries, is equal to the kilogram-force per square centimetre, or kilopond per square centimetre:

1 at = 1 kgf/cm^2 (or kp/cm^2) = **98 066.5** Pa

33.4 "Absolute" and "gauge" pressure

33.4.1 All the pressure units mentioned in **33.1**, **33.2** and **33.3** may be used to state the magnitude of an absolute pressure or of a pressure difference, and misunderstandings in interpretation and conversion may arise if the quantity concerned is not clearly expressed.

33.4.2 It has been internationally recommended that pressure units themselves should not be modified to indicate whether the pressure value is "absolute" (i.e. with zero pressure as the datum) or "gauge" (i.e. with atmospheric pressure as the datum).

[24] For detailed information on barometer conventions see BS 2520.

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33.4.3 Both in the UK and USA it was common practice to use the abbreviation p.s.i. to indicate lbf/in^2, and to differentiate between gauge and absolute pressures by adding the further letters "g" and "a" to make "p.s.i.g." and "p.s.i.a.", respectively. A similar situation existed in German practice, where the symbol for the technical atmosphere (at) was modified to atü or ata to indicate the expression of "gauge" (über) or "absolute" pressure respectively[25]. Of these, only "at" was an internationally recognized unit symbol; furthermore the modifications did not change the units of measurement, but were in fact an indication of the quantity being expressed.

33.4.4 From the recommendation in **33.4.2** it follows that, if the context leaves any doubt as to which quantity is meant, the word "pressure" should be qualified appropriately:

e.g. "at a gauge pressure of 12.5 bar"

or "at a gauge pressure of 1.25 MPa"

or "at an absolute pressure of 2.34 bar"

or "at an absolute pressure of 234 kPa".

33.4.5 Absolute pressures are always positive, but gauge pressures are shown as negative when indicating a pressure less than the datum pressure.

It is common practice in the power and process industries to refer to "vacuum" values,
e.g. "1 mmHg vacuum" represents a gauge pressure of −1 mmHg, and "one per cent of vacuum" represents a gauge pressure of minus one per cent of the datum atmosphere in use.

Interconversion factors for the above units are given in, or can be deduced from, Table 32, Table 33 and Table 34. See also Clause 34, Stress.

34 Stress (force/area)

Though it is a different physical quantity, stress is naturally treated with pressure, since it is also force divided by area. Many, but not all, of the units mentioned in connection with pressure are used for stress, so the conversion factors in Table 32, Table 33 and Table 34 might be found useful.

The coherent SI unit of stress is again the pascal (Pa), i.e. the newton per square metre (N/m^2).

Technical units that have been widely used for stresses in metals and some other materials are the kilogram-force per square millimetre (kgf/mm^2), pound-force per square inch (lbf/in^2) and UKton-force per square inch (UKtonf/in^2)[26]. In the change to SI, a practical unit of similar size to the kgf/mm^2 was sought, the first proposal being the hectobar (hbar), which came into some use. However, the hbar has been superseded by the N/mm^2, which can be otherwise stated as MN/m^2 or MPa:

1 N/mm^2	=	1 MN/m^2	=	1 MPa
1 kgf/mm^2	=	**9.806 65** N/mm^2	=	**9.806 65** MPa
1 hbar	=	100 bar = $10^2 \times 10^5$ N/m^2	=	10 MPa

Interconversion factors for these and other units used for stresses are given in, or can be deduced from, Table 32, Table 33 and Table 34. See also Clause 33, Pressure.

[25] With the atü, the datum is an absolute pressure of 1 at.

[26] In the USA, the expression "k.s.i." is often used to signify kips per square inch (i.e. 1 000 lbf/in^2).

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Table 32 — Pressure

Exact values are printed in bold type

	pascal Pa (or newton per square metre N/m^2)	**newton per square millimetre**[a] N/mm^2	**hectobar** hbar	**kilogram-force per square centimetre**[b] kgf/cm^2	**poundal per square foot** pdl/ft^2	**pound-force per square inch** lbf/in^2	**pound-force per square foot** lbf/ft^2	**UKton-force per square inch** $tonf/in^2$	**UKton-force per square foot** $tonf/ft^2$
1 pascal = 1 newton per square metre Pa N/m^2 =	**1**	**1** $\times 10^{-6}$	**1** $\times 10^{-7}$	$1.019\ 72 \times 10^{-5}$	0.671 969	$1.450\ 38 \times 10^{-4}$	0.020 885 4	$6.474\ 90 \times 10^{-8}$	$9.323\ 85 \times 10^{-6}$
1 newton per square millimetre[a] N/mm^2 =	**1** $\times 10^{6}$	**1**	**0.1**	10.197 2	671 969	145.038	20 885.4	$6.474\ 90 \times 10^{-2}$	9.323 85
1 hectobar hbar =	**1** $\times 10^{7}$	**10**	**1**	101.97 2	6 719 690	1 450.38	208 854	0.647 490	93.238 5
1 kilogram-force per square centimetre[b] kgf/cm^2 =	**9.806 65** $\times 10^{4}$	**9.806 65** $\times 10^{-2}$	**9.806 65** $\times 10^{-3}$	**1**	65 897.6	14.223 3	2 048.16	$6.349\ 71 \times 10^{-3}$	0.914 358
1 poundal per square foot pdl/ft^2 =	1.488 16	$1.488\ 16 \times 10^{-6}$	$1.488\ 16 \times 10^{-7}$	$1.517\ 50 \times 10^{-5}$	**1**	$2.158\ 40 \times 10^{-4}$	0.031 081 0	$9.635\ 71 \times 10^{-8}$	$1.387\ 54 \times 10^{-5}$
1 pound-force per square inch lbf/in^2 =	$6.894\ 76 \times 10^{3}$	$6.894\ 76 \times 10^{-3}$	$6.894\ 76 \times 10^{-4}$	0.070 307 0	4 633.06	**1**	**144**	$4.464\ 29 \times 10^{-4}$	0.064 285 7
1 pound-force per square foot lbf/ft^2 =	47.880 3	$4.788\ 03 \times 10^{-5}$	$4.788\ 03 \times 10^{-6}$	$4.882\ 43 \times 10^{-4}$	32.174 0	$6.944\ 44 \times 10^{-3}$	**1**	$3.100\ 20 \times 10^{-6}$	$4.464\ 29 \times 10^{-4}$
1 UKton-force per square inch $tonf/in^2$ =	$1.544\ 43 \times 10^{7}$	15.444 3	1.544 43	157.488	$1.037\ 81 \times 10^{7}$	**2 240**	**322 560**	**1**	**144**
1 UKton-force per square foot $tonf/ft^2$ =	$1.072\ 52 \times 10^{5}$	0.107 252	$1.072\ 52 \times 10^{-2}$	1.093 66	72 069.9	15.555 6	**2 240**	$6.944\ 44 \times 10^{-3}$	**1**

[a] 1 N/mm^2 (used for stress in metals) = 1 MN/m^2 = 1 MPa.

[b] Also called the kilopond per square centimetre (kp/cm^2) and sometimes known as the "technical atmosphere" (at). It is equal to 10 mH_2O (see **33.2**).

1 kgf/mm^2 = 100 kgf/cm^2

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Table 33 — Pressure *(continued)*

Exact values are printed in bold type

	pascal Pa (or newton per square metre N/m²)	**bar** bar	**millibar** mbar[a]	**standard atmosphere** atm	**kilogram-force per square centimetre**[b] kgf/cm²	**pound-force per square inch** lbf/in²	**torr**[c]	**(conventional) inch of mercury** inHg
1 pascal = Pa 1 newton per square metre N/m² =	**1**	**1** × 10^{-5}	**0.01**	9.869 23 × 10^{-6}	1.019 72 × 10^{-5}	1.450 38 × 10^{-4}	0.750 062 × 10^{-2}	2.953 00 × 10^{-4}
1 bar bar =	**1** × 10^{5}	**1**	**1 000**	0.986 923	1.019 72	14.503 8	750.062	29.530 0
1 millibar mbar[a] =	**100**	**0.001**	**1**	9.869 23 × 10^{-4}	1.019 72 × 10^{-3}	0.014 503 8	0.750 062	0.029 530 0
1 standard atmosphere atm =	**101 325.0**	**1.013 25**	**1 013.250**	**1**	1.033 23	14.695 9	**760**	29.921 3
1 kilogram-force per square centimetre[b] kgf/cm² =	**98 066.5**	**0.980 665**	**980.665**	0.967 841	**1**	14.223 3	735.559	28.959 0
1 pound-force per square inch lbf/in² =	6 894.76	0.068 947 6	68.947 6	0.068 046 0	0.070 307 0	**1**	51.714 9	2.036 02
1 torr[c] =	133.322	0.001 333 22	1.333 22	1.315 79 × 10^{-3}	1.359 51 × 10^{-3}	0.019 336 8	**1**	0.039 370 1
1 (conventional) inch of mercury inHg =	3 386.39	0.033 863 9	33.863 9	0.033 421 1	0.034 531 6	0.491 154	25.400 0	**1**

[a] The abbreviation mb is used in meteorology.
[b] This unit is equal to 10 (conventional) metres of water (10 mH_2O), see **33.2**.
[c] To within 1 part in 7 million, the torr is equal to the (conventional) millimetre of mercury (mmHg).

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Table 34 — Pressure *(continued)*

Exact values are printed in bold type

	pascal Pa (or newton per square metre N/m^2)	**millibar** mbar[a]	**kilogram-force per square metre**[b] kgf/m^2	**pound-force per square foot** lbf/ft^2	**(conventional) inch of water** inH_2O	**(conventional) foot of water** ftH_2O	**(conventional) millimetre of mercury** mmHg	**(conventional) inch of mercury** inHg
1 pascal = 1 newton per square metre Pa N/m^2 =	**1**	**0.01**	0.101 972	$2.088\ 54 \times 10^{-2}$	$4.014\ 63 \times 10^{-3}$	$3.345\ 53 \times 10^{-4}$	$7.500\ 62 \times 10^{-3}$	$2.953\ 00 \times 10^{-4}$
1 millibar mbar[a] =	**100**	**1**	10.197 2	2.088 54	0.401 463	0.033 455 3	0.750 062	0.029 530 0
1 kilogram-force per square metre[b] kgf/m^2 =	**9.806 65**	**0.098 066 5**	**1**	0.204 816	0.039 370 1	$3.280\ 84 \times 10^{-3}$	0.073 555 9	$2.895\ 90 \times 10^{-3}$
1 pound-force per square foot lbf/ft^2 =	47.880 3	0.478 803	4.882 43	**1**	0.192 222	0.016 018 5	0.359 131	0.014 139 0
1 (conventional) inch of water inH_2O =	249.089	2.490 89	**25.4**	5.202 33	**1**	0.083 333 3	1.868 32	0.073 555 9
1 (conventional) foot of water ftH_2O =	2 989.07	29.890 7	**304.8**	62.428 0	**12**	**1**	22.419 8	0.882 671
1 (conventional) millimetre of mercury mmHg =	133.322	1.333 22	**13.595 1**	2.784 50	0.535 240	0.044 603 3	**1**	0.039 370 1
1 (conventional) inch of mercury inHg =	3 386.39	33.863 9	345.316	70.726 2	**13.595 1**	1.132 92	**25.4**	**1**

[a] The abbreviation mb is used in meteorology.
[b] This unit is equal to the conventional millimetre of water (mmH_2O), see **33.2**.

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35 Viscosity, dynamic (stress/velocity gradient)

35.1 The coherent SI unit of dynamic viscosity is the pascal second (Pa·s), which may also be expressed as the newton second per square metre ($N \cdot s/m^2$), or as the kilogram per metre second [kg/(m·s)].

This unit has also been called the poiseuille (Pl) in France. (It should be noted that this is not the same as the poise (P), described in **35.2**.)

35.2 The poise (P) is the corresponding CGS unit.

$1\ P = 1\ dyn \cdot s/cm^2 = 10^{-1}\ N \cdot s/m^2 = 10^{-1}\ Pa \cdot s.$

The commonly used submultiple is the centipoise (cP).

$1\ cP = 10^{-2}\ P = 10^{-3}\ Pa \cdot s.$

35.3 Other metric and imperial units that have been used for dynamic viscosity are:

kilogram-force second per square metre		($kgf \cdot s/m^2$)
poundal second per square foot	= pound per foot second, lb/(ft·s)	($pdl \cdot s/ft^2$)
pound-force second per square foot	= slug per foot second, slug/(ft·s)	($lbf \cdot s/ft^2$)
pound-force hour per square foot	= slug hour per foot second squared, $slug \cdot h/(ft \cdot s^2)$	($lbf \cdot h/ft^2$)
pound-force second per square inch		($lbf \cdot s/in^2$)
pound per foot hour		(lb/ft·h)

$1\ kgf \cdot s/m^2$	=	**9.806 65** Pa·s		
$1\ pdl \cdot s/ft^2$	=	1.488 16 Pa·s		
$1\ lbf \cdot s/ft^2$	=	47.880 3 Pa·s		
$1\ lbf \cdot h/ft^2$	=	$1.723\ 69 \times 10^5$ Pa·s		
$1\ lbf \cdot s/in^2$	=	6 894.76 Pa·s		
1 lb/ft·h	=	$4.133\ 79 \times 10^{-4}$ kg/(m·s)	=	$4.133\ 79 \times 10^{-4}$ Pa·s

NOTE 1 The pound-force second per square inch is sometimes called the "reyn".

NOTE 2 For reference to frequently used but empirical units of viscosity, such as the Redwood second, see Clause **36**, Viscosity, kinematic.

Interconversion factors for most of these units are given in Table 35.

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Table 35 — Viscosity (dynamic)

Exact values are printed in bold type

		pascal second Pa·s	centipoise cP	kilogram-force second per square metre kgf·s/m²	poundal second per square foot pdl·s/ft²	pound-force second per square foot lbf·s/ft²	pound-force hour per square foot lbf·h/ft²
1 pascal second Pa·s	=	**1**	**1 000**	0.101 972	0.671 969	$2.088\ 54 \times 10^{-2}$	$5.801\ 51 \times 10^{-6}$
1 centipoise cP	=	**0.001**	**1**	$1.019\ 72 \times 10^{-4}$	$6.719\ 69 \times 10^{-4}$	$2.088\ 54 \times 10^{-5}$	$5.801\ 51 \times 10^{-9}$
1 kilogram-force second per square metre $kgf{\cdot}s/m^2$	=	**9.806 65**	**9 806.65**	**1**	6.589 76	0.204 816	$5.689\ 34 \times 10^{-5}$
1 poundal second per square foot [=1 lb/(ft·s)] $pdl{\cdot}s/ft^2$	=	1.488 16	1 488.16	0.151 750	**1**	0.031 081 0	$8.633\ 60 \times 10^{-6}$
1 pound-force second per square foot [=1 slug/(ft·s)] $lbf{\cdot}s/ft^2$	=	47.880 3	47 880.3	4.882 43	32.174 0	**1**	$2.777\ 78 \times 10^{-4}$
1 pound-force hour per square foot $lbf{\cdot}h/ft^2$	=	$1.723\ 69 \times 10^{5}$	$1.723\ 69 \times 10^{8}$	$1.757\ 67 \times 10^{4}$	$1.158\ 27 \times 10^{5}$	**3 600**	**1**

NOTE 1 lb/(ft·h) = $4.133\ 79 \times 10^{-4}$ kg/(m·s) = $4.133\ 79 \times 10^{-4}$ Pa·s (see **35.3**).

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36 Viscosity, kinematic (length squared/time)

36.1 The coherent SI unit of kinematic viscosity (which is dynamic viscosity divided by density) is the metre squared per second (m^2/s).

36.2 The corresponding CGS unit is the stokes (St).

$1\ St = 1\ cm^2/s = 10^{-4}\ m^2/s$

The common submultiple is the centistokes (cSt).

$1\ cSt = 10^{-2}\ St = 10^{-6}\ m^2/s\ (= 1\ mm^2/s)$

36.3 Another metric unit sometimes used is the metre squared per hour (m^2/h).

$1\ m^2/h = 2.777\ 78 \times 10^{-4}\ m^2/s$

36.4 A selection of imperial units is:

inch squared per second in^2/s

foot squared per second ft^2/s

inch squared per hour in^2/h

foot squared per hour ft^2/h

$1\ in^2/s = \mathbf{6.451\ 6} \times 10^{-4}\ m^2/s$

$1\ ft^2/s = 9.290\ 30 \times 10^{-2}\ m^2/s$

$1\ in^2/h = 1.792\ 11 \times 10^{-7}\ m^2/s$

$1\ ft^2/h = \mathbf{2.580\ 64} \times 10^{-5}\ m^2/s$

36.5 The units referred to in **36.1** to **36.4** are absolute units with physical dimensions, as distinct from values on frequently used but empirical scales such as the Redwood second, Saybolt Universal scale, and Engler degrees. For tables from which viscosity values in these empirical scales may be converted to centistokes see ESDU Item No. 68036 [4].

Interconversion factors for the units in 36.1 to 36.4 are given in Table 36.

Note that this table may be used for the conversion of values of thermal diffusivity, which also has the dimensions of length squared/time.

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Table 36 — Viscosity (kinematic)

Exact values are printed in bold type

	metre squared per second m^2/s	centistokes cSt	inch squared per second in^2/s	foot squared per second ft^2/s	inch squared per hour in^2/h	foot squared per hour ft^2/h	metre squared per hour m^2/h
1 metre squared per second m^2/s =	**1**	**1** $\times 10^{6}$	$1.550\ 00 \times 10^{3}$	10.763 9	$5.580\ 01 \times 10^{6}$	$3.875\ 01 \times 10^{4}$	**3 600**
1 centistokes cSt =	**1** $\times 10^{-6}$	**1**	$1.550\ 00 \times 10^{-3}$	$1.076\ 39 \times 10^{-5}$	5.580 01	$3.875\ 01 \times 10^{-2}$	**0.003 6**
1 inch squared per second in^2/s =	**6.451 6** $\times 10^{-4}$	**645.16**	**1**	$6.944\ 44 \times 10^{-3}$	**3 600**	**25**	2.322 58
1 foot squared per second ft^2/s =	$9.290\ 30 \times 10^{-2}$	92 903.0	**144**	**1**	**518 400**	**3 600**	334.451
1 inch squared per hour in^2/h =	$1.792\ 11 \times 10^{-7}$	0.179 211	$2.777\ 78 \times 10^{-4}$	$1.929\ 01 \times 10^{-6}$	**1**	$6.944\ 44 \times 10^{-3}$	**6.451 6** $\times 10^{-4}$
1 foot squared per hour ft^2/h =	**2.580 64** $\times 10^{-5}$	**25.806 4**	**0.04**	$2.777\ 78 \times 10^{-4}$	**144**	**1**	0.092 903 0
1 metre squared per hour m^2/h =	$2.777\ 78 \times 10^{-4}$	277.778	0.430 556	$2.989\ 98 \times 10^{-3}$	1 550.00	10.763 9	**1**

NOTE This table may also be used for the conversion of values of thermal diffusivity (area/time), for which the conversion factors employed are the same as those for kinematic viscosity.

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37 Energy (work, heat, etc.)

37.1 General

37.1.1 The coherent SI unit for the expression of all forms of energy is the joule (symbol J). Just as energy arises in many ways, the connection between the joule and other SI units may be indicated in different ways, e.g:

$$1\ \mathrm{J} = 1\ \mathrm{N{\cdot}m}\ \text{(force × distance, newton metre)}$$
$$= 1\ \mathrm{W{\cdot}s}\ \text{(electrical energy, watt second)}$$
$$= 1\ \mathrm{Pa{\cdot}m^3}\ \text{(pressure × volume, pascal cubic metre)}$$

This unit was, prior to the SI, known as the absolute joule, but it is now simply the joule (J).
The "international" joule, which became obsolete in 1948, was approximately equal to 1.000 19 J.

37.1.2 Arising from the historical development of the SI from the CGS system, the unit of energy in the CGS system (the erg) is decimally related to the joule.

$$1\ \text{erg} = 1\ \mathrm{dyn{\cdot}cm} = 1 \times 10^{-5}\ \mathrm{N} \times 0.01\ \mathrm{m}$$
$$= 10^{-7}\ \mathrm{N{\cdot}m} = 10^{-7}\ \mathrm{J}$$

37.1.3 A unit in extensive use for the expression of electrical energy is the kilowatt hour (kW·h).

$$1\ \mathrm{kW{\cdot}h} = 1 \times 1\ 000\ \mathrm{W} \times \mathbf{3\ 600}\ \mathrm{s}$$
$$= 3.6 \times 10^6\ \mathrm{W{\cdot}s} = \mathbf{3.6}\ \mathrm{MJ}$$

37.1.4 Two other metric units used for the expression of energy are the kilogram-force metre[27] (kgf·m) and the litre atmosphere.

1 kgf·m	=	9.806 65 N·m	=	**9.806 65** J		
1 litre atmosphere	=	1 dm^3 × 101 325 Pa	=	101.325 Pa·m^3	=	**101.325** J

[The litre used here is equal to 1 decimetre cubed (see **5.3** and **5.4**), and the atmosphere used is the standard atmosphere (see **33.3**).]

37.1.5 Some corresponding imperial units for the statement of energy are the foot poundal (ft·pdl), the foot pound-force (ft·lbf) and the horsepower hour (hp·h).

1 ft·pdl	=	1 × 0.304 8 m × 0.453 592 37 × 0.304 8 N (see **31.3**)
	=	0.042 140 1 J (approx.)
1 ft·lbf	=	1 × 0.304 8 m × 0.453 592 37 × 9.806 65 N (see **31.3**)
	=	1.355 82 J (approx.)
1 hp·h	=	550 ft lbf/s × 3 600 s (see **38.3**)
	=	1.98 × 10^6 ft·lbf
	=	2.684 52 × 10^6 J (approx.)

[27] Known as the kilopond metre (kp·m) in Germany.

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37.2 Heat units

Heat is one of the forms of energy and, as stated in **37.1.1**, the SI unit for all forms is the joule. The following heat units originally arose from the concept of the heat required to warm unit mass of water through unit temperature, but some of these are now precisely defined in terms of the joule:

— the various *calories* (originally relating to the gram of water and the degree Celsius);

— the various *British thermal units*, now obsolete (originally relating to the pound of water and degree Fahrenheit); and

— the various *Centigrade heat units* (based on the pound of water and the degree Celsius).

The specific heat capacity of water changes with temperature and a number of different calories, British thermal units, and Centigrade heat units came into use according to their means of definition.

Three of the calories, when used in precise work, need to be separately identified.

These are the International Table calorie (cal_{IT}), the thermochemical calorie (cal_{th}) and the 15 °C calorie (cal_{15}) described below:

1 cal_{IT}	=	**4.186 8** J	(as defined at the Fifth International Conference on Properties of Steam, London 1956).
1 cal_{th}	=	**4.184 0** J	(a “defined” calorie).
1 cal_{15}	=	4.185 5 J (approx.)	(This is defined as the amount of heat required to warm 1 g of air-free water from 14.5 °C to 15.5 °C at a constant pressure of 1 atm. The joule equivalent shown above was adopted by the CIPM in 1950 as being the most accurate value which could then be deduced from experiment.)

Associated with the cal_{15} are the thermie (th), also sometimes described as the “tonne-calorie” and the frigorie, used in connection with the extraction of heat.

1 thermie	=	10^6 cal_{15}	=	4.185 5 MJ (approx.)
1 frigorie	=	-10^3 cal_{15}	=	−4.185 5 kJ (approx.)

The “calorie” commonly referred to in nutritional science is in fact a kilocalorie, which is sometimes called a “kilogram-calorie” or “large calorie”. In this standard, if the symbol cal is used without qualification, it refers to the International Table calorie (cal_{IT}). (The dietitians calorie is based on the cal_{15}.) The use of the joule is strongly recommended, because of the wide variety of meanings of the “calorie”.

The British thermal unit (Btu) used in this standard is the one corresponding to the International Table calorie and it is defined by the equation:

1 Btu/lb = **2.326** J/g

Thus:

1 Btu = 2.326 × 453.592 37 J = 1 055.06 J (approx.)

Other British thermal units formerly in use but now obsolete are the following.

The “60 °F British thermal unit” (heat required to warm 1 lb of water from 60 °F to 61 °F).

1 $Btu_{60/61}$ = 1 054.5 J (approx.)

The “mean British thermal unit” (1/180 of the heat required to warm 1 lb of liquid water from 32 °F to 212 °F).

1 Btu_{mean} = 1 055.8 J (approx.)

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The British thermal unit once used for most purposes by the British Gas Industry relates to the 15 °C calorie and is equal to:

$$2.326 \times 453.592\ 37\ \text{J} \times \frac{4.185\ 5}{4.186\ 8} = 1\ 054.73\ \text{J (approx.)}$$

Associated with the Btu is the therm, once used as an energy unit by the Gas Industry.

1 therm = 100 000 Btu = 105.5 MJ (approx.)

The "Centigrade heat unit" (C.H.U.), based on the lb of water and the °C, is still sometimes used.

1 C.H.U. = 1.8 Btu (but to each British thermal unit there corresponds a Centigrade heat unit)

1 $\text{C.H.U.}_{\text{mean}}$ = 1.8 Btu_{mean} = 1 900.4 J (approx.)

For interconversion factors for most of the above units see Table 37 and Table 38.

38 Power (energy/time)

38.1 The coherent SI unit for all forms of power, including heat flow rate, is the watt (symbol W), which is equal to the joule per second.

1 W = 1 J/s

The kilowatt (kW) is a commonly-used multiple of the watt.

38.2 Two metric technical units of power are the kilogram-force metre per second (kgf·m/s) and the metric horsepower[28].

1 kgf·m/s	=	**9.806 65** J/s	=	**9.806 65** W
1 metric horsepower	=	75 kgf·m/s	=	735.499 W

38.3 Similar technical units in the imperial system are the foot pound-force per second (ft·lbf/s) and the horsepower (hp).

1 ft·lbf/s	=	1.355 82 J/s (see **37.1.5**)	=	1.355 82 W
1 hp	=	550 ft·lbf/s	=	745.700 W

38.4 The following is a selection of heat flow units shown in terms of the watt (see **37.2**):

calorie per second	1 cal/s	= **4.186 8** W
kilocalorie per hour	1 kcal/h	= **1.163** W
British thermal unit per hour	1 Btu/h	= 0.293 071 W

"ton of refrigeration" = 12 000 Btu/h = 3.516 85 kW

For interconversion factors for most of the above units see Table 39.

[28] The metric horsepower goes under the name "cheval vapeur" in France and sometimes the symbols ch or CV are used. In Germany it is called the "Pferdestärke" (symbol PS).

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Table 37 — Energy

Exact values are printed in bold type

	joule J	kilowatt hour kW·h	kilogram-force metre kgf·m	litre[a] atmosphere	foot poundal ft·pdl	foot pound-force ft·lbf	horsepower hour hp·h
1 joule J =	**1**	$2.777\ 78 \times 10^{-7}$	0.101 972	$0.986\ 923 \times 10^{-2}$	23.730 4	0.737 562	$3.725\ 06 \times 10^{-7}$
1 kilowatt hour kW·h =	**3.6** $\times 10^{6}$	**1**	$3.670\ 98 \times 10^{5}$	$3.552\ 92 \times 10^{4}$	$8.542\ 93 \times 10^{7}$	$2.655\ 22 \times 10^{6}$	1.341 02
1 kilogram-force metre kgf·m =	**9.806 65**	$2.724\ 07 \times 10^{-6}$	**1**	0.096 784 1	232.715	7.233 01	$3.653\ 04 \times 10^{-6}$
1 litre[a] atmosphere =	**101.325**	$2.814\ 58 \times 10^{-5}$	10.332 3	**1**	**2 404.48**	74.733 5	$3.774\ 42 \times 10^{-5}$
1 foot poundal ft·pdl =	0.042 140 1	$1.170\ 56 \times 10^{-8}$	0.004 297 10	$4.158\ 91 \times 10^{-4}$	**1**	0.031 081 0	$1.569\ 74 \times 10^{-8}$
1 foot pound-force ft·lbf =	1.355 82	$3.766\ 16 \times 10^{-7}$	0.138 255	$1.338\ 09 \times 10^{-2}$	32.174 0	**1**	$5.050\ 51 \times 10^{-7}$
1 horsepower hour hp·h =	$2.684\ 52 \times 10^{6}$	0.745 700	$2.737\ 45 \times 10^{5}$	$2.649\ 41 \times 10^{4}$	$6.370\ 46 \times 10^{7}$	**1.98** $\times 10^{6}$	**1**

[a] The litre used here is equal to one decimetre cubed. (See **5.3**.)

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Table 38 — Energy *(continued)*

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	joule J	kilowatt hour kW·h	foot pound-force ft·lbf	horsepower hour hp·h	calorie[a] cal (cal_{IT})	thermochemical calorie cal_{th}	15 °C calorie cal_{15}	British thermal unit Btu
1 joule = J	**1**	$2.777\ 78 \times 10^{-7}$	0.737 562	$3.725\ 06 \times 10^{-7}$	0.238 846	0.239 006	0.238 920	$9.478\ 17 \times 10^{-4}$
1 kilowatt hour = kW·h	$\mathbf{3.6} \times 10^{6}$	**1**	$2.655\ 22 \times 10^{6}$	1.341 02	859 845	860 421	860 112	3 412.14
1 foot pound-force = ft·lbf	1.355 82	$3.766\ 16 \times 10^{-7}$	**1**	$5.050\ 51 \times 10^{-7}$	0.323 832	0.324 048	0.323 932	$1.285\ 07 \times 10^{-3}$
1 horsepower hour = hp·h	$2.684\ 52 \times 10^{6}$	0.745 700	$\mathbf{1.98} \times 10^{6}$	**1**	641 186	641 616	641 386	2 544.43
1 calorie[a] = cal (cal_{IT})	**4.186 8**	$\mathbf{1.163} \times 10^{-6}$	3.088 03	$1.559\ 61 \times 10^{-6}$	**1**	1.000 67	1.000 31	$3.968\ 32 \times 10^{-3}$
1 thermochemical calorie = cal_{th}	**4.184**	$1.162\ 22 \times 10^{-6}$	3.085 96	$1.558\ 57 \times 10^{-6}$	0.999 331	**1**	0.999 642	$3.965\ 67 \times 10^{-3}$
1 15 °C calorie = cal_{15}	4.185 5	$1.162\ 64 \times 10^{-6}$	3.087 07	$1.559\ 12 \times 10^{-6}$	0.999 690	1.000 36	**1**	$3.967\ 09 \times 10^{-3}$
1 British thermal unit = Btu	1 055.06	$2.930\ 71 \times 10^{-4}$	778.169	$3.930\ 15 \times 10^{-4}$	251.996	252.164	252.074	**1**

[a] This is the International Table calorie. For a description of the three calories mentioned here, see **37.2**.

1 thermie (th) = 10^{6} cal_{15}.

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Table 39 — Power

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		watt W	**kilogram-force metre per second** kgf·m/s	**metric horsepower**	**foot pound-force per second** ft·lbf/s	**horsepower** hp	**calorie[a] per second** cal/s	**kilocalorie[a] per hour** kcal/h	**British thermal unit per hour** Btu/h
1 watt W	=	**1**	0.101 972	$1.359\ 62 \times 10^{-3}$	0.737 562	$1.341\ 02 \times 10^{-3}$	0.238 846	0.859 845	3.412 14
1 kilogram-force metre per second kgf·m/s	=	**9.806 65**	**1**	0.013 333 3	7.233 01	0.013 150 9	2.342 28	8.432 20	33.461 7
1 metric horsepower	=	735.499	**75**	**1**	542.476	0.986 320	175.671	632.415	2 509.63
1 foot pound-force per second ft·lbf/s	=	1.355 82	0.138 255	$1.843\ 40 \times 10^{-3}$	**1**	$1.818\ 18 \times 10^{-3}$	0.323 832	1.165 79	4.626 24
1 horsepower hp	=	745.700	76.040 2	1.013 87	**550**	**1**	178.107	641.186	2 544.43
1 calorie[a] per second cal/s	=	**4.186 8**	0.426 935	$5.692\ 46 \times 10^{-3}$	3.088 03	$5.614\ 59 \times 10^{-3}$	**1**	**3.6**	14.286 0
1 kilocalorie[a] per hour kcal/h	=	**1.163**	0.118 593	$1.581\ 24 \times 10^{-3}$	0.857 785	$1.559\ 61 \times 10^{-3}$	0.277 778	**1**	3.968 32
1 British thermal unit per hour Btu/h	=	0.293 071	$2.988\ 49 \times 10^{-2}$	$3.984\ 66 \times 10^{-4}$	0.216 158	$3.930\ 15 \times 10^{-4}$	0.069 998 8	0.251 996	**1**

[a] This refers to the International Table calorie. See also **37.2**.

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39 Temperature, including temperature difference or interval

39.1 The SI unit of temperature is the kelvin (K). It is one of the base units of the SI and is defined as a specified fraction (1/273.16) of the thermodynamic temperature of the triple point[29)] of water. The kelvin is used for the expression of thermodynamic temperature, for which the datum is absolute zero; it can also be used for the expression of any temperature difference or temperature interval.

39.2 The temperature unit recognized for use in conjunction with the SI, is the degree Celsius (°C). The degree Centigrade (°C) was renamed the degree Celsius in 1948 by the 9th Conference of the CGPM mainly to prevent confusion with an angular measure, the centigrade (equal to one hundredth of a grade; see **8.3** and Clause **8**, Note 1). The term "Centigrade", although now incorrect, remains in widespread use for Celsius. The zero datum for Celsius temperature (0 °C) is now exactly defined by the thermodynamic temperature 273.16 K; formerly it was defined by the melting point of ice at 1 atm. The units of temperature difference, one degree Celsius and one kelvin, are exactly equal, by definition. In this sense:

1 °C = 1 K

and any temperature difference therefore has the same numerical value when expressed in °C as it has when expressed in K.

For formulae showing the interrelationships between Celsius temperatures and thermodynamic temperatures expressed in kelvins, and some other temperatures mentioned below, see Table 40.

39.3 Traditional in practical use in the UK and USA is Fahrenheit temperature, which has now been displaced in the UK by Celsius. The Fahrenheit scale is not formally defined, but it is generally recognized that:

32 °F is the ice point;

212 °F is the boiling point of water at 1 atm;

and that the unit of temperature difference one degree Fahrenheit (1 °F) is equal to five ninths of the unit of temperature difference the degree Celsius (1 °C). In this sense:

$$1\ ^\circ\mathrm{F} = \left(\frac{5}{9}\ ^\circ\mathrm{C}\right) = \left(\frac{5}{9}\ \mathrm{K}\right)$$

For formulae giving the interrelationship between Fahrenheit, Celsius, and other temperatures see Table 40.

39.4 For thermodynamic temperatures, the degree Rankine (°R) is still occasionally used. The unit interval of the degree Rankine is equal to 1 °F, a thermodynamic temperature of 0 °R being absolute zero. See Table 40.

39.5 In the 1959 edition of this standard, for *temperature interval* the letters "deg" were recommended, instead of the degree sign (°) which was reserved for *temperature*. In 1967-68, the 13th Conference of the CGPM considered the arguments for and against this practice and decided to recommend that the use of "deg" should be discontinued.

39.6 For the purpose of practical measurements the CIPM adopted in 1968 the "International Practical Temperature Scale of 1968", IPTS - 68, based on reproducible fixed points and interpolation instruments and procedures. The IPTS - 68 was designed so that the International Practical Kelvin and Celsius temperatures closely approximate the kelvin and Celsius temperatures described in **39.1** and **39.2**. The IPTS - 68 is defined only from a thermodynamic temperature of 13.81 K upwards. 13.81 K is the triple point of hydrogen. Some amendments were made subsequently in "The International Temperature Scale of 1990" (ITS-90). The triple point of water (273.16 K) is used as the defining point, instead of the freezing point of water (273.15 K). The scale now extends to lower temperatures, viz. 0.65 K, and the range of the platinum resistance thermometer as defining instrument has been extended from 630 °C up to the silver point 962 °C.

[29)] The temperature at the triple point of water, (where water, ice, and water vapour are in equilibrium) is very slightly removed from the temperature of the melting point of ice at atmospheric pressure (the ice point).

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Table 40 — Equivalent values on four temperature scales

Exact values are printed in bold type

For the same temperature, if $[T]$ K, $[\theta]$ °C, $[t]$ °F and $[r]$ °R represent that temperature on the kelvin, Celsius, Fahrenheit and Rankine scales respectively, then the formulae relating the pure numbers $[T]$, $[\theta]$, $[t]$ and $[r]$ are as shown below.						
(kelvins)	$[T]$	=	$[\theta] + \mathbf{273.15}$	= $\frac{\mathbf{5}}{\mathbf{9}}([t] + \mathbf{459.67})$	=	$\frac{\mathbf{5}}{\mathbf{9}}[r]$
(degrees Celsius)	$[\theta]$	=	$[T] - \mathbf{273.15}$	= $\frac{\mathbf{5}}{\mathbf{9}}([t] - \mathbf{32})$	=	$\frac{\mathbf{5}}{\mathbf{9}}([r] - \mathbf{491.67})$
(degrees Fahrenheit)	$[t]$	=	$\frac{\mathbf{9}}{\mathbf{5}}[T] - \mathbf{459.67}$	= $\frac{\mathbf{9}}{\mathbf{5}}[\theta] + \mathbf{32}$	=	$[r] - \mathbf{459.67}$
(degrees Rankine)	$[r]$	=	$\frac{\mathbf{9}}{\mathbf{5}}[T]$	= $\frac{\mathbf{9}}{\mathbf{5}}[\theta] + \mathbf{491.67}$	=	$[t] + \mathbf{459.67}$
For the same temperature difference: (temperature difference in °C or K) = $\frac{5}{9}$ (temperature difference in °F or °R).						

40 Specific energy [(energy or heat)/mass]

40.1 There are several different terms for energy per unit mass which are used in different contexts, e.g.:

specific enthalpy

specific latent heat

calorific value, mass basis

The SI unit for all such quantities is the joule per kilogram (J/kg).

40.2 Other units are:

kilocalorie per kilogram (kcal/kg) (see **37.2**)

kilogram-force metre per kilogram (kgf·m/kg)

1 $kcal_{IT}$/kg = **4 186.8** J/kg
1 $kcal_{th}$/kg = **4 184** J/kg
1 $kcal_{15}$/kg = 4 185.5 J/kg (approx.)
1 kgf·m/kg = **9.806 65** J/kg

40.3 Corresponding imperial units are:

British thermal unit per pound (Btu/lb)

foot pound-force per pound (ft·lbf/lb)

1 Btu/lb = **2 326** J/kg
1 ft·lbf/lb = 2.989 07 J/kg (approx.)

For interconversion factors see Table 41.

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41 Heat content, volume basis (heat/volume) (e.g. calorific value, volume basis)

41.1 The SI unit for this quantity, which is mainly used in connection with the combustion of gaseous or liquid fuels, is the joule per cubic metre (J/m^3). For most practical purposes either the kJ/m^3 or MJ/m^3 are suitable multiples.

41.2 Units that have been in common use are:

kilocalorie per cubic metre ($kcal/m^3$) (see **37.2** for the various calories)

thermie per litre (th/litre)

1 $kcal_{IT}/m^3$	=	**4 186.8** J/m^3
1 $kcal_{th}/m^3$	=	**4 184** J/m^3
1 $kcal_{15}/m^3$	=	4 185.5 J/m^3
1 thermie/litre	=	4 185.5 × 10^6 J/m^3 (see **5.3** and **5.4** for litre)

41.3 Corresponding imperial units are:

British thermal unit per cubic foot (Btu/ft^3)

therm per UK gallon (therm/UKgal)

1 Btu/ft^3	=	37 258.9 J/m^3
1 therm/UKgal	=	2.320 80 × 10^{10} J/m^3

41.4 In **41.2** and **41.3** and in Table 42 it is assumed that, where gases are concerned, the volumes involved in the conversion have the same reference conditions of temperature, pressure and humidity. For some conversions of calorific value (volume basis) when the reference conditions are different, see Table 43 and Table 44.

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Table 41 — Specific energy (e.g. calorific value, mass basis; specific latent heat; specific enthalpy)

Exact values are printed in bold type

		joule per kilogram J/kg	**kilocalorie[a] per kilogram** $kcal_{IT}/kg$	**thermochemical kilocalorie per kilogram** $kcal_{th}/kg$	**15 °C kilocalorie per kilogram** $kcal_{15}/kg$	**British thermal unit per pound** Btu/lb	**foot pound-force per lb** ft·lbf/lb	**kilogram-force metre per kilogram** kgf·m/kg
1 joule per kilogram J/kg	=	**1**	$0.238\ 846 \times 10^{-3}$	$0.239\ 006 \times 10^{-3}$	$0.238\ 920 \times 10^{-3}$	$0.429\ 923 \times 10^{-3}$	0.334 553	0.101 972
1 kilocalorie[a] per kilogram $kcal_{IT}/kg$	=	**4 186.8**	**1**	1.000 67	1.000 31	**1.8**	1 400.70	426.935
1 thermochemical kilocalorie per kilogram cal_{th}/kg	=	**4 184**	0.999 331	**1**	0.999 642	1.798 80	1 399.77	426.649
1 15 °C kilocalorie per kilogram $kcal_{15}/kg$	=	**4 185.5**	0.999 690	1.000 36	**1**	1.799 44	1 400.27	426.802
1 British thermal unit per pound Btu/lb	=	**2 326**	0.555 556	0.555 927	0.555 728	**1**	778.169	237.186
1 foot pound-force per pound ft·lbf/lb	=	2.989 07	$7.139\ 26 \times 10^{-4}$	$7.144\ 04 \times 10^{-4}$	$7.141\ 48 \times 10^{-4}$	$1.285\ 07 \times 10^{-3}$	**1**	**0.304 8**
1 kilogram-force metre per kilogram kgf·m/kg	=	**9.806 65**	$2.342\ 28 \times 10^{-3}$	$2.343\ 85 \times 10^{-3}$	$2.343\ 01 \times 10^{-3}$	$4.216\ 10 \times 10^{-3}$	3.280 84	**1**

[a] This is the International Table kilocalorie. For a description of the three calories mentioned here see **37.2**.

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Table 42 — Calorific value, volume basis

Exact values are printed in bold type

	joule per cubic metre J/m^3	kilocalorie[a] per cubic metre $kcal_{IT}/m^3$	thermochemical kilocalorie per cubic metre $kcal_{th}/m^3$	15 °C kilocalorie per cubic metre $kcal_{15}/m^3$	British thermal unit per cubic foot[b] Btu/ft^3	therm per UK gallon therm/UKgal	thermie per litre[c] th/litre
1 joule per cubic metre J/m^3 =	**1**	$0.238\ 846 \times 10^{-3}$	$0.239\ 006 \times 10^{-3}$	$0.238\ 920 \times 10^{-3}$	$26.839\ 2 \times 10^{-6}$	$4.308\ 86 \times 10^{-11}$	$2.389\ 20 \times 10^{-10}$
1 kilocalorie[a] per cubic metre $kcal_{IT}/m^3$ =	**4 186.8**	**1**	1.000 67	1.000 31	0.112 370	$1.804\ 04 \times 10^{-7}$	$1.000\ 31 \times 10^{-6}$
1 thermochemical kilocalorie per cubic metre $kcal_{th}/m^3$ =	**4 184**	0.999 331	**1**	0.999 642	0.112 295	$1.802\ 83 \times 10^{-7}$	$0.999\ 642 \times 10^{-6}$
1 15 °C kilocalorie per cubic metre $kcal_{15}/m^3$ =	4 185.5	0.999 690	1.000 36	**1**	0.112 335	$1.803\ 47 \times 10^{-7}$	**1** $\times 10^{-6}$
1 British thermal unit per cubic foot[b] Btu/ft^3 =	37 258.9	8.899 15	8.905 10	8.901 91	**1**	$1.605\ 44 \times 10^{-6}$	$8.901\ 91 \times 10^{-6}$
1 therm per UK gallon therm/UKgal =	$2.320\ 80 \times 10^{10}$	$5.543\ 13 \times 10^{6}$	$5.546\ 84 \times 10^{6}$	$5.544\ 85 \times 10^{6}$	$6.228\ 83 \times 10^{5}$	**1**	5.544 85
1 thermie per litre[c] th/litre =	$4\ 185.5 \times 10^{6}$	$0.999\ 690 \times 10^{6}$	$1.000\ 36 \times 10^{6}$	**1** $\times 10^{6}$	$0.112\ 335 \times 10^{6}$	0.180 347	**1**

NOTE In this table, where gases are concerned, it is assumed that the volumes involved in the conversion are measured under the same conditions of temperature, pressure and humidity. (See also Table 43 and Table 44.)

[a] This is the International Table kilocalorie. For a description of the three calories mentioned see **37.2**.
[b] 1 therm/ft³ = 10^5 Btu/ft³.
[c] The litre here = 1 dm³. See **5.3**.

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Table 43 — Calorific value of gases, volume basis (with differing reference conditions)

	Btu/ft³ (60 °F, 30 inHg wet)	kJ/m³ (0 °C, 760 mmHg dry)	kJ/m³ (15 °C, 760 mmHg dry)	kcal/m³ (0 °C, 760 mmHg dry)	kcal/m³ (0 °C, 760 mmHg wet)	kcal/m³ (15 °C, 760 mmHg dry)	kcal/m³ (15 °C, 760 mmHg wet)	kcal/m³ (60 °F, 30 inHg wet)
1 Btu/ft³ (60 °F, 30 inHg, wet) =	1	39.972	37.891	9.547 1	9.489 5	9.050 1	8.898 0	8.899 1
1 kJ/m³ (0 °C, 760 mmHg, dry) =	0.025 018							
1 kJ/m³ (15 °C, 760 mmHg, dry) =	0.026 392							
1 kcal/m³ (0 °C, 760 mmHg, dry) =	0.104 74							
1 kcal/m³ (0 °C, 760 mmHg, wet) =	0.105 38							
1 kcal/m³ (15 °C, 760 mmHg, dry) =	0.110 50							
1 kcal/m³ (15 °C, 760 mmHg, wet) =	0.112 38							
1 kcal/m³ (60 °F, 30 inHg, wet) =	0.112 37							

The values of the vapour pressure of water used in the computation of the factors given in this table are as follows:

Temperature	Vapour pressure mmHg
0 °C	4.581
15 °C	12.771
60 °F	13.235

For definitions of pressure units mmHg and inHg see **33.2**.

NOTE 1 In this table the designation "wet" means "saturated with water vapour at the temperature stated".

NOTE 2 760 mmHg = 1 atm = 1 013.25 mbar = 101.325 kPa

30 inHg = 762 mmHg = 1 015.92 mbar = 101.592 kPa

NOTE 3 For historical and legal reasons, the reference bases of conversion factors for calorific value once used by the United Kingdom Gas Industry differ in some respects from those in this table. (See Table 44 and the notes to that table.)

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Table 44 — Conversion factors previously used by the UK Gas Industry

The following information and conversion factors were extracted from the booklet *SI Units and conversion factors for use in the British Gas Industry* issued by the Gas Council and Society of British Gas Industries, May 1972 edition.

The conversion factor for converting from British thermal units per cubic foot (measured at 60 °F, 30 inches Hg (@ 60 °F, latitude 53 °N) and saturated with water) to megajoules per standard cubic metre (measured at 15 °C 1 013.25 mbar and dry) is:

1 Btu/ft^3 = 0.037 96 MJ/m^3 1 MJ/m^3 = 26.34 Btu/ft^3

Other conversion factors for various conditions are given in the table below.

Whereas two bases for the British thermal unit are included, for practical purposes there is no significant difference between them. In the gas industry the British thermal unit was based on the 15° calorie.

		MJ/m^3 15 °C 1 013.25 mbar		Btu/ft^3 60 °F, 30 inches Hg (IT calorie)		Btu/ft^3 60 °F, 30 inches Hg (15 °C calorie)	
		Dry	**Sat.**	**Dry**	**Sat.**	**Dry**	**Sat.**
MJ/m^3 15 °C 1 013.25 mbar	Dry	1	0.983 2	26.80	26.33	26.81	26.34
	Sat.	1.017	1	27.26	26.78	27.27	26.79
Btu/ft^3 60 °F 30 inches Hg (International calorie basis)	Dry	0.037 31	0.036 69	1	0.982 6	1.000	0.982 9
	Sat.	0.037 97	0.037 34	1.018	1	1.018	1.000
Btu/ft^3 60 °F 30 inches Hg (15° calorie basis)	Dry	0.037 30	0.036 67	0.999 7	0.982 3	1	0.982 6
	Sat.	0.037 96	0.037 32	1.017	0.999 7	1.018	1

NOTE (This note is for users of BS 350 and is not part of the GC/SBGI booklet.)

Attention is called to the following differences in the reference bases of Table 43 and Table 44.

a) In Table 43 the only British thermal unit used is the one corresponding to the International Table calorie (see **37.2**). In Table 44 this Btu is indicated by the parenthetic (International calorie basis) or (IT calorie), and factors relating to a Btu based on the 15 °C calorie are stated in the preamble above the table and included in the table.

b) The pressure "30 inches Hg" as shown in, and under the conditions stated in, Table 44, is given as being equal to 1 013.740 5 mbar. The pressure 30 inHg shown in Table 43 (and as defined in **33.2**) is, approximately, 1 015.916 6 mbar.

42 Specific heat capacity[30] [heat/(mass × temperature interval)]

42.1 The SI unit of specific heat capacity is the joule per kilogram kelvin [J/(kg·K)].

42.2 The degree Celsius is often used in the expression of the above unit:

1 J/(kg·°C) = 1 J/(kg·K)

This is also the case with other units including the kelvin, given in **42.3** and **42.4**.

42.3 Other metric units are:

kilocalorie per kilogram kelvin [kcal/(kg·K)] (See **37.2** for the various calories.)

kilogram-force metre per kilogram kelvin [kgf·m/(kg·K)]

1 kcal$_{IT}$/(kg·K) = **4 186.8** J/(kg·K)
1 kcal$_{th}$/(kg·K) = **4 184** J/(kg·K)
1 kcal$_{15}$/(kg·K) = 4 185.5 J/(kg·K)
1 kgf·m/(kg·K) = **9.806 65** J/(kg·K)

[30] The older and simpler term "specific heat" referred to heat capacities, usually on a mass basis but sometimes on a volume basis. It is now preferred to reserve "specific" for the meaning "per unit mass".

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42.4 Corresponding imperial units are:

British thermal unit per pound degree Fahrenheit [Btu/(lb·°F)]

foot pound-force per pound degree Fahrenheit [ft·lbf/(lb·°F)]

1 Btu/(lb·°F)	=	**4 186.8** J/(kg·K)
1 ft·lbf/(lb·°F)	=	5.380 32 J/(kg·K)

For interconversion factors for the above units see Table 45.

43 Specific entropy [heat/(mass × thermodynamic temperature)]

Table 45 may also be used for the conversion of values of specific entropy, expressed in joules per kilogram kelvin, J/(kg·K), in kilocalories per kilogram kelvin, kcal/(kg·K), or in British thermal units per pound degree Rankine, Btu/(lb·°R).

44 Heat capacity, volume basis[31)] [heat/(volume × temperature interval)]

44.1 The SI unit of heat capacity, volume basis, is the joule per cubic metre kelvin [J/(m^3·K)].

44.2 The degree Celsius is often used in the expression of the above unit:

1 J/(m^3·°C) = 1 J/(m^3·K)

This is also the case with other units including the kelvin, given in **44.3** and **44.4**.

44.3 Other metric units are:

kilocalorie per cubic metre kelvin [kcal/(m^3·K)] (See **37.2** for the various calories.)

1 kcal$_{IT}$/(m^3·K)	=	**4 186.8** J/(m^3·K)
1 kcal$_{th}$/(m^3·K)	=	**4 184** J/(m^3·K)
1 kcal$_{15}$/(m^3·K)	=	4 185.5 J/(m^3·K)

44.4 The corresponding imperial unit is:

British thermal unit per cubic foot degree Fahrenheit [Btu/(ft^3·°F)]

1 Btu/(ft^3·°F) = 67 066.1 J/(m^3·K)

For interconversion factors for the above units see Table 46.

In Table 46 and in the above conversion factors it is assumed that, for gases, the volumes involved in the conversions are measured under the same conditions of temperature, pressure and humidity.

[31)] This is sometimes known as "specific heat, volume basis" but see footnote to Clause **42**.

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45 Heat flux density [heat/(area × time)]

45.1 The SI unit for this quantity, which is sometimes known as intensity of heat flow rate, and commonly appears, for example, in calculations of heat losses from surfaces, is the watt per square metre (W/m^2).

45.2 Other metric units are:

calorie per square centimetre second [$cal/(cm^2 \cdot s)$] (See **37.2** for the various calories.)

kilocalorie per square metre hour [$kcal/(m^2 \cdot h)$]

1 $cal_{IT}/(cm^2 \cdot s)$	=	**41 868** W/m^2
1 $kcal_{IT}/(m^2 \cdot h)$	=	**1.163** W/m^2

45.3 Corresponding units in the imperial system are:

British thermal unit per square foot hour [$Btu/(ft^2 \cdot h)$]

watt per square inch (W/in^2)

1 $Btu/(ft^2 \cdot h)$	=	3.154 59 W/m^2
1 W/in^2	=	1 550.00 W/m^2

For conversion factors for the above see Table 47.

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Table 45 — Specific heat, mass basis

Exact values are printed in bold type

		joule per kilogram kelvin[a] J/(kg·K)	kilocalorie[b] per kilogram kelvin kcal_{IT}/(kg·K)	thermochemical kilocalorie per kilogram kelvin kcal_{th}/(kg·K)	15 °C kilocalorie per kilogram kelvin kcal_{15}/(kg·K)	British thermal unit per pound degree Fahrenheit Btu/(lb·°F)	foot pound-force per pound degree Fahrenheit ft·lbf/(lb·°F)	kilogram-force metre per kilogram kelvin kgf·m/(kg·K)
1 joule per kilogram kelvin[a] J/(kg·K)	=	**1**	$0.238\ 846 \times 10^{-3}$	$0.239\ 006 \times 10^{-3}$	$0.238\ 920 \times 10^{-3}$	$0.238\ 846 \times 10^{-3}$	0.185 863	0.101 972
1 kilocalorie[b] per kilogram kelvin kcal_{IT}/(kg·K)	=	**4 186.8**	**1**	1.000 67	1.000 31	**1**	778.169	426.935
1 thermochemical kilocalorie per kilogram kelvin kcal_{th}/(kg·K)	=	**4 184**	0.999 331	**1**	0.999 642	0.999 331	777.649	426.649
1 15 °C kilocalorie per kilogram kelvin kcal_{15}/(kg·K)	=	4 185.5	0.999 690	1.000 36	**1**	0.999 690	777.928	426.802
1 British thermal unit per pound degree Fahrenheit Btu/(lb·°F)	=	**4 186.8**	**1**	1.000 67	1.000 31	**1**	778.169	426.935
1 foot pound-force per pound degree Fahrenheit ft·lbf/(lb·°F)	=	5.380 32	$1.285\ 07 \times 10^{-3}$	$1.285\ 93 \times 10^{-3}$	$1.285\ 47 \times 10^{-3}$	$1.285\ 07 \times 10^{-3}$	**1**	0.548 64
1 kilogram-force metre per kilogram kelvin kgf·m/(kg·K)	=	**9.806 65**	$2.342\ 28 \times 10^{-3}$	$2.343\ 85 \times 10^{-3}$	$2.343\ 01 \times 10^{-3}$	$2.342\ 28 \times 10^{-3}$	1.822 69	**1**

NOTE This table may also be used for interconversion of values of specific entropy e.g. J/(kg·K), kcal/(kg·K), Btu/(lb·°R).

[a] Wherever the kelvin (K) occurs in this table it may be replaced by the degree Celsius (°C) e.g. J/(kg·K) is often shown as J/(kg·°C).

[b] This is the International Table kilocalorie. For a description of the three calories mentioned see **37.2**.

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Table 46 — Heat capacity, volume basis

Exact values are printed in bold type

		joule per cubic metre kelvin[a] $J/(m^3 \cdot K)$	kilocalorie[b] per cubic metre kelvin $kcal_{IT}/(m^3 \cdot K)$	thermochemical kilocalorie per cubic metre kelvin $kcal_{th}/(m^3 \cdot K)$	15 °C kilocalorie per cubic metre kelvin $kcal_{15}/(m^3 \cdot K)$	British thermal unit per cubic foot degree Fahrenheit $Btu/(ft^3 \cdot °F)$
1 joule per cubic metre kelvin[a] $J/(m^3 \cdot K)$	=	**1**	$0.238\ 846 \times 10^{-3}$	$0.239\ 006 \times 10^{-3}$	$0.238\ 920 \times 10^{-3}$	$14.910\ 7 \times 10^{-6}$
1 kilocalorie[b] per cubic metre kelvin $kcal_{IT}/(m^3 \cdot K)$	=	**4 186.8**	**1**	1.000 67	1.000 31	0.062 428 0
1 thermochemical kilocalorie per cubic metre kelvin $kcal_{th}/(m^3 \cdot K)$	=	**4 184**	0.999 331	**1**	0.999 642	0.062 386 2
1 15 °C kilocalorie per cubic metre kelvin $kcal_{15}/(m^3 \cdot K)$	=	4 185.5	0.999 690	1.000 36	**1**	0.062 408 6
1 British thermal unit per cubic foot degree Fahrenheit $Btu/(ft^3 \cdot °F)$	=	67 066.1	16.018 5	16.029 2	16.023 4	**1**

NOTE In this table it is assumed that, for gases, the volumes involved in the conversions are measured under the same conditions of temperature, pressure and humidity.

[a] Wherever the kelvin occurs in this table it may be replaced by the degree Celsius (°C), e.g. $J/(m^3 \cdot K)$ is often shown as $J/(m^3 \cdot °C)$.
[b] This is the International Table kilocalorie. For a description of the three calories mentioned see **37.2**.

Table 47 — Heat flux density, intensity of heat flow rate (e.g. heat loss from surfaces)

Exact values are printed in bold type

		W/m^2	W/in^2	$cal_{IT}/(cm^2 \cdot s)$	$kcal_{IT}/(m^2 \cdot h)$	$Btu/(ft^2 \cdot h)$
1 watt per square metre W/m^2	=	**1**	$\mathbf{6.451\ 6} \times 10^{-4}$	$0.238\ 846 \times 10^{-4}$	0.859 845	0.316 998
1 watt per square inch W/in^2	=	1 550.00	**1**	$3.702\ 12 \times 10^{-2}$	1 332.76	491.348
1 calorie[a] per square centimetre second $cal_{IT}/(cm^2 \cdot s)$	=	**41 868**	27.011 6	**1**	**36 000**	13 272.1
1 kilocalorie[a] per square metre hour $kcal_{IT}/(m^2 \cdot h)$	=	**1.163**	$7.503\ 21 \times 10^{-4}$	$2.777\ 78 \times 10^{-5}$	**1**	0.368 669
1 British thermal unit per square foot hour $Btu/(ft^2 \cdot h)$	=	3.154 59	$2.035\ 22 \times 10^{-3}$	$7.534\ 61 \times 10^{-5}$	2.712 46	**1**

[a] This refers to the International Table calorie. For other calories see **37.2**.

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46 Thermal conductance (heat transfer coefficient)

[heat/(area × time × temperature difference)] or [power/(area × temperature difference)][32)]

46.1 The SI unit is the watt per square metre kelvin [$W/(m^2 \cdot K)$]

46.2 The degree Celsius (°C) is often used in the expression of the above unit:

$1\ W/(m^2 \cdot °C) = 1\ W/(m^2 \cdot K)$

This is also the case with other units including the kelvin, given in **46.3** and **46.4**.

46.3 Other metric units are:

calorie per square centimetre second kelvin [$cal/(cm^2 \cdot s \cdot K)$]

kilocalorie per square metre hour kelvin [$kcal/(m^2 \cdot h \cdot K)$]

(The conversion factors given below refer to the International Table calorie; see **37.2** for other calories.)

$1\ cal/(cm^2 \cdot s \cdot K)$ = **41 868** $W/(m^2 \cdot K)$

$1\ kcal/(m^2 \cdot h \cdot K)$ = **1.163** $W/(m^2 \cdot K)$

46.4 The imperial unit is:

British thermal unit per square foot hour degree Fahrenheit [$Btu/(ft^2 \cdot h \cdot °F)$]

$1\ Btu/(ft^2 \cdot h \cdot °F) = 5.678\ 26\ W/(m^2 \cdot K)$

For interconversion factors for the above units see Table 48.

Table 48 — Thermal conductance

Exact values are printed in bold type

		$W/(m^2 \cdot K)$[a]	cal[b]$/(cm^2 \cdot s \cdot K)$	kcal[b]$/(m^2 \cdot h \cdot K)$	$Btu/(ft^2 \cdot h \cdot °F)$
1 watt per square metre kelvin[a] $W/(m^2 \cdot K)$	=	**1**	$0.238\ 846 \times 10^{-4}$	0.859 845	0.176 110
1 calorie[b] per square centimetre second kelvin $cal/(cm^2 \cdot s \cdot K)$	=	**41 868**	**1**	**36 000**	7 373.38
1 kilocalorie[b] per square metre hour kelvin $kcal/(m^2 \cdot h \cdot K)$	=	**1.163**	$2.777\ 78 \times 10^{-5}$	**1**	0.204 816
1 British thermal unit per square foot hour degree Fahrenheit $Btu/(ft^2 \cdot h \cdot °F)$	=	5.678 26	$1.356\ 23 \times 10^{-4}$	4.882 43	**1**

[a] Wherever the kelvin occurs in this table it may be replaced by the degree Celsius: e.g. $W/(m^2 \cdot K)$ is often shown as $W/(m^2 \cdot °C)$

[b] This refers to the International Table calorie. For other calories see **37.2**.

[32)] Also corresponds to (heat flux density/temperature difference).

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47 Thermal conductivity [heat × length/(area × time × temperature difference)]

47.1 The SI unit is the watt per metre kelvin [W/(m·K)]

47.2 The degree Celsius (°C) is often used in the expression of the above unit:

1 W/(m·°C) = 1 W/(m·K)

This is also the case with other units including the kelvin, given in **47.3** and **47.4**.

47.3 Other metric units are:

calorie per centimetre second kelvin [cal/(cm·s·K)]

kilocalorie per metre hour kelvin [kcal/(m·h·K)]

(The conversion factors given below refer to the International Table calorie; see **37.2** for other calories.)

1 cal/(cm·s·K) = **418.68** W/(m·K)
1 kcal/(m·h·K) = **1.163** W/(m·K)

47.4 Two imperial units are:

British thermal unit per foot hour degree Fahrenheit [Btu/(ft·h·°F)]

British thermal unit inch per square foot hour degree Fahrenheit [Btu·in/(ft^2·h·°F)]

1 Btu/(ft·h·°F) = 1.730 73 W/(m·K)
1 Btu·in/(ft^2·h·°F) = 0.144 228 W/(m·K)

For interconversion factors for the above units see Table 49.

Table 49 — Thermal conductivity

Exact figures are printed in bold type

		W/(m·K)[a]	cal/(cm·s·K)[b]	kcal/(m·h·K)	Btu/(ft·h·°F)	Btu·in/(ft^2·h·°F)
1 watt per metre kelvin[a] W/(m·K)	=	**1**	$0.238\ 846 \times 10^{-2}$	0.859 845	0.577 789	6.933 47
1 calorie[b] per centimetre second kelvin cal/(cm·s·K)	=	**418.68**	**1**	**360**	241.909	2 902.91
1 kilocalorie[a] per metre hour kelvin kcal/(m·h·K)	=	**1.163**	$2.777\ 78 \times 10^{-3}$	**1**	0.671 969	8.063 63
1 British thermal unit per foot hour degree Fahrenheit Btu/(ft·h·°F)	=	1.730 73	$4.133\ 79 \times 10^{-3}$	1.488 16	**1**	**12**
1 British thermal unit inch per square foot hour degree Fahrenheit Btu·in/(ft^2·h·°F)	=	0.144 228	$3.444\ 82 \times 10^{-4}$	0.124 014	0.083 333 3	**1**

[a] Wherever the kelvin occurs in this table it may be replaced by the degree Celsius (°C) e.g. W/(m·K) is often shown as W/(m·°C).
[b] This refers to the International Table calorie. For other calories see **37.2**.

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48 Thermal resistivity [area × time × temperature difference/(heat × length)]

The SI unit of thermal resistivity (the inverse of thermal conductivity) is the metre kelvin per watt (m·K/W).

Interconversion factors between the above and some other units are given in Table 50.

Similar comments concerning the use of the degree Celsius and the other calories apply as in Clause **47** and Table 49.

Table 50 — Thermal resistivity

Exact figures are printed in bold type

		m·K/W	cm·s·K/cal[a]	m·h·K/kcal[a]	ft·h·°F/Btu	ft^2·h·°F/(Btu·in)
1 m·K/W	=	**1**	**418.68**	**1.163**	1.730 73	0.144 228
1 cm·s·K/cal[a]	=	0.238 846 × 10^{-2}	**1**	2.777 78 × 10^{-3}	4.133 79 × 10^{-3}	3.444 82 × 10^{-4}
1 m·h·K/kcal[a]	=	0.859 845	**360**	**1**	1.488 16	0.124 014
1 ft·h·°F/Btu	=	0.577 789	241.909	0.671 969	**1**	0.083 333 3
1 ft^2·h·°F/(Btu·in)	=	6.933 47	2 902.91	8.063 63	**12**	**1**

NOTE For thermal conductivity, see Table 49, the notes to which also apply here.

[a] This refers to the International Table calorie. For other calories see **37.2**.

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49 Heat release rate (e.g. as used in connection with furnaces) [heat/(volume × time)], or (power/volume)

49.1 The SI unit for this quantity is the watt per cubic metre (W/m^3).

49.2 Other metric units are:

calorie per cubic centimetre second [$cal/(cm^3 \cdot s)$]

kilocalorie per cubic metre hour [$kcal/(m^3 \cdot h)$]

The conversion factors given below refer to the International Table calorie. (See **37.2** for other calories.)

$1\ cal/(cm^3 \cdot s)$ = **4.186 8** × 10^6 W/m^3

$1\ kcal/(m^3 \cdot h)$ = **1.163** W/m^3

49.3 A similar imperial unit is:

British thermal unit per cubic foot hour [$Btu/(ft^3 \cdot h)$]

$1\ Btu/(ft^3 \cdot h) = 10.349\ 7\ W/m^3$

For interconversion factors for the above units see Table 51.

Table 51 — Heat release rate

Exact values are printed in bold type

		watt per cubic metre W/m^3	**calorie[a]/cubic centimetre second** $cal/(cm^3 \cdot s)$	**kilocalorie[a]/cubic metre hour** $kcal/(m^3 \cdot h)$	**British thermal unit/cubic foot hour** $Btu/(ft^3 \cdot h)$
1 watt per cubic metre W/m^3	=	**1**	$0.238\ 846 \times 10^{-6}$	0.859 845	$9.662\ 11 \times 10^{-2}$
1 calorie[a] per cubic centimetre second $cal/(cm^3 \cdot s)$	=	**4.186 8** × 10^6	**1**	**3.6** × 10^6	$4.045\ 33 \times 10^5$
1 kilocalorie[a] per cubic metre hour $kcal/(m^3 \cdot h)$	=	**1.163**	$2.777\ 78 \times 10^{-7}$	**1**	0.112 370
1 British thermal unit per cubic foot hour $Btu/(ft^3 \cdot h)$	=	10.349 7	$2.471\ 99 \times 10^{-6}$	8.899 15	**1**

[a] This refers to the International Table calorie. For other calories see **37.2**.
$1\ W/cm^3 = 10^6\ W/m^3 = 1\ MW/m^3$.

50 Thermal diffusivity (area/time)

The SI unit of thermal diffusivity (which is thermal conductivity divided by heat capacity per unit volume) is the metre squared per second (m^2/s).

Since kinematic viscosity has the same dimensions as thermal diffusivity, for units and conversion factors reference can be made to Clause **36** and Table 36.

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Annex A (informative) Commentary on imperial and metric systems of measurement and units

A.1 Development of units

In the past, units have evolved in a haphazard manner to meet the basic measurement requirements of early and often unconnected societies. With improvement in communications and extension of trade it became necessary to standardize the units in use and also to establish the relationship between existing units used to measure the same physical quantities. Often, as this latter process developed, the numerical factors relating one such unit to another were cumbersome and difficult to use in calculations (for example, the mile is 1 760 yards and the UK ton is 2 240 pounds). Moreover, while one physical quantity might be a simple derivative of another, there was often no correspondingly simple relationship between their respective units, (for example, area and volume are simple derivatives of length, but 1 acre is 4 840 square yards and 1 UK gallon is 0.160 544 cubic feet).

As science and technology developed, many new and complex units were required. Inevitably these were derived from the available units in common usage and the result was a muddled conglomeration of technical units involving many awkward factors which were difficult to remember and inconvenient to use. The learning of these factors was once a necessary part of scientific and engineering education.

A.2 Unit systems and coherence

The various physical quantities used in science and technology are related to one another by certain mathematical or physical laws. For example, area equals length multiplied by length, velocity equals length divided by time, force equals mass multiplied by acceleration, momentum equals mass multiplied by velocity.

In a coherent system of units, the units used to measure the various physical quantities are consistent with these physical laws. A minimum number of independent physical quantities are arbitrarily selected and base units are defined for these. Units for all other physical quantities can then be derived in accordance with the physical laws, preserving a unity relationship in terms of the base units. Thus, if unit area results when unit length is multiplied by unit length, the units are coherent with the particular physical law expressing the relationship between length and area, and no factors are involved in calculations concerned with this relationship.

With further development of science and technology, certain “systems” of units came into use, (for example the foot-pound-second system and the centimetre-gram-second system). While the base units concerned were clearly defined, the total extent of each of these systems and also units for some physical quantities were in certain respects vague. The units comprising these systems were coherent with respect to some of the physical laws, but not to others.

A.3 The metric system of measurement

The SI (Système International d’Unités) is now the most widely used source of units in the UK. The SI is the latest development of the metric system. Only a few imperial measures are still permitted.

In Britain, units of length, weight (mass) and so on have been standardized for a long time, but prior to the adoption of the metric system this was not the case in France and in other mainland European countries. When the metric system was introduced it met two main requirements. The first was the standardization and definition of the important units of measurement, the metre for length and the gram for mass, from which other units then required for general use and for trade were derived. The second was the provision of a convenient and systematic relationship between different-sized units for the same quantity. These were related by powers of ten and a system of prefixes developed to indicate these powers. This gave a flexible means of expression for a wide range of magnitudes, avoiding the need for very large or very small numerical values, and enabled the different-sized units to be memorized and converted with ease.

In technology, probably the most widely used metric system is one in which the base units for length, mass and time are the metre, kilogram and second respectively, but in which there is a non-coherent relationship between the units for mass, force and acceleration. The unit of force used is the kilogram-force (sometimes described as a “metric technical unit of force”), and because this force acting on a mass of 1 kilogram produces an acceleration of “g” (9.81 m/s^2 approximately) the factor 9.81 is introduced in an awkward manner into many engineering calculations. The SI has now largely superseded this system.

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There are other metric systems still in use in some sectors of industry and science, which are dynamically coherent, and from the first two of which the development of the SI can directly be traced. Some are shown in Table A.1.

Table A.1 — Other metric systems

Description and abbreviation	mass unit	force unit
centimetre-gram-second (CGS)	gram	dyne
metre-kilogram-second (MKS)	kilogram	newton
metre-tonne-second (MTS)	tonne	sthène

Scientists were quick to recognize the convenience of the metric approach in the CGS system and this system was developed by them to meet their immediate needs, according to their knowledge at the time, and among other things it served in the development of electrostatics and electromagnetism. Although it gained considerable usage in industrial technology, many of the associated units were inconveniently sized for this purpose. It was also clear that more than the three base units provided in the CGS system were required in the framework of the metric system to deal adequately with the physical quantities required in science and technology. Also, some of the subsidiary units that had come into use in conjunction with the CGS system were not coherent.

These factors led in due course to the evolution of the MKS system, thence to the MKSA system, incorporating the independent quantity electric current and the base unit ampere. This system embodied the joule as the derived and coherent unit of energy in all its forms, and the watt as the unit of power.

A.4 The International System of units (SI)

This "modern metric system" expanded on the MKS system to include a total of seven base units and two supplementary units which, in conjunction with derived units, meet all known needs for a coherent system of units both in science and technology.

The base and supplementary quantities, and their units (defined in BS 5555:1993) are shown in Table A.2.

Table A.2 — Base and supplementary quantities, units and symbols in the SI system

Quantity	Name of unit	Symbol
Base		
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd
Supplementary		
Plane angle	radian	rad
Solid angle	steradian	sr

There are, for practical applications or for everyday life, certain other units, some metric and some non-metric, which at present are authorized for use in conjunction with the International System. Such units are listed in categories in BS 5555:1993 and their use introduces an element of non-coherence.

The metric prefixes, which now form part of the International System, are shown in detail in **2.1**. As is evident from the foregoing description of a coherent system, the use of multiples in the form of a prefix also introduces non-coherence, but in the SI the prefixed units still retain a simple decimal relationship one with the other. This is an important feature, which is not sacrificed by the fact that the base unit for mass is the *kilo*gram. Recent discussions were aimed at renaming the kilogram to avoid the use of the prefix, but it now appears no change will be made in the immediate future.

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A.5 Imperial systems

Before the advent of metric systems in the UK, the most widely used British system was one in which the base units for length, mass and time were the foot, pound and second respectively. But, in this system there is a non-coherent relationship between the units used for mass, force and acceleration i.e. there is not "dynamic coherence". The unit of force used is the pound-force (sometimes described as a "technical unit of force"), and, because this force acting on a mass of one pound produces an acceleration of "*g*" (= 32.2 ft/s^2 approximately), the factor 32.2 was introduced in an awkward manner into many engineering calculations.

There are two other systems based on imperial units formerly used in some sections of industry which are dynamically coherent. The first is a variant of the foot-pound-second system which has the poundal as its force unit. The poundal acting on a mass of one pound produces an acceleration of unity (1 ft/s^2). The other is the foot-slug-second system in which the mass unit is the slug (= 32.2 lb approximately) and the force unit the pound-force. Again, the acceleration produced by the pound-force on the slug is unity.

In the above, only dynamic coherence has been mentioned. While this is of vital importance in mechanics, there are many other important physical quantities and laws; further base units had to be introduced and the corresponding units that came about in conjunction with these imperial systems were frequently non-coherent. Furthermore, in dealing with the foot-pound-second, and foot-slug-second systems, there are the practical complications in calculations caused by the awkward relationships between the foot, inch and yard, and the pound and ton. In the measurement sense these units all form part of the imperial system.

A.6 Comparison of United Kingdom (UK or imperial) and United States systems of measurement

The yard has the same value in both the UK and US systems and is defined in terms of the SI base unit of length, the metre. Similarly, the pound has the same value in the UK and US systems and is defined in terms of the SI base unit of mass, the kilogram.

The UK Weights and Measures Act, 1985 [1], defines these units in the UK. In the USA the same definitions are valid for all purposes except for coast and geodetic surveys within the USA, for which the foot previously adopted there will continue temporarily to be used under the name "US survey foot".

Most of the subsidiary units of length are identical in both the UK and US systems. There are marked differences between some subsidiary units of mass used in the UK and US systems, notably in the "long" and "short" tons and hundredweights. These differences arise from different whole number relationships between units.

There are also marked differences between the subsidiary units of capacity used in the UK and US systems. These differences arise both from some different whole number relationships between units and also from different definitions of capacity in the two systems.

In order to avoid confusion where those differences occur, the units to be distinguished are denoted by the use of prefixes, for example:

UK gallon, symbolized by UKgal

US gallon, symbolized by USgal

This notation is similar to one adopted by the International Organization for Standardization (ISO).
In certain contexts the qualification "imperial" or "imp" is also used to make it clear that the unit qualified by UK does in fact belong to the imperial system of units.

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Index of symbols and abbreviations

Symbol or abbreviation	Name of unit or prefix, where appropriate	Textual reference
A	ampere	**A.4**
Å	ångström	**3.3**
a	are	**4.3**
a	atto (prefix)	**2.1**
a	year	Clause **10**, Note 2
at	technical atmosphere	**33.3**
ata	technical atmosphere (absolute, German)	**33.4**
atm	standard atmosphere	**33.3**
atü	technical atmosphere (gauge, German)	**33.4**
AU	astronomical unit	**3.3**
bar	bar	**33.1.2**
bbl	barrel (US, for petroleum)	**5.10**
bbl (dry)	dry barrel (US)	**5.11**
Btu	British thermal unit	**37.2**
$\mathrm{Btu}_{\mathrm{mean}}$	mean British thermal unit	**37.2**
$\mathrm{Btu}_{60/61}$	60 °F British thermal unit	**37.2**
bu	bushel (US)	**5.9**, **5.11**
c	centi (prefix)	**2.1**
c	cycle	**13.1**
°C	degree Celsius	**39.2**
cal	calorie	**37.2**
$\mathrm{cal}_{\mathrm{IT}}$	International Table calorie	**37.2**
$\mathrm{cal}_{\mathrm{th}}$	thermochemical calorie	**37.2**
cal_{15}	15 °C calorie	**37.2**
cd	candela	**A.4**
ch	cheval vapeur (metric horsepower) (French)	**38.2**, footnote
C.H.U.	Centigrade heat unit	**37.2**
cl	centilitre	**5.3**
cm	centimetre	**3.2**
cP	centipoise	**35.2**
cSt	centistokes	**36.2**
ctl	cental	**15.5**
cumec	cubic metre per second	**24.1**, footnote
cusec	cubic foot per second	**24.3**, footnote
CV	cheval vapeur (metric horsepower) (French)	**38.2**, footnote
cwt	hundredweight	**15.5**
d	day	**10.3**
d	deci (prefix)	**2.1**
da	deca (prefix)	**2.1**

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Symbol or abbreviation	Name of unit or prefix, where appropriate	Textual reference
deg	(to indicate temperature interval)	**39.5**
dm	decimetre	**3.2**
dr	dram (avoirdupois)	**15.5**
dry qt	dry quart (US)	**5.11**
dyn	dyne	**29.2**
E	exa (prefix)	**2.1**
erg	erg	**37.1.2**
°F	degree Fahrenheit	**39.3**
f	femto (prefix)	**2.1**
f	fermi	**3.3**
fl dr	fluid drachm (UK)	**5.8**
fl dr	fluid dram (US)	**5.10**
fl oz	fluid ounce	**5.8**
fm	fermi	**3.3**
Fm	Festmeter (German)	**5.5**
ft	foot	**3.5**
ftH_2O	conventional foot of water	**33.2**
G	giga (prefix)	**2.1**
g	gram	**15.2**
g	acceleration due to gravity	**14.4**
g_n	standard acceleration due to gravity ("standard gravity")	**14.4**
^{g}	grade	**8.3**
Gal	galileo (or gal)	**14.2**
gal	gallon	**5.8**
gi	gill (US)	**5.10**
gon	gon (German)	**8.3**
gr	grain	**15.5**
h	hecto (prefix)	**2.1**
h	hour	**10.3**
ha	hectare	**4.3**
hbar	hectobar	Clause **34**
hl	hectolitre	**5.3**
hp	horsepower	**38.3**
hp·h	horsepower hour	**37.1.5**
Hz	hertz	**13.1**
in	inch	**3.5**
inHg	conventional inch of mercury	**33.2**
inH_2O	conventional inch of water	**33.2**

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Symbol or abbreviation	Name of unit or prefix, where appropriate	Textual reference
J	joule	**37.1.1**
K	kelvin	**39.1**
k	kilo (prefix)	**2.1**
kg	kilogram	**15.1**
kgf	kilogram-force	**29.2**
kip	1 000 pounds-force (US)	**29.3**
km	kilometre	**3.2**
kn	knot (international)	**11.5**
kp	kilopond (kilogram-force, German)	**29.2**
k.s.i.	kips per square inch (US)	**33.1.4**
kW	kilowatt	**38.1**
kW·h	kilowatt hour	**37.1.3**
l	litre	**5.3**
lb	pound	**15.4**
lbf	pound-force	**29.3**
liq dr	liquid dram (US)	**5.10**, footnote
liq oz	liquid ounce (US)	**5.10**, footnote
liq pt	liquid pint (US)	**5.10**
liq qt	liquid quart (US)	**5.10**
l.y.	light year	**3.3**
M	mega (prefix)	**2.1**
m	metre	**3.1**
m	milli (prefix)	**2.1**
mb	millibar	**33.1.2**, footnote
mil	(of area)	**4.5**, and Clause **4**, Note 2
mil	(of angle)	Clause **8**, Note 2
mil	(of length)	**3.6**, and Clause **3**, Note 8
mil	(of volume)	**5.5**
Mg	megagram	**15.2**
mg	milligram	**15.2**
mGal	milligal	**14.2**
mH_2O	conventional metre of water	**33.2**
min	minute (of time)	**10.3**
min	minim	**5.8**
ml	millilitre	**5.3**
mm	millimetre	**3.2**
mmHg	conventional millimetre of mercury	**33.2**
mmH_2O	conventional millimetre of water	**33.2**
mol	mole	**21.1**, **A.4**
ms	millisecond	Clause **10**, Note 1

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Symbol or abbreviation	Name of unit or prefix, where appropriate	Textual reference
N	newton	**29.1**
n	nano (prefix)	**2.1**
n mile	nautical mile (international)	**3.3**
ns	nanosecond	Clause **10**, Note 1
oz	ounce	**15.5**
oz ap	apothecaries' ounce (US)	**15.5**
oz apoth	apothecaries' ounce (UK)	**15.5**
ozf	ounce-force	**29.3**
oz t	ounce troy (US)	**15.5**
oz tr	ounce troy (UK)	**15.5**
P	peta (prefix)	**2.1**
P	poise	**35.2**
p	pico (prefix)	**2.1**
Pa	pascal	**33.1**
pc	parsec	**3.3**
pdl	poundal	**29.3**
pk	peck (US)	**5.11**
Pl	poiseuille (French)	**35.1**
PS	Pferdestärke (metric horsepower) (German)	**38.2**, footnote
p.s.i.	pound-force per square inch	**33.1.4**
p.s.i.a.	pound-force per square inch (absolute)	**33.4**
p.s.i.g.	pound-force per square inch (gauge)	**33.4**
pt	pint	**5.8**
pz	pièze (French)	**33.1.2**
q	quintal	**15.3**
qr	quarter	**15.5**
qt	quart	**5.8**
°R	degree Rankine	**39.4**
r	revolution	**12.2**
rad	radian	**8.1**
rev	revolution	**12.2**
reyn	(viscosity unit)	**35.3**, Note 1
Rm	Raummeter (German)	**5.5**
s	second (of time)	**10.1**
sh cwt	short hundredweight (US)	**15.5**
sh ton	short ton (US)	**15.5**
sn	sthène (French)	**29.2**
sr	steradian	Clause **9**
St	stokes	**36.2**
st	stère (French)	**5.5**

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Symbol or abbreviation	Name of unit or prefix, where appropriate	Textual reference
T	tera (prefix)	**2.1**
t	tonne	**15.2**
th	thermie	**37.2**
ton	ton (UK)	**15.5**
tonf	ton-force	**29.3**
u	atomic mass unit	**15.3**
UKgal	gallon (UK)	**5.8**
UKpt	pint (UK)	**5.8**
UKqt	quart (UK)	**5.8**
USgal	gallon (US)	**5.10**
W	watt	**38.1**
y	yocto (prefix)	**2.1**
Y	yotta (prefix)	**2.1**
yd	yard	**3.4**, **3.5**
z	zepto (prefix)	**2.1**
Z	zetta (prefix)	**2.1**
°	degree (of angle)	**8.2**
°	degree (temperature)	Clause **39**
′	minute (of angle)	**8.2**
″	second (of angle)	**8.2**
γ	gamma (microgram)	Clause **15**, Note 1
μ	micro (prefix)	**2.1**
μ	micron (micrometre) (abrogated)	**3.2**
μ	micron (micrometre of mercury) (incorrect)	**33.2**
μg	microgram	**15.2**
μin	micro-inch	**3.6**
μl	microlitre	**5.3**
μm	micrometre	**3.2**
μmHg	micrometre of mercury	**33.2**
μs	microsecond	Clause **10**, Note 1
∟	right angle	**8.1**

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metric ton	—	**15.2**	—
micro (prefix)	µ	**2.1**	Table 1
microgram	µg	**15.2**	*use* Table 16
micro-inch	µin	**3.6**	*use* Table 3
microlitre	µl	**5.3**	*use* Table 8
micrometre	µm	**3.2**	*use* Table 3
micron (length)	—	*see* **3.2**	—
micron (pressure)	µmHg	**33.2**	*use* Table 34
microsecond	µs	Clause **10**, Note 1	—
mil, circular (area)	—	**4.5** and Clause **4**, Note 2	Table 5
mil (angle)	mil	Clause **8**, Note 2	—
mil (length)	mil	**3.6** and Clause **3**, Note 8	Table 2
mil (volume)	—	**5.5**	—
mile	mile	**3.5**	Table 3
mile, international nautical	n mile	**3.3**	Table 3
mile (statute)	mile	**3.5** and Clause **3**, Note 6	Table 3
mile, telegraph nautical	—	**3.6**	—
mile, UK nautical	—	**3.6** and Clause **3**, Note 16	Table 3
mile per gallon (UK)	mile/UKgal	Clause **25**	Table 28
mile per gallon (US)	mile/USgal	*see* Clause **25**	Table 28
mile per hour	mile/h	**11.4**	Table 12
milli (prefix)	m	**2.1**	Table 1
millibar	mbar (mb)	**33.1.2** and footnote	Table 33, Table 34

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
milligal	mGal	**14.2**	Table 14, Note
milligram	mg	**15.2**	*use* Table 16
milligram per square centimetre	mg/cm^2	**17.2**	Table 19, footnote
milligram per square millimetre	mg/mm^2	**17.2**	Table 19, footnote
millilitre	ml	**5.3**	Table 8
millimetre	mm	**3.2**	*use* Table 3
millimetre cubed (modulus of section)	mm^3	**6.2**	*use* Table 6
millimetre of mercury, conventional	mmHg	**33.2**	Table 34
millimetre of water, conventional	mmH_2O	**33.2**	Table 34, footnote
millimetre to the fourth	mm^4	Clause **7**	Table 10
million	—	**2.2**	Table 2
millisecond	ms	Clause **10**, Note 1	—
minim (UK)	UKmin	**5.8**	Table 8, Table 9
minim (US)	—	**5.10**	Table 9
minute (angle)	′	**8.2**	Table 11
minute (time)	min	**10.3**	—
modulus of section	—	Clause **6**	Table 6
mole	mol	**21.1**, **A.4**	—
moment of area, first	—	Clause **6**	Table 6
moment of area, second	—	Clause **7**	Table 10
moment of force	—	Clause **31**	Table 31
moment of inertia	—	Clause **26**	Table 29
moment of inertia, geometrical	—	Clause **7**	Table 10
momentum, angular	—	Clause **28**	—
momentum (linear)	—	Clause **27**	—
month	—	**10.4**	—
nano (prefix)	n	**2.1**	Table 1
nanosecond	ns	Clause **10**, Note 1	—
nautical mile, international	n mile	**3.3**	Table 3
nautical mile, telegraph	—	**3.6**	—
nautical mile, UK	—	**3.6**	Table 3
newton	N	**29.1**	Table 30
newton metre	N·m	**31.1**, **37.1.1**	Table 31
newton per metre	N/m	**32.1**	—
newton per square metre	N/m^2	**33.1.1**	Table 32, Table 33, Table 34
newton per square millimetre	N/mm^2	Clause **34**	Table 32
newton second per square metre	$N{\cdot}s/m^2$	**35.1**	*use* Table 35
number	—	Clause **2**	Table 1, Table 2
ounce (apothecaries' UK)	oz apoth	**15.5**	Table 16
ounce (apothecaries' US)	oz ap	**15.5**	Table 16
ounce (avoirdupois)	oz	**15.5**	Table 16
ounce, fluid (UK)	UKfl oz	**5.8**	Table 8, Table 9
ounce, fluid (US)	USfl oz	**5.10**	Table 8, Table 9
ounce, liquid (US)	liq oz	**5.10**, footnote	—
ounce-force	ozf	**29.3**	Table 30

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
ounce-force inch	ozf·in	**31.3**	Table 31
ounce inch squared	oz·in^2	**26.3**	Table 29
ounce per square foot	oz/ft^2	**17.3**	Table 19
ounce per square yard	oz/yd^2	**17.3**	Table 19
ounce per UK gallon	oz/UKgal	**21.3**	Table 23
ounce per US gallon	oz/USgal	**21.3**	Table 23
ounce troy (UK)	oz tr	**15.5**	Table 16
ounce troy (US)	oz t	**15.5**	Table 16
parsec	pc	**3.3**	—
pascal	Pa	**33.1.1**, Clause **34**	Table 32, Table 33, Table 34
pascal second	Pa·s	**35.1**	Table 35
peck (UK)	—	**5.8**	Table 9
peck (US)	pk	**5.11**	Table 9
perch	—	**3.6** and Clause **3**, Note 15	—
peta (prefix)	P	**2.1**	Table 1
Petrograd standard	—	Clause **5**, Note 4	—
Pferdestärke (metric horsepower, German)	PS	**38.2**, footnote	Table 39
pico (prefix)	p	**2.1**	Table 1
pièze	pz	**33.1.2**	—
pin	—	**5.8**	—
pint (UK)	UKpt	**5.8**	Table 7, Table 9
pint, dry (US)	—	**5.11**	Table 6, Table 9
pint, liquid (US)	liq pt	**5.10**	Table 7, Table 9
plane angle	—	Clause **8**	Table 11
point	—	**3.6** and Clause **3**, Note 9	—
poise	P	**35.2**	—
poiseuille (French)	Pl	**35.1**	—
pole	—	**3.6** and Clause **3**, Note 15	—
pound	lb	**15.4**	Table 15, Table 17
pound foot squared	lb·ft^2	**26.3**	Table 29
pound-force	lbf	**29.3**	Table 30
pound-force foot	lbf·ft	**31.3**	Table 31
pound-force hour per square foot	lbf·h/ft^2	**35.3**	Table 35
pound-force inch	lbf·in	**31.3**	Table 31
pound-force per square foot	lbf/ft^2	**33.1.4**	Table 34
pound-force per square inch (pressure)	lbf/in^2 (p.s.i.)	**33.1.4**	Table 32, Table 33
pound-force per square inch (absolute)	p.s.i.a	**33.4**	—
pound-force per square inch (gauge)	p.s.i.g	**33.4**	—
pound-force per square inch (stress)	lbf/in^2	Clause **34**	Table 32, Table 33
pound-force second per square inch	lbf·s/in^2	**35.3**	—
pound-force second per square foot	lbf·s/ft^2	**35.3**	Table 35
pound inch squared	lb·in^2	**26.3**	Table 29

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
pound per acre	lb/acre	**17.3**	Table 19
pound per cubic foot	lb/ft^3	**20.3**	Table 22
pound per cubic inch	lb/in^3	**20.3**	Table 22
pound per foot	lb/ft	**16.3**	Table 18
pound per foot hour	lb/(ft·h)	**35.3**	Table 35, Note
pound per foot second	lb/(ft·s)	**35.3**	Table 35
pound per (UK) gallon	lb/UKgal	**20.3**	Table 22
pound per (US) gallon	lb/USgal	**20.3**	Table 22
pound per hour	lb/h	**23.3**	Table 25
pound per inch	lb/in	**16.3**	Table 18
pound per mile	lb/mile	**16.3**	Table 18
pound per second	lb/s	**23.3**	Table 25
pound per thousand square feet	lb/1 000 ft^2	**17.3**	Table 19
pound per yard	lb/yd	**16.3**	Table 18
pound troy (US)	—	**15.5**	—
poundal	pdl	**29.3**	Table 30
poundal foot	pdl·ft	**31.3**	Table 31
poundal per square foot	pdl/ft^2	**33.1.4**	Table 32
poundal second per square foot	pdl·s/ft^2	**35.3**	Table 35
power	—	Clause **38**	Table 39
pressure	—	Clause **33**	Table 32, Table 33, Table 34
pressure, absolute	—	**33.4**	—
pressure, gauge	—	**33.4**	—
quadrillion	—	**2.2**	Table 2
quart (UK)	UKqt	**5.8**	Table 9
quart, dry (US)	dry qt	**5.11**	Table 9
quart, liquid (US)	liq qt	**5.10**	Table 9
quarter	qr	**15.5**	—
quintal	q	**15.3**	—
radian	rad	**8.1**	Table 11
radian per minute	rad/min	**12.2**	Table 13
radian per second	rad/s	**12.1**	Table 13
Rankine, degree	°R	**39.4**	Table 40
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Redwood second	—	**36.5**	—
refrigeration, ton of	—	**38.4**	—
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release rate, heat	—	Clause **49**	Table 51
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revolution per minute (angular velocity)	rev/min r/min	**12.2**	Table 13
revolution per minute (rotational frequency)	rev/min r/min	**13.3**	—
revolution per second (angular velocity)	rev/s r/s	**12.2**	Table 13
revolution per second (rotational frequency)	rev/s r/s	**13.2**	—
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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
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rood	—	**4.4** and Clause **4**, Note 1	Table 4
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rotational speed	—	Clause **12**, footnote	—
rotational velocity	—	Clause **12**, footnote	—
Saybolt universal scale	—	**36.5**	—
Scale, International Practical Temperature of 1968	IPTS - 68	**39.6**	—
Scale, International Temperature of 1990	ITS - 90	**39.6**	—
scruple (apothecaries')	—	**15.5**	—
second (angle)	″	**8.2**	Table 11
second (time)	s	**10.1**	—
second, ephemeris	—	**10.2**	—
second, inverse	s^{-1}	**13.1**, **13.2**	—
second moment of area	—	Clause **10**	Table 10
section, modulus of	—	Clause **6**	*use* Table 6
short hundredweight (US)	sh cwt	**15.5**	Table 17
short ton (US)	sh ton	**15.5**	Table 17
slug	—	**15.6** and Clause **15**, Note 5	Table 15
slug hour per foot second squared	$slug{\cdot}h/(ft{\cdot}s^2)$	**35.3**	*use* Table 35
slug per foot second	$slug/(ft{\cdot}s)$	**35.3**	*use* Table 35
solid angle	—	Clause **9**	—
specific energy	—	Clause **40**	Table 41
specific enthalpy	—	**40.1**	Table 41
specific entropy	—	Clause **43**	*see* Table 45
specific gravity	—	Clause **20**, footnote	—
specific heat	—	Clause **42**, footnote	—
specific heat, volume basis	—	Clause **44**, footnote	—
specific heat capacity	—	Clause **42**	Table 45
specific latent heat	—	**40.1**	Table 41
specific surface	—	Clause **18**	Table 20
specific volume	—	Clause **22**	Table 24
speed	—	Clause **11**	Table 12
speed of rotation	—	Clause **12**, footnote	—
speed, rotational	—	Clause **12**, footnote	—
square centimetre	cm^2	**4.2**	*use* Table 4
square centimetre per milligram	cm^2/mg	**18.2**	*use* Table 20
square decimetre	dm^2	**4.2**	*use* Table 4
square foot	ft^2	**4.4**	Table 4
square foot hour degree Fahrenheit per British thermal unit inch	$ft^2{\cdot}h{\cdot}°F/(Btu{\cdot}in)$	—	Table 50
square foot per gallon	ft^2/gal	Clause **19**	Table 21
square foot per ounce	ft^2/oz	**18.3**	Table 20
square foot (thousand) per pound	$1\,000\ ft^2/lb$	**18.3**	Table 20
square inch	in^2	**4.4**	Table 4, Table 5
square kilometre	km^2	**4.2**	*use* Table 4
square metre	m^2	**4.1**	Table 4

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
square metre per gram	m^2/g	**18.2**	*use* Table 20
square metre per kilogram	m^2/kg	**18.1**	Table 20
square metre per litre	m^2/l	Clause **19**	Table 21
square mile	$mile^2$	**4.4**	Table 4
square mile per UK ton	$mile^2/ton$	**18.3**	Table 20
square millimetre	mm^2	**4.2**	Table 5, *use also* Table 4
square millimetre per milligram	mm^2/mg	**18.2**	Table 20, footnote
square yard	yd^2	**4.4**	Table 4
square yard per gallon	yd^2/gal	Clause **19**	Table 21
square yard per ounce	yd^2/oz	**18.3**	Table 20
standard, Petrograd	—	Clause **5**, Note 4	—
standard atmosphere	atm	**33.3**	Table 33
standard gravity	g_n	**14.4**	Table 14
steradian	sr	Clause **9**	—
stère (French)	st	**5.5**	—
sthène (French)	sn	**29.2**	Table 30, Note
stokes	St	**36.2**	*use* Table 36
stone	—	**15.5**	—
stress	—	Clause **34**	Table 32, Table 33, Table 34
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technical atmosphere, absolute (German)	ata	**33.4**	—
technical atmosphere, gauge (German)	atü	**33.4**	—
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temperature difference	—	Clause **39**	—
temperature interval	—	Clause **39**	—
tera (prefix)	T	**2.1**	Table 1
tex	—	**16.2**	—
therm	—	**37.2**	—
therm per UK gallon	therm/UKgal	**41.3**	Table 42
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thermal conductivity	—	Clause **47**	Table 49
thermal diffusivity	—	Clause **50**	*see* Table 36
thermal resistivity	—	Clause **48**	Table 50
thermie	th	**37.2**	Table 38, footnote
thermie per litre	th/litre	**41.2**	Table 42
thermodynamic temperature	—	Clause **39**	—
thou	thou	**3.6** and Clause **3**, Note 7	—
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ton (UK)	ton	**15.5**	Table 17
ton, assay (UK)	—	**15.6** and Clause **15**, Note 3	—
ton, assay (US)	—	**15.6** and Clause **15**, Note 4	—
ton, gross (US)	—	**15.5**	—
ton, long (US)	—	**15.5**	—
ton, metric	—	**15.2**	—

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
ton, short (US)	sh ton	**15.5**	Table 17
ton-force	tonf	**29.3**	Table 30
ton-force (US)	—	**29.3**	*use* Table 30
ton-force foot	tonf·ft	**31.3**	Table 31
ton-force per square foot	tonf/ft^2	**33.1.4**	Table 32
ton-force per square inch	tonf/in^2	**33.1.4**, Clause **34**	Table 32
ton mile	UKton·mile	Clause **25**	—
ton mile per gallon	UKton·mile/UKgal	Clause **25**	—
ton of refrigeration	—	**38.4**	—
ton per cubic yard	UKton/yd^3	**20.3**	Table 22
ton per hour	UKton/h	**23.3**	Table 25
ton per mile	ton/mile	**16.3**	Table 18
ton per square mile	ton/mile^2	**17.3**	Table 19
ton per thousand yards	ton/1 000 yd	**16.3**	Table 18
tonne	t	**15.2**	Table 17
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tropical year	—	**10.4**, footnote	—
troy units	—	**15.5**	—
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velocity, linear	—	Clause **11**	Table 12
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viscosity, dynamic	—	Clause **35**	Table 35
viscosity, kinematic	—	Clause **36**	Table 36
volume	—	Clause **5**	Table 6, Table 7, Table 8
volume, specific	—	Clause **22**	Table 24
volume rate of flow	—	Clause **24**	Table 26
Vollwinkel (German)	—	Clause **8**, Note 3	—
watt	W	**38.1**	Table 39
watt per cubic metre	W/m^3	**49.1**	Table 51
watt per metre degree Celsius	W/(m·°C)	**47.2**	Table 49, footnote
watt per metre kelvin	W/(m·K)	**47.1**	Table 49
watt per square inch	W/in^2	**45.3**	Table 47
watt per square metre	W/m^2	**45.1**	Table 47
watt per square metre degree Celsius	$\text{W/(m}^2\cdot°\text{C)}$	**46.2**	Table 48, footnote
watt per square metre kelvin	$\text{W/(m}^2\cdot\text{K)}$	**46.1**	Table 48
week	—	**10.4**	—

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Term	Symbol or abbreviation	Textual reference and important notes	Table reference
weight	—	Clause **30**	Table 15, Table 16, Table 17, Table 30
work	—	Clause **37**	Table 37, Table 38
yard	yd	**3.4**	Table 3
year	a	**10.4**	—
year, calendar	—	**10.4**, footnote	—
year, light	l.y.	**3.3**	—
year, tropical	—	**10.4**, footnote	—
yocto (prefix)	y	**2.1**	Table 1
yotta (prefix)	Y	**2.1**	Table 1
zepto (prefix)	z	**2.1**	Table 1
zetta (prefix)	Z	**2.1**	Table 1

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