

Conversion factors for units

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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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- Royal Society of Chemistry
- Society of Chemical Industry
- Trading Standards Institute
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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 It supersedes BS 350-1:1974 which is withdrawn.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 BS 350-2 was withdrawn in 1981 since many of the tables included in it had become inconsistent with the International System of Units (SI) and the increasing use of pocket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 PD 6203 was withdrawn in 1998.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
<i>To indicate multiples</i>		
$\times 10^{24}$	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
<i>To indicate submultiples</i>		
$\times 10^{-1}$	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

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:

$$1 \text{ yard} = \mathbf{0.914\ 4\ m}$$

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

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.)

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.

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.

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:

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

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

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

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

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

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

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

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

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

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

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 $\times 10^{-4} \text{ m}^2$)	—
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 $\times 10^6 \text{ m}^2$)	—
		(1 mile^2	= 258.999 ha)	—

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

Refer to
note

$$1 \text{ circular mil} = 7.853\,98 \times 10^{-7} \text{ in}^2 = 5.067\,07 \times 10^{-10} \text{ m}^2$$

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

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 m³), 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 (dm³), the cubic centimetre (cm³), and the cubic millimetre (mm³) are common examples.

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

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

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

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

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 l¹⁾).

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

(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).

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

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

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

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

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.

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 × 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 other²⁾ 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 dm³ (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.

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.

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 (m³).

6.2 They may also be expressed in terms of the cube of any suitable submultiple of the metre; the centimetre cubed (cm³) and millimetre cubed (mm³) are commonly used.

6.3 The imperial units are the foot cubed (ft³) and the inch cubed (in³).

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 (m⁴). Other commonly used units are the centimetre to the fourth (cm⁴) and millimetre to the fourth (mm⁴). The imperial units are the foot to the fourth (ft⁴) and the inch to the fourth (in⁴). See Table 10 for conversion factors for these units.

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.									

Table 7 — Volume and capacity (continued)

Exact values are printed in bold type

	cubic metre	cubic decimetre	litre (1901) ^a	cubic inch	cubic foot	UK pint ^b	UK gallon ^c	US liquid pint	US gallon
	m ³	dm ³ litre ^a l		in ³	ft ³	UKpt	UKgal	US liq pt	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	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 = l ^a									
1 litre (1901) ^a =	1.000 028 × 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 × 10 ⁻⁵	0.016 387 1	0.016 386 6	1	5.787 04 × 10 ⁻⁴	0.028 837 2	3.604 65 × 10 ⁻³	0.034 632 0	4.329 00 × 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 × 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 × 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 × 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 × 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”.									

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 µl (see also 5.2).							
^a For explanation of the litre and the litre (1901) see 5.3 and 5.4.							

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 .				

8 Plane angle

8.1 The coherent SI unit of plane angle is the radian (symbol rad), a coherent derived⁵⁾ 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 ($\perp$)

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

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 ($^\circ$), minute ($'$) and second ($''$) of arc.

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

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

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

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

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.

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

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.

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 =	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) =	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 derived⁶⁾ 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.

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 (μ s) 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).

$$1 \text{ km/h} = 0.277\,778 \text{ m/s}$$

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.

$$1 \text{ kn} = 1\,852 \text{ m/h} = 0.514\,444 \text{ m/s}$$

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

$$1 \text{ UK knot} = 6\,080 \text{ ft/h} = 0.514\,773 \text{ m/s}$$

For interconversion factors for the above units see Table 12.

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

12 Angular velocity⁹⁾ (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.)

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

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,

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

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,

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

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.).

$$\begin{aligned}
 1 \text{ rev/min} &= \frac{1}{60} \text{ rev/s} \\
 &= (\text{in SI terms}) \quad \frac{1}{60 \text{ s}} \quad \text{or} \quad \frac{1}{60} \text{ s}^{-1}
 \end{aligned}$$

13.4 Corresponding angular velocities are obtainable from Table 13,

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

NOTE See also footnote to Clause 12, Angular velocity.

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).

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

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

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

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

$$1 \text{ ft/s}^2 = 0.3048 \text{ m/s}^2$$

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 32.1740 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 = $1 \text{ cm/s}^2 = 10^{-2} \text{ m/s}^2$ 1 mGal = 10^{-5} m/s^2 (see 14.2).			

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:

$$1 \text{ lb} = 0.453\,592\,37 \text{ kg}$$

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)

(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 UK¹⁰) 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)
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(The apothecaries’ ounce¹⁰) 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.

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

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).							