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NIST Special Publication 811

Guide for the Use of the International System of Units

The Modernized Metric System

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The enclosed NIST SP 811, *Guide for the Use of the International System of Units,* has been found to contain several typographical errors, as follows:

Page	Item	Correction
3	Table 2 volt	change "s^{-1}" to "s^{-3}"
6	Table 9 bar	change "10^3 Pa" to "10^5 Pa"
C8	Footnote 21	change "(1,000 028 dm^3)" to "(1.000 028 dm^3)"
C10	teaspoon	delete "$meter^3$ (m^3)"
C17	lb/yd^3	change "$meter^2$" to "$meter^3$" change "(kg/m^2)" to "(kg/m^3)"
C17	ton(short)/yd^3	change "$meter^2$" to "$meter^3$" change "(kg/m^2)" to "(kg/m^3)"
C18	tor	change "tor" to "torr"

Please note these corrections.

A revised SP 811 will be printed in early spring.

Replacements or additional multiple copies can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, stock # 003-003-03113-5, $2.50 ea.

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PREFACE

The National Institute of Standards and Technology (formerly the National Bureau of Standards) has published a number of documents to assist users of the International System of Units, abbreviated SI, (the modernized metric system) and to provide the guidance required by new developments in the technical details of the SI. The most recent document in this series, NBS Letter Circular LC 1120 (1979), was widely distributed to the public and it was incorporated into the manual of instructions for the preparation of technical publications at the National Institute of Standards and Technology (NIST). The present guideline replaces LC 1120 and Exhibit 2-D of Chapter 2 in the *NBS Communications Manual for Scientific, Technical, and Public Information (1980).*

In order to increase the effectiveness of this publication as a practical guide for the use of the SI in the United States, a summary has been included, as Appendix A, to identify the authoritative documentary sources of information on: 1) the International System of Units; 2) the interpretation of the SI for use in the United States; and 3) the official records of actions that link United States customary measurement units to the SI. Appendix B gives recommendations on writing style to be used for the expression of quantities in SI units; Appendix C provides precision factors for converting the numerical values of quantities expressed in units customarily used in the United States to the corresponding numerical values of the same quantities expressed in units of the International System of Units. The final appendix addresses the correct use of the terms "mass" and "weight"; the different meanings of these terms are seldom recognized in everyday communications.

Arthur O. McCoubrey

April 1991

GUIDE FOR THE USE OF THE INTERNATIONAL SYSTEM OF UNITS

Introduction

The International System of Units (SI)[1] is frequently called the metric system in informal discussions that involve measurements; however, a number of substantially different metric systems have evolved through the years and it is more appropriate to refer to the SI as the *modernized metric system*. This guide for the use of the International System of Units has been prepared by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce; the purpose of the guide is to help members of the staff to use the SI for the communication of the results of their work to others.

The General Conference on Weights and Measures (CGPM), a formal diplomatic organization established by the Treaty of the Meter in 1875,[2] is responsible for the maintenance of the International System of Units in harmony with advances in science and technology. The United States, as one of the original seventeen signatory nations, participates in the CGPM and the work of its committees. The National Institute of Standards and Technology provides official United States representation in the various bodies established by the Treaty.

Section 5164 (Metric Usage) of Public Law 100-418 (Omnibus Trade and Competitiveness Act of 1988) amends the Metric Conversion Act of 1975 and declares that it is the policy of the United States:

> "to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce;" and
>
> "to require that each Federal agency, by a date certain and to the extent economically feasible by the end of the fiscal year 1992, use the metric system of measurement in its procurements, grants, and other business-related activities, except to the extent that such use is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms, ..."

In accordance with these legislative Acts and, as required by related provisions of the Code of Federal Regulations,[3] the National Institute of Standards and Technology (NIST) shall use the International System of Units (abbreviation: SI), that is, the modern metric system of measurement units, in all publications. When the field of application or the special needs of users of NIST publications require the use of non-SI units, the values of quantities will be first stated in SI units and the corresponding values expressed in non-SI units will follow in parentheses. Exceptions to this policy require the approval of the Director.

Authoritative Sources of Information

Documents that define the International System of Units and explain the System for use in the United States are described in Appendix A. Additional information is available from the Fundamental Constants Data Center, Building 221, Room B160, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, telephone: (301) 975-4220. Information regarding Federal Government use of the International System of Units is available from the Metric Program Office, U.S. Department of Commerce, Washington, DC 20230, telephone: (202) 377-0944.

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[1] The International System of Units (SI) was defined and given official status in 1960 by the 11th General Conference on Weights and Measures. A complete description of the SI is given in NIST Special Publication 330 [2]. Summary tables of SI units are reproduced in this document.

[2] The various organs of the Treaty of the Meter that established the CGPM are described in NIST Special Publication 330.

[3] The voluntary aspect of conversion to the use of SI was removed for agencies of the Federal Government as set forth in the Federal Register, Vol. 56, No. 23, page 160, January 2, 1991.

The International System of Units

The International System of Units (SI) is constructed using seven base units for independent quantities, and two supplementary units for plane angle and solid angle; these units are given in Table 1. Units for all other quantities are derived from these nine units. Nineteen SI derived units with special names are listed in Table 2. These units are derived from the base and supplementary units in a coherent manner; that is, they are expressed as products or quotients of the nine base and supplementary units without numerical factors. All other SI derived units, including those in Tables 3 and 4, are derived in a coherent manner from the base units, the supplementary units, and the SI derived units with special names. Prefixes, given in Table 5, are used to form multiples and submultiples of the SI units. In the case of mass, the prefixes are to be applied to the gram instead of the SI base unit, the kilogram.

The SI units together with the SI prefixes provide a logical and interconnected framework for measurements in science, industry, and commerce. NIST requires the use of SI for communications of NIST program results and it strongly encourages the use of SI units throughout the United States.

Table 1. SI Base and suplementary units

	Quantity	Unit Name	Unit Symbol
	length	meter	m
	mass	kilogram	kg
SI base units	time	second	s
	electric current	ampere	A
	thermodynamic temperature	kelvin	K
	amount of substance	mole	mol
	luminous intensity	candela	cd
SI supplementary units	plane angle	radian	rad
	solid angle	steradian	sr

Table 2. SI derived units with special names

Quantity	SI Unit			
	Name	Symbol	Expression in terms of other units	Expression in terms of SI base units
frequency	hertz	Hz		s^{-1}
force	newton	N		$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
quantity of electricity, electric charge	coulomb	C	$A \cdot s$	$s \cdot A$
electric potential, potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-1} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius	°C		K
luminous flux	lumen	lm		$cd \cdot sr$
illuminance	lux	lx	lm/m^2	$m^{-2} \cdot cd \cdot sr$
activity (of a radionuclide)	becquerel	Bq		s^{-1}
absorbed dose, specific energy imparted, kerma, absorbed dose index	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent, dose equivalent index	sievert	Sv	J/kg	$m^2 \cdot s^{-2}$

Table 3. Some SI derived units expressed in terms of base units

Quantity	SI Unit	Unit Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
density, mass density	kilogram per cubic meter	kg/m^3
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
concentration (of amount of substance)	mole per cubic meter	mol/m^3
specific volume	cubic meter per kilogram	m^3/kg
luminance	candela per square meter	cd/m^2

Table 4. Some SI derived units expressed by means of special names

Quantity	SI Unit Name	Symbol	Expression in terms of SI base units
dynamic viscosity	pascal second	$Pa \cdot s$	$m^{-1} \cdot kg \cdot s^{-1}$
moment of force	newton meter	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
surface tension	newton per meter	N/m	$kg \cdot s^{-2}$
power density, heat flux density, irradiance	watt per square meter	W/m^2	$kg \cdot s^{-3}$
heat capacity, entropy	joule per kelvin	J/K	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin	$J/(kg \cdot K)$	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific energy	joule per kilogram	J/kg	$m^2 \cdot s^{-2}$
thermal conductivity	watt per meter kelvin	$W/(m \cdot K)$	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
energy density	joule per cubic meter	J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
electric field strength	volt per meter	V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric charge density	coulomb per cubic meter	C/m^3	$m^{-3} \cdot s \cdot A$
electric flux density	coulomb per square meter	C/m^2	$m^{-2} \cdot s \cdot A$
permittivity	farad per meter	F/m	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
permeability	henry per meter	H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
molar energy	joule per mole	J/mol	$m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1}$
molar entropy, molar heat capacity	joule per mole kelvin	$J/(mol \cdot K)$	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
exposure (x and γ rays)	coulomb per kilogram	C/kg	$kg^{-1} \cdot s \cdot A$
absorbed dose rate	gray per second	Gy/s	$m^2 \cdot s^{-3}$

Table 5. SI Prefixes

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

Note: Prefixes and prefix symbols for numbers greater than 10^{18} and for numbers less than 10^{-18} have been proposed by the CIPM and submitted for adoption by the 19th CGPM in October 1991.

Non-SI Units That Are Used With SI

Certain units that are not part of the International System are essential and used so widely that they are recognized for use with the International System. These units are listed in Table 6. Occasionally, it is necessary to use additional units of this kind; for example, circumstances may require that intervals of time be expressed in weeks, months or years. In such cases, if a standardized symbol for the unit is not available, the name of the unit should usually be written out in full.

It is also necessary to recognize, outside the International System, the units given in Table 7. These units are used in specialized fields; their values in SI units must be obtained from experiment and, therefore, they are not known exactly.

In some cases, particularly in basic science, quantities are expressed in terms of fundamental constants of nature or *natural units*. Such units are not SI units; however, the use of these units with SI is acceptable when it is necessary for the most effective communication of information. In all such cases, the author should clearly identify the specific natural units that are used; broad terms, such as *atomic units*, should be avoided. Typical examples of quantities used as natural units are given in Table 8.

Table 6. Units in use with the International System

Name	Symbol	Value in SI units
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s
degree	°	1 ° = (π/180)rad
minute	′	1 ′ = (1/60)° = (π/10 800) rad
second	″	1 ″ = (1/60)′ = (π/648 000) rad
liter[a]	L	1 L = 1 dm^3 = 10^{-3} m^3
metric ton	t	1 t = 10^3 kg

[a] Both L and l are internationally accepted symbols for liter. Because "l" can easily be confused with the numeral "1", the symbol "L" is recommended for United States use. The script letter "*l*" is not approved as a symbol for liter.

Table 7. Units used with the International System whose values in SI units are obtained experimentally

Name	Symbol	Definition
electronvolt	eV	*(a)*
unified atomic mass unit	u	*(b)*

[a] The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 volt in vacuum; 1 eV = $1.602\,18 \times 10^{-19}$ J approximately.
[b] The unified atomic mass unit is equal to (1/12) of the mass of an atom of the nuclide ^{12}C; 1 u = $1.660\,54 \times 10^{-27}$ kg approximately.

Table 8. Examples of quantities sometimes used as natural units

Unit	Symbol
elementary charge	e
electron mass	m_e
proton mass	m_p
Bohr radius	a_0
electron radius	r_e
Compton wavelength of electron	λ_c
Bohr magneton	μ_B
nuclear magneton	μ_N
speed of light in vacuum	c
Planck constant	h

The units listed in Table 9 are used in limited fields; they have been recognized by the International Committee for Weights and Measures (CIPM)[4] for temporary use in those fields. These units should not be introduced where they are not used at present and, in general, the continuing use of these units is discouraged.

Logarithmic measures such as pH, dB (decibel), and Np (neper) are acceptable for use with the SI.[5]

When it is necessary to use additional units with the International System, authors are encouraged to consult the American National Standard: Metric Practice [7]. The publications on measurement units of the International Organization for Standardization [5] and the corresponding publications of the International Electrotechnical Commission [6] also provide authoritative information.

Table 9. Units in use temporarily with the International System

Name	Symbol	Value in SI unit
nautical mile		1 nautical mile = 1 852 m
knot		1 nautical mile per hour = (1852/3600) m/s
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
are	a	1 a = 1 dam^2 = 10^2 m^2
hectare	ha	1 ha = 1 hm^2 = 10^4 m^2
barn	b	1 b = 100 fm^2 = 10^{-28} m^2
bar	bar	1 bar = 0.1 MPa = 100 kPa = 1000 hPa = 10^5 Pa
gal	Gal	1 Gal = 1 cm/s^2 = 10^{-2} m/s^2
curie	Ci	1 Ci = 3.7×10^{10} Bq
roentgen	R	1 R = 2.58×10^{-4} C/kg
rad	rad	1 rad = 1 cGy = 10^{-2} Gy
rem	rem	1 rem = 1 cSv = 10^{-2} Sv

Special Names for SI Units

Special names for compound units, such as "coulomb" for "ampere second" and "pascal" for "newton per square meter", exist for convenience; either the special name or the compound form is correct (see Table 2). For example, because of the descriptive value implicit in the compound phrase, communication is sometimes facilitated if the author expresses magnetic flux in the compound unit, volt seconds, instead of using the special name, webers.

Other Considerations

The kelvin, K, is the SI base unit of temperature; this unit is properly used for expressing both thermodynamic temperature and temperature intervals. However, wide use is also made of the degree Celsius (symbol °C) for expressing temperature and temperature intervals on the Celsius scale.

Celsius temperature, t, is related to thermodynamic temperature, T, by the equation:

$$t = T - T_0$$

where T_0 = 273.15 K by definition.

The temperature interval, one degree Celsius, equals one kelvin, exactly.

The term weight is ambiguous; it is sometimes used to mean mass and other times it is used to mean *force*. In this connection, NIST supports the recommendation of the American National Standard for Metric Practice, ANSI/IEEE Std 268 (1982) [7]; specifically, authors of technical publications should avoid using the term weight except under circumstances in which its meaning is completely clear. See Appendix D for further discussion of this matter.

It is also recommended that the terms, *relative atomic mass*, and *relative molecular mass*, be used in accordance with standardized international practice.[6]

[4] The International Committee for Weights and Measures (CIPM) is an organization of the General Conference on Weights and Measures (CGPM); it guides the technical work of the diplomatic Treaty of the Meter.

[5] For additional information see *Annex C* (pH) of ISO 31/8-1980 [5] and *Special Remarks* (decibel and neper) following the introductions to ISO 31/2 or ISO 31/7 [5].

[6] ISO 31-8 (1980) "Quantities and Units of Physical Chemistry and Molecular Physics," items 8-1.1 and 8-1.2 [5].

Use of Symbols in Expressions and Text

Words and symbols should not be mixed when mathematical operations are involved. All of the forms "joules per mole," "J/mol," or "$J \cdot mol^{-1}$" are considered good usage, but the forms "joules/mole" and "$\text{joules} \cdot \text{mole}^{-1}$" are not. See Appendix B for additional rules.

Essential Data

Essential data express or interpret quantitative results being reported. All such data shall be expressed in SI units. In those cases where:

- the sole use of SI units would compromise good communications; or
- units other than SI have been specified as a contractual requirement;

quantities shall be expressed in SI units followed, in parentheses, by the same quantities expressed in non-SI units.

Exceptions may sometimes be necessary for commercial devices, technical standards, or quantities having special legal significance; examples include commercial weights and measures devices and the related laws and regulations. However, even in such cases, quantities expressed in SI units shall be used when possible with the equivalent expression of the same quantities in customary units following in parentheses.

Descriptive Information

Descriptive information characterizes arrangements, environments, generalized dimensions of objects, apparatus or materials, and non-quantitative attributes that do not enter directly into calculations or results. When necessary for effective communication, such information may be expressed using customary terms that are widely used and recognized. Examples include, common drill sizes and traditional tools used in the United States, U.S. standard fastener sizes, commercial pipe sizes, United States sports facilities, and other common terms used in the trades, the professions, the market place and various social activities.

APPENDIX A

SOURCE DOCUMENTS FOR TECHNICAL INFORMATION

1. The defining document [1] for the International System of Units (SI) is published by the International Bureau of Weights and Measures (BIPM)[7] in French and English. This document is revised from time to time in accordance with formal diplomatic decisions of the General Conference on Weights and Measures.

2. A United States interpretation of the English version of the defining document is prepared by the National Institute of Standards and Technology as NIST Special Publication 330 [2]. The document contains the same technical information as the BIPM document cited in 1 above; however, editorial differences have been incorporated as follows:

   - the spelling of English language words is, in accordance with the United States Government Printing Office Style Manual [3], based on Webster's Third New International Dictionary rather than the Oxford Dictionary used in many English speaking countries. The spelling reflects practice in the United States and the recommendation of the American National Standard on Metric Practice (see below);

   - editorial notes regarding the use of SI units in the United States are added.

   The resulting document, *NIST SP 330*, is the authoritative source document that interprets the International System of Units for use in the United States and for the purposes of these guidelines.

3. *ISO 1000-1981* is an international consensus standard [4] published by the International Organization for Standardization (ISO) to promote international uniformity in the technical interpretation of the actions of the CGPM as they are published by BIPM in reference [1].

4. *ISO 31/0-1981* through *ISO 31/13-1981* constitute a series of international consensus standards [5] published by ISO to promote international uniformity in the practical use of SI measurement units in various fields of science and technology and to standardize practical units to be used with SI. These standards are compatible with reference [1] published by BIPM. They are recommended when specific guidance is not available from United States national standards or this *Guide*.

5. *IEC Publication 27* of the International Electrotechnical Commission (IEC) is a series of international consensus standards [6] that promote international uniformity in the practical use of SI measurement units in electrical technology and that standardize practical electrical units for use with the SI. These IEC standards are also compatible with the BIPM document [1], and they are coordinated with the ISO standards cited in [5]. The IEC standards are recommended in connection with electrical technology when specific guidance is not available from United States national standards or this *Guide*. The IEC standards should be regarded as more authoritative than the corresponding ISO standards only in connection with electrical technology.

6. *ANSI/IEEE Std 268-1982* is an American National Standard for Metric Practice [7]; it is based on the International System of Units as interpreted for use in the United States [2]. It has been approved by a consensus of providers and consumers that includes interests in industrial organizations, government agencies, and scientific associations. This standard was developed by the Institute of Electrical and Electronics Engineers (IEEE), and approved as an American National Standard by the American National

[7] The International Bureau of Weights and Measures (BIPM) is an international organization created by the diplomatic Treaty of the Meter; it is located in Sèvres, a suburb of Paris, France, and functions under the direction of the International Committee of Weights and Measures (CIPM). The International Bureau of Weights and Measures is responsible for technical activities that are necessary for the international compatibility of physical measurements based on the SI.

Standards Institute (ANSI).[8] *ANSI/IEEE Std 268-1982* has been adopted for use by the United States Department of Defense (DoD) and it is recommended as a comprehensive source of authoritative information for the practical use of SI measurement units in the United States.

7. Important details concerning United States customary units of measurement and the interpretation of the International System of Units for the United States is published from time to time in the Federal Register; these notices have status as official United States Government policy.

   A Federal Register Notice of July 1, 1959 [8], states the values of conversion factors to be used in technical and scientific fields to obtain the values of the United States yard and pound from the SI meter and the SI kilogram. These conversion factors were adopted on the basis of an agreement of English-speaking countries to reconcile small differences in the values of the inch-pound units as they were used in different parts of the world. This action did not affect the value of the yard or foot used for geodetic surveys in the United States; thus, at that time, it became necessary, to recognize, on a temporary basis, a small difference between United States customary units of length for "international measure" and "survey measure." A Federal Register Notice of July 19, 1988 [9] announced a tentative decision not to adopt the international foot of 0.3048 meters for surveying and mapping activities in the United States. A final decision to continue the use of the survey foot indefinitely is pending the completion of an analysis of public comments on the tentative decision; this decision will also be announced in the Federal Register.

   Even if a final decision affirms the continued use of the survey foot in surveying and mapping services of the United States, it is significant to note that the Office of Charting and Geodetic Services of the National Ocean Service in the National Oceanic and Atmospheric Administration uses the meter exclusively for the North American Datum [10]. The North American Datum of 1983, the most recent definition and adjustment of this information, was announced in a Federal Register Notice of June 14, 1989 [11].

   The definitions of the international foot and yard and the corresponding survey units are also addressed in a Federal Register Notice published on February 3, 1975 [12].

   A Federal Register Notice of July 27, 1968 [13], provides a list of the common customary measurement units used in commerce throughout the United States, together with the conversion factors that link them with the meter and the kilogram.

   A recent Federal Register Notice concerning the International System of Units [14] is a restatement of the interpretation of the SI for use in the United States, and it brings up to date the corresponding information published in earlier notices. The most recent Federal Register Notice [15] provides policy direction to assist Federal agencies in their transition to the use of the metric system of measurement.

[8] The American National Standards Institute, Inc. (11 West 42nd Stree, New York, NY 10036) is a private sector organization that serves as a standards coordinating body, accredits standards developers that follow procedures sanctioned by ANSI, designates as American National Standards those standards submitted for and receiving approval, serves as the United States Member Body of the International Organization for Standardization (ISO) and functions as the administrator of the United States National Committee for the International Electrotechnical Commission (IEC).

APPENDIX B

STYLE GUIDE

1. CAPITALS

Units: When written in full, the names of all units start with a lowercase letter, except at the beginning of a sentence or in capitalized material such as a title. Note that in degree Celsius the unit "degree" is lowercase but the modifier "Celsius" is capitalized. The "degree centigrade" is obsolete.

Symbols: Unit symbols are written with lowercase letters except that (a) the first letter is uppercase when the name of the unit is derived from the name of a person and (b) the recommended symbol for liter is capital L. However, it is noted that both l and L are recognized symbols for the liter; see Table 6.

Prefixes: The symbols for numerical prefixes for zetta (Z), yotta (Y), exa (E), peta (P), tera (T), giga (G), and mega (M) are written with uppercase letters; all the other prefix symbols are written with lowercase letters. When written out in full, lower case letters are used for the names of all prefixes except where the entire unit name is written in uppercase letters or at the beginning of a sentence. When the unit is written in full, write the prefix in full: megahertz; neither Mhertz, nor megaHz.

2. PLURALS

a. When written in full, the names of units are made plural when required by the rules of English grammar. Fractions, both common and decimal, are always singular. Examples: 10 kelvins; 0.3 meter. The names of the units, lux, hertz and siemens are the same in the singular and plural forms.

b. Symbols for units are the same in singular and plural ("s" is never added to indicate a plural).

3. PERIODS

A period is NOT used after a symbol, except to mark the end of a sentence.

4. DECIMAL MARKER

The dot (point) is used as the decimal marker and is it placed on the line. In numbers less than one, a zero must be written to the left of (preceding) the decimal point.

5. GROUPING OF DIGITS

a. Digits may be separated into groups of three, counting, to the left, from the decimal marker. A space rather than a comma shall be used as a separator because many countries use a comma as the decimal marker.

b. In numbers of four digits, the separation by a space is not recommended unless four-digit numbers are grouped in a column with numbers of five digits or more: 3456, not 3 456.

6. SPACING

a. When joining a prefix and an SI unit or symbol, do not leave a space between the prefix and the unit or symbol: megahertz, not mega hertz; MHz, not M Hz.

b. When a symbol follows a number to which it refers, a space must be left between the number and the symbol. An exception is made only in the case of degree, minute, and second when the symbols for these units are used to express plane angles.[9] Examples: 150 m, not 150m; 45° (of angle), not 45 ° (of angle); 72 °C, not 72°C. Note: the symbol °C is never written with a space between the two characters.

7. COMPOUND UNITS

In the symbol for a compound unit that is formed by the multiplication of two or more units, a centered dot or a space is used. For example, N · m or N m.

When spelling out the name of a compound unit, a space is recommended (or a hyphen is permissible) but never a centered dot. For example, newton meter or newton-meter, not newton · meter.

8. TABLES AND GRAPHS

In tables, SI and customary units may be shown in parallel columns. If coordinate markings in non-SI units are included in graphs, they shall be given a secondary status. For example, non-SI ordinate marks may be placed along the right side of the graph and non-SI abscissa marks may be placed across the top. Alternately, lighter weight marks and smaller associated text may be used to indicate values in non-SI units.

[9] This rule is consistent with the CIPM publication on SI units [1], ISO 31-0, ISO 31-1, and ISO 31-4 [5]; it is also consistent with the American National Standard Metric Practice. However, one widely used industry standard, and possibly others, depart from this rule by leaving no space between the numerical value and the symbol, °C.

APPENDIX C

CONVERSION FACTORS[10]

C.1 General:

C.1.1 The following tables are an expansion of those in Reference [16]. They provide equivalent values in the International System of Units for miscellaneous units of measure. The numerical values are multiplying factors for converting values expressed in miscellaneous units to corresponding values expressed in SI units.

C.1.2 The SI values are expressed in terms of the base, supplementary, and derived units of SI to provide a coherent presentation of the conversion factors and to facilitate computations. If desired, the user can avoid the powers of 10 in the factors by selecting appropriate SI prefixes (see Table 5) and shifting the decimal marker if necessary. For example, the factor for converting from the British thermal unit (I.T.) to the kilojoule is 1.055 056.

C.1.3 A few conversion factors to non-SI units are included for convenience, for example, mile per hour to kilometer per hour.

C.2 Notation

C.2.1 Conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number equal to or greater than one and less than ten with six or less decimal places. This number is followed by the letter E (for exponent), plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

$$3.523\,907 \text{ E}-02 \text{ is } 3.523\,907 \times 10^{-2}$$

or

$$0.035\,239\,07$$

Similarly:

$$3.386\,389 \text{ E}+03 \text{ is } 3.386\,389 \times 10^{3}$$

or

$$3\,386.389$$

C.2.2 An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. All other conversion factors have been rounded to the figures given in accordance with accepted practice.[11] Where less than six decimal places are shown, more precision is not warranted.

C.2.3 Further example of use of tables:

To convert from:	to:	Multiply by:
pound-force per square foot	Pa	4.788 026 E+01
inch	m	2.540 000*E−02

means $1 \text{ lbf/ft}^2 = 47.880\,26 \text{ Pa}$
$1 \text{ inch} = 0.0254 \text{ m}$ (exactly)

[10] Reprinted from IEEE Std 268-1982, *IEEE Standard Metric Practice*, ©1982 by the Institute of Electrical and Electronics Engineers, Inc. with permission of the IEEE.

[11] See section 4.4, IEEE Std 268-1982 [7], p. 19.

C.3 Organization:

C.3.1 The conversion factors are listed in two ways – alphabetically and classified by physical quantity. Both lists contain those units which have specific names and compound units derived from these specific units. The classified list contains the more frequently used units for each physical quantity.

C.3.2 The conversion factors for other compound units can easily be generated from numbers given in the alphabetical list by the substitution of converted units, as follows:

EXAMPLE: To find the conversion factor of lb · ft/s to kg · m/s:

first convert 1 lb to 0.453 592 4 kg

and 1 ft to 0.3048 m ;

then substitute: (0.453 592 4 kg) · (0.3048 m)/s = 0.138 255 kg · m/s ;

thus the factor is 1.382 55 E – 01

EXAMPLE: To find the conversion factor of oz · in^2 to kg · m^2:

first convert 1 oz to 0.028 349 52 kg

and 1 in^2 to 0.000 645 16 m^2 ;

then substitute: (0.028 349 52 kg) · (0.000 645 16 m^2) = 0.000 018 289 98 kg · m^2 ;

thus the factor is 1.828 998 E – 05.

In the tables that follow, the non-SI quantities in the left-hand columns are written as they are often used customarily; the rules recommended in this *Guide* are not necessarily observed. Many of the non-SI quantities listed are obsolete and some are not consistent with good technical practice. The equivalent SI quantities in the center columns are, however, written in accordance with the rules recommended in this *Guide*.

Alphabetical List of Units

(Symbols of SI units given in parentheses)

Factors with an asterisk (*) are exact

To convert from	to	Multiply by
abampere	ampere (A)	1.000 000*E+01
abcoulomb	coulomb (C)	1.000 000*E+01
abfarad	farad (F)	1.000 000*E+09
abhenry	henry (H)	1.000 000*E−09
abmho	siemens (S)	1.000 000*E+09
abohm	ohm (Ω)	1.000 000*E−09
abvolt	volt (V)	1.000 000*E−08
acre foot[14]	meter^3 (m^3)	1.233 5 E+03
acre[14]	meter^2 (m^2)	4.046 873 E+03
ampere hour	coulomb (C)	3.600 000*E+03
ångström	meter (m)	1.000 000*E−10
are	meter^2 (m^2)	1.000 000*E+02
astronomical unit	meter (m)	1.495 979 E+11
atmosphere (standard)	pascal (Pa)	1.013 250*E+05
atmosphere (technical = 1 kgf/cm^2)	pascal (Pa)	9.806 650*E+04

[14] The U.S. Metric Law of 1866 gave the relationship, 1 meter equals 39.37 inches. Since 1893 the U.S. yard has been derived from the meter. In 1959 a refinement was made in the definition of the yard to bring the U.S. yard and the yard used in other countries into agreement. The U.S. yard was changed from 3600/3937 m to 0.9144 m exactly. The new length is shorter by exactly two parts in a million.

At the same time it was decided that any data in feet derived from and published as a result of geodetic surveys within the United States would remain with the old standard (1 ft = 1200/3937 m) until further decision. This foot is named the U.S. survey foot and the following relationships:

1 rod (pole or perch) = 16 1/2 feet
1 chain = 66 feet
1 mile (U.S. statute) = 5280 feet

To convert from	to	Multiply by
bar	pascal (Pa)	1.000 000*E+05
barn	meter^2 (m^2)	1.000 000*E−28
barrel (for petroleum, 42 gal)	meter^3 (m^3)	1.589 873 E−01
board foot	meter^3 (m^3)	2.359 737 E−03
British thermal unit (International Table)[15]	joule (J)	1.055 056 E+03
Britsh thermal unit (mean)	joule (J)	1.055 87 E+03
Britsh thermal unit (thermochemical)	joule (J)	1.054 350 E+03
Britsh thermal unit (39 °F)	joule (J)	1.059 67 E+03
Britsh thermal unit (59 °F)	joule (J)	1.054 80 E+03
Britsh thermal unit (60 °F)	joule (J)	1.054 68 E+03
Btu (International Table) · ft/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.730 735 E+00
Btu (thermochemical) · ft/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.729 577 E+00
Btu (International Table) · in/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.442 279 E−01
Btu (thermochemical) · in/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.441 314 E−01
Btu (International Table) · in/(s · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	5.192 204 E+02
Btu (thermochemical) · in/(s · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	5.188 732 E+02
Btu (International Table)/h	watt (W)	2.930 711 E−01
Btu (International Table)/s	watt (W)	1.055 056 E+03
Btu (thermochemical)/h	watt (W)	2.928 751 E−01
Btu (thermochemical)/min	watt (W)	1.757 250 E+01
Btu (thermochemical)/s	watt (W)	1.054 350 E+03
Btu (International Table)/ft^2	joule per meter^2 (J/m^2)	1.135 653 E+04
Btu (thermochemical)/ft^2	joule per meter^2 (J/m^2)	1.134 893 E+04
Btu (International Table)/(ft^2 · h)	watt per meter^2 (W/m^2)	3.154 591 E+00
Btu (International Table)/(ft^2 · s)	watt per meter^2 (W/m^2)	1.135 653 E+04
Btu (thermochemical)/(ft^2 · h)	watt per meter^2 (W/m^2)	3.152 481 E+00
Btu (thermochemical)/(ft^2 · min)	watt per meter^2 (W/m^2)	1.891 489 E+02
Btu (thermochemical)/(ft^2 · s)	watt per meter^2 (W/m^2)	1.134 893 E+04
Btu (thermochemical)/(in^2 · s)	watt per meter^2 (W/m^2)	1.634 246 E+06
Btu (International Table)/(h · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	5.678 263 E+00
Btu (thermochemical)/(h · ft^2 · °F)	watt per meter^2 kelvin [W/m^2 · K)]	5.674 466 E+00
Btu (International Table)/(s · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	2.044 175 E+04
Btu (thermochemical)/(s · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	2.042 808 E+04
Btu (International Table)/lb	joule per kilogram (J/kg)	2.326 000*E+03
Btu (thermochemical)/lb	joule per kilogram (J/kg)	2.324 444 E+03
Btu (International Table)/(lb · °F) (specific heat capacity)	joule per kilogram kelvin (J/(kg · K)]	4.186 800*E+03
Btu (thermochemical)/(lb · °F) (specific heat capacity)	joule per kilogram kelvin [J/(kg · K)]	4.184 000*E+03
Btu (International Table)/ft^3	joule per meter^3 (J/m^3)	3.725 895 E+04
Btu (thermochemical)/ft^3	joule per meter^3 (J/m^3)	3.723 402 E+04

[15] The Fifth International Conference on the Properties of Steam (London, July 1956) defined the calorie (International Table) as 4.1868 J. Therefore the exact conversion for the Btu (International Table) is 1.055 055 852 62 kJ.

To convert from	to	Multiply by
bushel	meter^3 (m^3)	3.523 907 E−02
calorie (International Table)	joule (J)	4.186 800*E+00
calorie (mean)	joule (J)	4.190 02 E+00
calorie (thermochemical)	joule (J)	4.184 000*E+00
calorie (15 °C)	joule (J)	4.185 80 E+00
calorie (20 °C)	joule (J)	4.181 90 E+00
calorie (kilogram, International Table)	joule (J)	4.186 800*E+03
calorie (kilogram, mean)	joule (J)	4.190 02 E+03
calorie (kilogram, thermochemical)	joule (J)	4.184 000*E+03
cal (thermochemical)/cm^2	joule per meter^2 (J/m^2)	4.184 000*E+04
cal (International Table)/g	joule per kilogram (J/kg)	4.186 800*E+03
cal (thermochemical)/g	joule per kilogram (J/kg)	4.184 000*E+03
cal (International Table)/(g · °C)	joule per kilogram kelvin [J/(kg · K)]	4.186 800*E+03
cal (thermochemical)/(g · °C)	joule per kilogram kelvin [J/(kg · K)]	4.184 000*E+03
cal (thermochemical)/min	watt (W)	6.973 333 E−02
cal (thermochemical)/s	watt (W)	4.184 000*E+00
cal (thermochemical)/(cm^2 · min)	watt per meter^2 (W/m^2)	6.973 333 E−02
cal (thermochemical)/(cm^2 · s)	watt per meter^2 (W/m^2)	4.184 000 E+04
cal (thermochemical)/(cm · s · °C)	watt per meter kelvin [W/(m · K)]	4.184 000 E+02
cd/in^2	candela per meter^2 (cd/m^2)	1.550 003 E+03
carat (metric)	kilogram (kg)	2.000 000*E−04
centimeter of mercury (0 °C)	pascal (Pa)	1.333 22 E+03
centimeter of water (4 °C)	pascal (Pa)	9.806 38 E+01
centipoise	pascal second (Pa . s)	1.000 000*E−03
centistokes	meter^2 per second (m^2/s)	1.000 000*E−06
chain[14]	meter^2 (m^2)	5.067 075 E+01
circular mil	meter^2 (m^2)	5.067 075 E−10
clo	kelvin meter^2 per watt ($K \cdot m^2/W$)	2.003 712 E−01
cup	milliliter (mL)	2.366 E+02
curie	becquerel (Bq)	3.700 000*E+10
darcy[16]	meter^2 (m^2)	9.869 233 E−13
day	second (s)	8.640 000*E+04
day (sidereal)	second (s)	8.616 409 E+04
degree (angle)	radian (rad)	1.745 329 E−02
degree Celsius	kelvin (K)	$T_K = t_{°C} + 273.15$
degree centigrade	[see note below]	
degree Fahrenheit	degree Celsius (°C)	$t_{°C} = (t_{°F} - 32)/1.8$
degree Fahrenheit	kelvin (K)	$T_K = (t_{°F} + 459.67)/1.8$
degree Rankine	kelvin (K)	$T_K = T_{°R}/1.8$
°F · h · ft^2/Btu (International Table)	kelvin meter^2 per watt ($K \cdot m^2/W$)	1.761 102 E−01
°F · h · ft^2/Btu (thermochemical)	kelvin meter^2 per watt ($K \cdot m^2/W$)	1.762 280 E−01
°F · h · ft^2/[Btu (International Table) · in] (thermal resistivity)	kelvin meter^2 per watt ($K \cdot m^2/W$)	6.933 472 E+00
°F · h · ft^2/[Btu (thermochemical) · in] (thermal resistivity)	kelvin meter^2 per watt ($K \cdot m^2/W$)	6.938 112 E+00

[16] The darcy is a unit for measuring permeability of porous solids.

Note: The centigrade temperature scale is obsolete. The unit, degree centigrade, is only approximately equal to the degree Celsius.

To convert from	to	Multiply by
denier	kilogram per meter (kg/m)	1.111 111 E−07
dyne	newton (N)	1.000 000*E−05
dyne · cm	newton meter (N · m)	1.000 000*E−07
$dyne/cm^2$	pascal (Pa)	1.000 000*E−01
electronvolt	joule (J)	1.602 19 E−19
EMU of capacitance	farad (F)	1.000 000*E+09
EMU of current	ampere (A)	1.000 000*E+01
EMU of electric potential	volt (V)	1.000 000*E−08
EMU of inductance	henry (H)	1.000 000*E−09
EMU of resistance	ohm (Ω)	1.000 000*E−09
ESU of capacitance	farad (F)	1.112 650 E−12
ESU of current	ampere (A)	3.335 641 E−10
ESU of electric potential	volt (V)	2.997 925 E+02
ESU of inductance	henry (H)	8.987 552 E+11
ESU of resistance	ohm (Ω)	8.987 552 E+11
erg	joule (J)	1.000 000*E−07
$erg/cm^2 \cdot s$	watt per $meter^2$ (W/m^2)	1.000 000*E−03
erg/s	watt (W)	1.000 000*E−07
faraday (based on carbon-12)	coulomb (C)	9.648 70 E+04
faraday (chemical)	coulomb (C)	9.649 57 E+04
faraday (physical)	coulomb (C)	9.652 19 E+04
fathom[14]	meter (m)	1.828 8 E+00
fermi (femtometer)	meter (m)	1.000 000*E−15
fluid ounce (US)	$meter^3$ (m^3)	2.957 353 E−05
foot	meter (m)	3.048 000*E−01
foot (US survey)[14]	meter (m)	3.048 006 E−01
foot of water (39.2 °F)	pascal (Pa)	2.988 98 E+03
ft^2	$meter^2$ (m^2)	9.290 304*E−02
ft^2/h (thermal diffusivity)	$meter^2$ per second (m^2/s)	2.580 640*E−05
ft^2/s	$meter^2$ per second (m^2/s)	9.290 340*E−02
ft^3 (volume; section modulus)	$meter^3$ (m^3)	2.831 685 E−02
ft^3/min	$meter^3$ per second (m^3/s)	4.719 474 E−04
ft^3/s	$meter^3$ per second (m^3/s)	2.831 685 E−02
ft^4 (second moment of area)[17]	$meter^4$ (m^4)	8.630 975 E−03
ft/h	meter per second (m/s)	8.466 667 E−05
ft/min	meter per second (m/s)	5.080 000*E−03
ft/s	meter per second (m/s)	3.048 000*E−01
ft/s^2	meter per $second^2$ (m/s^2)	3.048 000*E−01
footcandle	lux (lx)	1.076 391 E+01
footlambert	candela per $meter^2$ (cd/m^2)	3.426 259 E+00
ft · lbf	joule (J)	1.355 818 E+00
ft · lbf/h	watt (W)	3.766 161 E−04
ft · lbf/min	watt (W)	2.259 697 E−02
ft · lbf/s	watt (W)	1.355 818 E+00
ft · poundal	joule (J)	4.214 011 E−02

[17] This is sometimes called the moment of section or area moment of inertia of a plane section about a specified axis.

To convert from	to	Multiply by
g, standard acceleration of free fall	meter per second^2 (m/s^2)	9.806 650*E+00
gal	meter per second^2 (m/s^2)	1.000 000*E−02
gallon (Canadian liquid)	meter^3 (m^3)	4.546 090*E−03
gallon (UK liquid)	meter^3 (m^3)	4.546 090*E−03
gallon (US liquid)	meter^3 (m^3)	3.785 412 E−03
gallon (US liquid) per day	meter^3 per second (m^3/s)	4.381 264 E−08
gallon (US liquid) per minute	meter^3 per second (m^3/s)	6.309 020 E−05
gallon (US liquid) per (hp · h) (SFC, specific fuel consumption)	meter^3 per joule (m^3/J)	1.410 089 E−09
gamma	tesla (T)	1.000 000*E−09
gauss	tesla (T)	1.000 000*E−04
gilbert	ampere (A)	7.957 747 E−01
gill (UK)	meter^3 (m^3)	1.420 654 E−04
gill (US)	meter^3 (m^3)	1.182 941 E−04
grade	degree (angular)	9.000 000*E−01
grade	radian (rad)	1.570 796 E−02
grain	kilogram (kg)	6.479 891*E−05
grain/gal (US liquid)	kilogram per meter^3 (kg/m^3)	1.711 806 E−02
gram	kilogram (kg)	1.000 000*E−03
g/cm^3	kilogram per meter^3 (kg/m^3)	1.000 000*E+03
gram-force/cm^2	pascal (PA)	9.806 650*E+01
hectare	meter^2 (m^2)	1.000 000*E+04
horsepower (550 ft · lbf/s)	watt (W)	7.456 999 E+02
horsepower (boiler)	watt (W)	9.809 50 E+03
horsepower (electric)	watt (W)	7.460 000*E+02
horsepower (metric)	watt (W)	7.354 99 E+02
horsepower (water)	watt (W)	7.460 43 E+02
horsepower (UK)	watt (W)	7.457 0 E+02
hour	second (s)	3.600 000*E+03
hour (sidereal)	second (s)	3.590 170 E+03
hundredweight (long)	kilogram (kg)	5.080 235 E+01
hundredweight (short)	kilogram (kg)	4.535 924 E+01
inch	meter (m)	2.540 000*E−02
inch of mercury (32 °F)[18]	pascal (Pa)	3.386 38 E+03
inch of mercury (60 °F)[18]	pascal (Pa)	3.376 85 E+03
inch of water (39.2 °F)	pascal (Pa)	2.490 82 E+02
inch of water (60 °F)	pascal (Pa)	2.488 4 E+02
in^2	meter^2 (m^2)	6.451 600*E−04
in^3 (volume; section modulus)[19]	meter^3 (m^3)	1.638 706 E−05
in^3/min	meter^3 per second (m^3/s)	2.731 177 E−07
in^4 (second moment of area)[17]	meter^4 (m^4)	4.162 314 E−07
in/s	meter per second (m/s)	2.540 000*E−02
in/s^2	meter per second^2 (m/s^2)	2.540 000*E−02
kayser	1 per meter (1/m)	1.000 000*E+02
kelvin	degree Celsius	$t_{°C} = T_K - 273.15$
kilocalorie (International Table)	joule (J)	4.186 800*E+03
kilocalorie (mean)	joule (J)	4.190 02 E+03
kilocalorie (thermochemical)	joule (J)	4.184 000*E+03
kilocalorie (thermochemical)/min	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/s	watt (W)	4.184 000*E+03

[18] Conversion factors for mercury manometer pressure units are calculated using the standard value for the acceleration of gravity and the density of mercury at the stated temperature. Higher levels of precision are not justified because the definitions of the units do not take into account the compressibility of mercury or the density value change caused by the revised practical temperaturea scale, ITS-90.
[19] The exact conversion factor is 1.638 706 4*E−05.

To convert from	to	Multiply by
kilogram-force (kgf)	newton (N)	9.806 650*E+00
kgf · m	newton meter (N · m)	9.806 650*E+00
kgf · s^2/m (mass)	kilogram (kg)	9.806 650*E+00
kgf/cm^2	pascal (Pa)	9.806 650*E+04
kgf/m^2	pascal (Pa)	9.806 650*E+00
kgf/mm^2	pascal (Pa)	9.806 650*E+06
km/h	meter per second (m/s)	2.777 778 E−01
kilopond (1 kp = 1 kgf)	newton (N)	9.806 650*E+00
kW · h	joule (J)	3.600 000*E+06
kip (1000 lbf)	newton (N)	4.448 222 E+03
kip/in^2 (ksi)	pascal (Pa)	6.894 757 E+06
knot (international)	meter per second (m/s)	5.144 444 E−01
lambert	candela per meter² (cd/m^2)	1/π *E+04
lambert	candela per meter² (cd/m^2)	3.183 099 E+03
langley	joule per meter² (J/m^2)	4.184 000*E+04
light year[20]	meter (m)	9.460 73 E+15
liter[21]	meter³ (m^3)	1.000 000*E−03
lumen per ft²	lumen per meter² (lm/m^2)	1.076 391 E+01
maxwell	weber (Wb)	1.000 000*E−08
mho	siemens (S)	1.000 000*E+00
microinch	meter (m)	2.540 000*E−08
micron	meter (m)	1.000 000*E−06
mil	meter (m)	2.540 000*E−05
mile (international)	meter (m)	1.609 344*E+03
mile (US statute)[14]	meter (m)	1.609 3 E+03
mile (international nautical)	meter (m)	1.852 000*E+03
mile (US nautical)	meter (m)	1.852 000*E+03
m² (international)	meter² (m^2)	2.589 988 E+06
mi² (US statute)[14]	meter² (m^2)	2.589 998 E+06
mi/h (international)	meter per second (m/s)	4.470 400*E−01
mi/h (international)	kilometer per hour (km/h)	1.609 344*E+00
mi/min (international)	meter per second (m/s)	2.682 240*E+01
mi/s (international)	meter per second (m/s)	1.609 344*E+03
millibar	pascal (Pa)	1.000 000*E+02
millimeter of mercury (0 °C)[18]	pascal (Pa)	1.333 22 E+02
minute (angle)	radian (rad)	2.908 882 E−04
minute	second (s)	6.000 000*E+01
minute (sidereal)	second (s)	5.983 617 E+01
oersted	ampere per meter (A/m)	7.957 747 E+01
ohm centimeter	ohm meter (Ω · m)	1.000 000*E−02
ohm circular-mil per ft	ohm meter (Ω · m)	1.662 426 E−09
ounce (avoirdupois)	kilogram (kg)	2.834 952 E−02
ounce (troy or apothecary)	kilogram (kg)	3.110 348 E−02
ounce (UK fluid)	meter³ (m^3)	2.841 307 E−05
ounce (US fluid)	meter³ (m^3)	2.957 353 E−05
ounce-force	newton (N)	2.780 139 E−01
ozf · in	newton meter (N · m)	7.061 552 E−03

[20] This conversion factor is based on the astronomical unit of time of one day (86 400 seconds); an interval of 36 525 days is one Julian year. (See the Astronomical Almanac for the Year 1991, page K6, U.S. Government Printing Office, Washington, DC.)

[21] In 1964 the General Conference on Weights and Measures reestablished the name liter as a special name for the cubic decimeter. Between 1901 and 1964, the liter was slightly larger (1,000 028 dm^3); in the use of high-accuracy volume data of that time interval, this fact must be kept in mind.

To convert from	to	Multiply by
oz (avoirdupois)/gal (UK liquid)	kilogram per meter^3 (kg/m^3)	6.236 023 E+00
oz (avoirdupois)/gal (US liquid)	kilogram per meter^3 (kg/m^3)	7.489 152 E+00
oz (avoirdupois)/in^3	kilogram per meter^3 (kg/m^3)	1.729 994 E+03
oz (avoirdupois)/ft^2	kilogram per meter^2 (kg/m^2)	3.051 517 E−01
oz (avoirdupois)/yd^2	kilogram per meter^2 (kg/m^2)	3.390 575 E−02
parsec	meter (m)	3.085 678 E+16
peck (US)	meter^3 (m^3)	8.809 768 E−03
pennyweight	kilogram (kg)	1.555 174 E−03
perm (0 °C)	kilogram per pascal second meter^2 [$kg/Pa \cdot s \cdot m^2$)]	5.721 35 E−11
perm (23 °C)	kilogram per pascal second meter^2 [$kg/(Pa \cdot s \cdot m^2)$]	5.745 25 E−11
perm · in (0 °C)	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]	1.453 22 E−12
perm · in (23 °C)	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]	1.459 29 E−12
phot	lumen per meter^2 (lm/m^2)	1.000 000*E+04
pica (printer's)	meter (m)	4.217 518 E−03
pint (US dry)	meter^3 (m^3)	5.506 105 E−04
pint (US liquid)	meter^3 (m^3)	4.731 765 E−04
point (printer's)	meter (m)	3.514 598*E−04
poise (absolute viscosity)	pascal second (Pa · s)	1.000 000*E−01
pound (avoirdupois)[22]	kilogram (kg)	4.535 924 E−01
pound (troy or apothecary)	kilogram (kg)	3.732 417 E−01
lb/ft	kilogram per meter (kg/m)	1.488 164 E+00
lb · ft^2 (moment of inertia)	kilogram per meter^2 ($kg \cdot m^2$)	4.214 011 E−02
lb · in^2 (moment of inertia)	kilogram per meter^2 ($kg \cdot m^2$)	2.926 397 E−04
lb/ft · h	pascal second (Pa · s)	4.133 789 E−04
lb/ft · s	pascal second (Pa · s)	1.488 164 E+00
lb/ft^2	kilogram per meter^2 (kg/m^2)	4.882 428 E+00
lb/ft^3	kilogram per meter^3 (kg/m^3)	1.601 846 E+01
lb/gal (UK liquid)	kilogram per meter^3 (kg/m^3)	9.977 633 E+01
lb/gal (US liquid)	kilogram per meter^3 (kg/m^3)	1.198 264 E+02
lb/h	kilogram per second (kg/s)	1.259 979 E−04
lb/hp · h (SFC, specific fuel consumption	kilogram per joule (kg/J)	1.689 659 E−07
lb/in	kilogram per meter (kg/m)	1.785 797 E+01
lb/in^3	kilogram per meter^3 (kg/m^3)	2.767 990 E+04
lb/min	kilogram per second (kg/s)	7.559 873 E−03
lb/s	kilogram per second (kg/s)	4.535 924 E−01
lb/yd^3	kilogram per meter^3 (kg/m^3)	5.932 764 E−01
poundal	newton (N)	1.382 550 E−01
poundal/ft^2	pascal (Pa)	1.488 164 E+00
poundal · s/ft^2	pascal second (Pa · s)	1.488 164 E+00
pound-force (lbf)[23]	newton (N)	4.448 222 E+00
lbf · ft	newton meter (N · m)	1.355 818 E+00
lbf · ft/in	newton meter per meter (N · m/m)	5.337 866 E+01
lbf · in	newton meter (N · m)	1.129 848 E−01
lbf · in/in	newton meter per meter (N · m/m)	4.448 222 E+00
lbf · s/ft^2	pascal second (Pa · s)	4.788 026 E+01

[22] The exact conversion factor is 4.535 923 7*E−01.
[23] The exact conversion factor is 4.448 221 615 260 5*E+00.

To convert from	to	Multiply by
lbf · s/in²	pascal second (Pa · s)	6.894 757 E+03
lbf/ft	newton per meter (N/m)	1.459 390 E+01
lbf/ft²	pascal (Pa)	4.788 026 E+01
lbf/in.	newton per meter (N/m)	1.751 268 E+02
lbf/in² (psi)	pascal (Pa)	6.894 757 E+03
lbf/lb (thrust/weight [mass] ratio)	newton per kilogram (N/kg)	9.806 650 E+00
quad	joule (J)	1.055 E+18
quart (US dry)	meter³ (m³)	1.101 221 E−03
quart (US liquid)	meter³ (m³)	9.463 529 E−04
rad (absorbed dose)	gray (Gy)	1.000 000*E−02
rem (dose equivalent)	sievert (Sv)	1.000 000*E−02
rhe	1 per pascal second [1/Pa · s)]	1.000 000*E+01
rod[14]	meter (m)	5.029 210 E+00
roentgen	coulomb per kilogram (C/kg)	2.58 E−04
second (angle)	radian (rad)	4.848 137 E−06
second (sidereal)	second (s)	9.972 696 E−01
shake	second (s)	1.000 000*E−08
slug	kilogram (kg)	1.459 390 E+01
slug/ft · s	pascal second (Pa · s)	4.788 026 E+01
slug/ft³	kilogram per meter³ (kg/m³)	5.153 788 E+02
statampere	ampere (A)	3.335 641 E−10
statcoulomb	coulomb (C)	3.335 641 E−10
statfarad	farad (F)	1.112 650 E−12
stathenry	henry (H)	8.987 552 E+11
statmho	siemens (S)	1.112 650 E−12
statohm	ohm (Ω)	8.987 552 E+11
statvolt	volt (V)	2.997 925 E+02
stere	meter³ (m³)	1.000 000*E+00
stilb	candela per meter² (cd/m²)	1.000 000*E+04
stokes (kinematic viscosity)	merter² per second (M²/s)	1.000 000*E−04
tablespoon	milliliter (mL)	1.479 E+01
teaspoon	meter³ (m³) milliliter (mL)	4.929 E+00
tex	kilogram per meter (kg/m)	1.000 000*E−06
therm (EEG)[24]	joule (J)	1.055 060*E+08
therm (US)[24]	joule (J)	1.054 804*E+08
ton (assay)	kilogram (kg)	2.916 667 E−02
ton (long, 2240 lb)	kilogram (kg)	1.016 047 E+03
ton (metric)	kilogram (kg)	1.000 000*E+03
ton (explosive energy of one ton of TNT)	joule (J)	4.184 E+09[25]
ton of refrigeration (12 000 Btu/h)	watt (W)	3.517 E+03
ton (register)	meter³ (m³)	2.831 685 E+00
ton (short, 2000 lb)	kilogram (kg)	9.071 847 E+02
ton (long)/yd³	kilogram per meter³ (kg/m³)	1.328 939 E+03
ton (short)/yd³	kilogram per meter³ (kg/m³)	1.186 553 E+03
ton (short)/h	kilogram per second (kg/s)	2.519 958 E−01
ton-force (2000 lbf)	newton (N)	8.896 443 E+03
tonne	kilogram (kg)	1.000 000*E+03

[24] The therm (EEG) is legally defined in the Council Directive of 20 December 1979, Council of the European Communities. The therm (US) is legally defined in the Federal Register of July 27, 1968. Although the therm (EEG), which is based on the International Table Btu, is frequently used by engineers in the US, the therm (US) is the legal unit used by the US natural gas industry.

[25] Defined (not measured) value.

To convert from	to	Multiply by
torr (mmHg, 0 °C)[18]	pascal (Pa)	1.333 22 E+02
unit pole	weber (Wb)	1.256 637 E−07
W · h	joule (J)	3.600 000*E+03
W · s	joule (J)	1.000 000*E+00
W/cm^2	watt per $meter^2$ (W/m^2)	1.000 000*E+04
W/in^2	watt per $meter^2$ (W/m^2)	1.550 003 E+03
yard	meter (m)	9.144 000*E−01
yd^2	$meter^2$ (m^2)	8.361 274 E−01
yd^3	$meter^3$ (m^3)	7.645 549 E−01
yd^3/min	$meter^3$ per second (m^3/s)	1.274 258 E−02
year (365 days)	second (s)	3.153 600*E+07
year (sidereal)	second (s)	3.155 815 E+07
year (tropical)	second (s)	3.155 693 E+07

To convert from	to	Multiply by
ACCELERATION		
ft/s^2	meter per second^2 (m/s^2)	3.048 000*E−01
g, standard acceleration of free fall	meter per second^2 (m/s^2)	9.806 650*E+00
gal	meter per second^2 (m/s^2)	1.000 000*E−02
in/s^2	meter per second^2 (m/s^2)	2.540 000*E−02
ANGLE		
degree	radian (rad)	1.745 329 E−02
grade	degree (angle)	9.000 000*E−01
grade	radian (rad)	1.570 796 E−02
minute	radian (rad)	2.908 882 E−04
second	radian (rad)	4.848 137 E−06
AREA		
acre[14]	meter^2 (m^2)	4.046 873 E+03
are	meter^2 (m^2)	1.000 000*E+02
barn	meter^2 (m^2)	1.000 000*E−28
circular mil	meter^2 (m^2)	5.067 075 E−10
darcy[16]	meter^2 (m^2)	9.869 233 E−13
ft^2	meter^2 (m^2)	9.290 304*E−02
hectare	meter^2 (m^2)	1.000 000*E+04
in^2	meter^2 (m^2)	6.451 600*E−04
mi^2 (international)	meter^2 (m^2)	2.589 988 E+06
mi^2 (US statute)[14]	meter^2 (m^2)	2.589 998 E+06
yd^2	meter^2 (m^2)	8.361 274 E−01
BENDING MOMENT OR TORQUE		
dyne · cm	newton meter (N · m)	1.000 000*E−07
kgf · m	newton meter (N · m)	9.806 650*E+00
ozf · in	newton meter (N · m)	7.061 552 E−03
lbf · in	newton meter (N · m)	1.129 848 E−01
lbf · ft	newton meter (N · m)	1.355 818 E+00
BENDING MOMENT OR TORQUE PER UNIT LENGTH		
lbf · ft/in	newton meter per meter (N · m/m)	5.337 866 E+01
lbf · in/in	newton meter per meter (N · m/m)	4.448 222 E+00

To convert from	to	Multiply by
CAPACITY (See VOLUME)		
DENSITY (See MASS PER UNIT VOLUME)		
ELECTRICITY AND MAGNETISM[26]		
abampere	ampere (A)	1.000 000*E+01
abcoulomb	coulomb (C)	1.000 000*E+01
abfarad	farad (F)	1.000 000*E+09
abhenry	henry (H)	1.000 000*E−09
abmho	siemens (S)	1.000 000*E+09
abohm	ohm (Ω)	1.000 000*E−09
abvolt	volt (V)	1.000 000*E−08
ampere hour	coulomb (C)	3.600 000*E+03
EMU of capacitance	farad (F)	1.000 000*E+09
EMU of current	ampere (A)	1.000 000*E+01
EMU of electric potential	volt (V)	1.000 000*E−08
EMU of inductance	henry (H)	1.000 000*E−09
EMU of resistance	ohm (Ω)	1.000 000*E−09
ESU of capacitance	farad (F)	1.112 650 E−12
ESU of current	ampere (A)	3.335 641 E−10
ESU of electric potential	volt (V)	2.997 925 E+02
ESU of inductance	henry (H)	8.987 552 E+11
ESU of resistance	ohm (Ω)	8.987 552 E+11
faraday (based on carbon-12)	coulomb (C)	9.648 70 E+04
faraday (chemical)	coulomb (C)	9.649 57 E+04
faraday (physical)	coulomb (C)	9.652 19 E+04
gamma	tesla (T)	1.000 000*E−09
gauss	tesla (T)	1.000 000*E−04
gilbert	ampere (A)	7.957 747 E−01
maxwell	weber (Wb)	1.000 000*E−08
mho	siemens (S)	1.000 000*E+00
oersted	ampere per meter (A/m)	7.957 747 E+01
ohm centimeter	ohm meter (Ω · m)	1.000 000*E−02
ohm circular-mil per foot	ohm meter (Ω · m)	1.662 426 E−09
	(Ω · mm²/m)	1.662 426 E−03
statampere	ampere (A)	3.335 641 E−10
statcoulomb	coulomb (C)	3.335 641 E−10
statfarad	farad (F)	1.112 650 E−12
stathenry	henry (H)	8.987 552 E+11
statmho	siemens (S)	1.112 650 E−12
statohm	ohm (Ω)	8.987 552 E+11
statvolt	volt (V)	2.997 925 E+02
unit pole	weber (Wb)	1.256 637 E−07
ENERGY (Includes WORK)		
British thermal unit (International Table)[15]	joule (J)	1.055 056 E+03
British thermal unit (mean)	joule (J)	1.055 87 E+03
British thermal unit (thermochemical)	joule (J)	1.054 350 E+03
British thermal unit (39 °F)	joule (J)	1.059 67 E+03
British thermal unit (59 °F)	joule (J)	1.054 80 E+03

[26] ESU means electrostatic cgs unit. EMU means electromagnetic cgs unit.

To convert from	to	Multiply by
British thermal unit (60 °F)	joule (J)	1.054 68 E+03
calorie (International Table)	joule (J)	4.186 800*E+00
calorie (mean)	joule (J)	4.190 02 E+00
calorie (thermochemical)	joule (J)	4.184 000*E+00
calorie (15 °C)	joule (J)	4.185 80 E+00
calorie (20 °C)	joule (J)	4.181 90 E+00
calorie (kilogram, International Table)	joule (J)	4.186 800*E+03
calorie (kilogram, mean)	joule (J)	4.190 02 E+03
calorie (kilogram, thermochemical)	joule (J)	4.184 000*E+03
electronvolt	joule (J)	1.602 19 E−19
erg	joule (J)	1.000 000*E−07
ft · lbf	joule (J)	1.355 818 E+00
ft · poundal	joule (J)	4.214 011 E−02
kilocalorie (International Table)	joule (J)	4.186 800*E+03
kilocalorie (mean)	joule (J)	4.190 02 E+03
kilocalorie (thermochemical)	joule (J)	4.184 000*E+03
kW · h	joule (J)	3.600 000*E+06
quad	joule (J)	1.055 E+18
therm (EEC)[24]	joule (J)	1.055 060*E+08
therm (US)[24]	joule (J)	1.054 804*E+08
ton (explosive energy of one ton of TNT)	joule (J)	4.184 E+09[25]
W · h	joule (J)	3.600 000*E+03
W · s	joule (J)	1.000 000*E+00

ENERGY PER UNIT AREA TIME

To convert from	to	Multiply by
Btu (International Table)/($ft^2 \cdot s$)	watt per meter^2 (W/m^2)	1.135 653 E+04
Btu (International Table)/($ft^2 \cdot h$)	watt per meter^2 (W/m^2)	3.154 591 E+00
Btu (thermochemical)/($ft^2 \cdot s$)	watt per meter^2 (W/m^2)	1.134 893 E+04
Btu (thermochemical)/($ft^2 \cdot min$)	watt per meter^2 (W/m^2)	1.891 489 E+02
Btu (thermochemical)/($ft^2 \cdot h$)	watt per meter^2 (W/m^2)	3.152 481 E+00
Btu (thermochemical)/($in^2 \cdot s$)	watt per meter^2 (W/m^2)	1.634 246 E+06
cal (thermochemical)/($cm^2 \cdot min$)	watt per meter^2 (W/m^2)	6.973 333 E+02
erg/($cm^2 \cdot s$)	watt per meter^2 (W/m^2)	1.000 000*E−03
W/cm^2	watt per meter^2 (W/m^2)	1.000 000*E+04
W/in^2	watt per meter^2 (W/m^2)	1.550 003 E+03

FLOW (See MASS PER UNIT TIME or VOLUME PER UNIT TIME)

FORCE

To convert from	to	Multiply by
dyne	newton (N)	1.000 000*E−05
kilogram-force	newton (N)	9.806 650*E+00
kilopond	newton (N)	9.806 650*E+00
kip (1000 lbf)	newton (N)	4.448 222 E+03
ounce-force	newton (N)	2.780 139 E−01
pound-force (lbf)[23]	newton (N)	4.448 222 E+00
lbf/lb (thrust/weight [mass] ratio)	newton per kilogram (N/kg)	9.806 650 E+00
poundal	newton (N)	1.382 550 E−01
ton-force (2000 lbf)	newton (N)	8.896 443 E+03

FORCE PER UNIT AREA (See PRESSURE)

FORCE PER UNIT LENGTH

To convert from	to	Multiply by
lbf/ft	newton per meter (N/m)	1.459 390 E+01
lbf/in	newton per meter (N/m)	1.751 268 E+02

To convert from	to	Multiply by
HEAT[27]		
Btu (International Table) · ft/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.730 735 E+00
Btu (thermochemical) · ft/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.729 577 E+00
Btu (International Table) · in/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.442 279 E−01
Btu (thermochemical) · in/(h · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	1.441 314 E−01
Btu (International Table) · in/(s · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	5.192 204 E+02
Btu (thermochemical) · in/(s · ft^2 · °F) (thermal conductivity)	watt per meter kelvin [W/(m · K)]	5.188 732 E+02
Btu (International Table)/ft^2	joule per meter^2 (J/m^2)	1.135 653 E+04
Btu (thermochemical)/ft^2	joule per meter^2 (J/m^2)	1.134 893 E+04
Btu (International Table)/(h · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	5.678 263 E+00
Btu (thermochemical)/(h · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	5.674 466 E+00
Btu (International Table)/(s · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	2.044 175 E+04
Btu (thermochemical)/(s · ft^2 · °F)	watt per meter^2 kelvin [W/(m^2 · K)]	2.042 808 E+04
Btu (International Table)/lb	joule per kilogram (J/kg)	2.326 000*E+03
Btu (thermochemical)/lb	joule per kilogram (J/kg)	2.324 444 E+03
Btu (International Table)/(lb · °F (specific heat capacity)	joule per kilogram kelvin [J/kg · K)]	4.186 800*E+03
Btu (thermochemical)/(lb · °F) (specific heat capacity)	joule per kilogram kelvin [J/kg · K)]	4.184 000*E+03
Btu (International Table)/ft^3	joule per meter^3 (J/m^3)	3.725 895 E+04
Btu (thermochemical)/ft^3	joule per meter^3 (J/m^2)	3.723 402 E+04
cal (thermochemical)/(cm · s · °C)	watt per meter kelvin [W/m · K)]	4.184 000*E+02
cal (thermochemical)/cm^2	joule per meter^2 (J/m^2)	4.184 000*E+04
cal (thermochemical)/(cm^2 · min)	watt per meter^2 (W/m^2)	6.973 333 E+02
cal (thermochemical)/(cm^2 · s)	watt per meter^2 (W/m^2)	4.184 000*E+04
cal (International Table)/g	joule per kilogram (J/kg)	4.186 800*E+03
cal (thermochemical)/g	joule per kilogram (J/kg)	4.184 000*E+03
cal (International Table)/(g · °C)	joule per kilogram kelvin (J/(kg · K)]	4.186 800*E+03
cal (thermochemical)/(g · °C)	joule per kilogram kelvin [J/(kg · K)]	4.184 000*E+03
cal (thermochemical)/min	watt (W)	6.973 333 E−02
cal (thermochemical)/s	watt (W)	4.184 000*E+00
clo	kelvin meter^2 per watt (K · m^2/W)	2.003 712 E−01
°F · h · ft^2/Btu (International Table)	kelvin meter^2 per watt (K · m^2/W)	1.761 102 E−01
°F · h · ft^2/Btu (thermochemical)	kelvin meter^2 per watt (K · m^2/W)	1.762 280 E−01
°F · h /ft^2/[Btu (International Table) · in] (thermal resistivity)	kelvin meter per watt (K · m/W)	6.933 472 E+00
°F · h · ft^2/[Btu (thermochemical) · in] (thermal resistivity)	kelvin meter per watt (K · m/W)	6.938 112 E+04
ft^2/h (thermal diffusivity)	meter^2 per second (m^2/s)	2.580 640*E−05
LENGTH		
ångström	meter (m)	1.000 000*E−10
astronomical unit	meter (m)	1.495 979 E+11
chain[14]	meter (m)	2.011 684 E+01
fathom	meter (m)	1.828 8 E+00
fermi (femtometer)	meter (m)	1.000 000*E−15

[27] For standard letter symbols and definitions of quantities in heat and thermodynamics se ANSI/ASME Y10.4-1982.

To convert from	to	Multiply by
foot	meter (m)	3.048 000*E−01
foot (US survey)[14]	meter (m)	3.048 006 E−01
inch	meter (m)	2.540 000*E−02
light year[20]	meter (m)	9.460 73 E+15
microinch	meter (m)	2.540 000*E−08
micron	meter (m)	1.000 000*E−06
mil	meter (m)	2.540 000*E−05
mile (international nautical)	meter (m)	1.852 000*E+03
mile (US nautical)	meter (m)	1.852 000*E+03
mile (international)	meter (m)	1.609 344*E+03
mile (US statute)[14]	meter (m)	1.609 347 E+03
parsec	meter (m)	3.085 678 E+16
pica (printer's)	meter (m)	4.217 518 E−03
point (printer's)	meter (m)	3.514 598*E−04
rod[14]	meter (m)	5.029 210 E+00
yard	meter (m)	9.144 000*E−01
cd/in^2	candela per meter^2 (cd/m^2)	1.550 003 E+03
footcandle	lux (lx)	1.076 391 E+01
footlambert	candela per meter^2 (cd/m^2)	3.426 259 E+00
lambert	candela per meter^2 (cd/m^2)	3.183 099 E+03
lumen per ft^2	lumen per meter^2 (lm/m^2)	1.076 391 E+01
phot	lumen per meter^2 (lm/m^2)	1.000 000*E+04
stilb	candela per meter^2 (cd/m^2)	1.000 000*E+04

MASS

carat (metric)	kilogram (kg)	2.000 000*E−04
grain	kilogram (kg)	6.479 891*E−05
gram	kilogram (kg)	1.000 000*E−03
hundredweight (long)	kilogram (kg)	5.080 235 E+01
hundredweight (short)	kilogram (kg)	4.535 924 E+01
kgf · s^2/m (mass)	kilogram (kg)	9.806 650*E+00
ounce (avoirdupois)	kilogram (kg)	2.834 952 E−02
ounce (troy or apothecary)	kilogram (kg)	3.110 348 E−02
pennyweight	kilogram (kg)	1.555 174 E−03
pound (avoirdupois)[22]	kilogram (kg)	4.535 924 E−01
pound (troy or apothecary)	kilogram (kg)	3.732 417 E−01
slug	kilogram (kg)	1.459 390 E+01
ton (assay)	kilogram (kg)	2.916 667 E−02
ton (long, 2240 lb)	kilogram (kg)	1.016 047 E+03
ton (metric)	kilogram (kg)	1.000 000*E+03
ton (short, 2000 lb)	kilogram (kg)	9.071 847 E+02
tonne	kilogram (kg)	1.000 000*E+03

MASS PER UNIT AREA

oz/ft^2	kilogram per meter^2 (kg/m^2)	3.051 517 E−01
oz/yd^2	kilogram per meter^2 (kg/m^2)	3.390 575 E−02
lb/ft^2	kilogram per meter^2 (kg/m^2)	4.882 428 E+00

To convert from	to	Multiply by
MASS PER UNIT CAPACITY (See MASS PER UNIT VOLUME)		
MASS PER UNIT LENGTH		
denier	kilogram per meter (kg/m)	1.111 111 E−07
lb/ft	kilogram per meter (kg/m)	1.488 164 E+00
lb/in	kilogram per meter (kg/m)	1.785 797 E+01
tex	kilogram per meter (kg/m)	1.000 000*E−06
MASS PER UNIT TIME (Includes FLOW)		
perm (0 °C)	kilogram per pascal second meter² [kg/Pa · s · m²)]	5.721 35 E−11
perm (23 °C)	kilogram per pascal second meter² [kg/(Pa · s · m²)]	5.745 25 E−11
perm · in (0 °C)	kilogram per pascal second meter [kg/(Pa · s · m)]	1.453 22 E−12
perm · in (23 °C)	kilogram per pascal second meter [kg/(Pa · s · m)]	1.459 29 E−12
lb/h	kilogram per second (kg/s)	1.259 979 E−04
lb/min	kilogram per second (kg/s)	7.559 873 E−03
lb/s	kilogram per second (kg/s)	4.535 924 E−01
lb/hp · h (SFC, specific fuel consumption)	kilogram per joule (kg/J)	1.689 659 E−07
ton (short)/h	kilogram per meter (kg/m)	2.519 958 E−01
MASS PER UNIT VOLUME (Includes DENSITY and MASS CONCENTRATION)		
grain/gal (US liquid)	kilogram per meter³ (kg/m³)	1.711 806 E−02
g/cm³	kilogram per meter³ (kg/m³)	1.000 000*E+03
oz (avoirdupois)/gal (UK liquid)	kilogram per meter³ (kg/m³)	6.236 023 E+00
oz (avoirdupois)/gal (US liquid)	kilogram per meter³ (kg/m³)	7.489 152 E+00
oz (avoirdupois)/in³	kilogram per meter³ (kg/m³)	1.729 994 E+03
lb/ft³	kilogram per meter³ (kg/m³)	1.601 846 E+01
lb/in³	kilogram per meter³ (kg/m³)	2.767 990 E+04
lb/gal (UK liquid)	kilogram per meter³ (kg/m³)	9.977 633 E+01
lb/gal (US liquid)	kilogram per meter³ (kg/m³)	1.198 264 E+02
lb/yd³	kilogram per meter² (kg/m²)	5.932 764 E−01
slug/ft³	kilogram per meter³ (kg/m³)	5.153 788 E+02
ton (long)/yd³	kilogram per meter³ (kg/m³)	1.328 939 E+03
ton (short)/yd³	kilogram per meter² (kg/m²)	1.186 553 E+03
POWER		
Btu (International Table)/h	watt (W)	2.930 711 E−01
Btu (International Table)/s	watt (W)	1.055 056 E+03
Btu (thermochemical)/h	watt (W)	2.928 751 E−01
Btu (thermochemical)/min	watt (W)	1.757 250 E+01
Btu (thermochemical)/s	watt (W)	1.054 350 E+03
cal (thermochemical)/min	watt (W)	6.973 333 E−02
cal (thermochemical)/s	watt (W)	4.184 000*E+00
erg/s	watt (W)	1.000 000*E−07
ft · lbf/h	watt (W)	3.766 161 E−04
ft · lbf/min	watt (W)	2.259 697 E−02
ft · lbf/s	watt (W)	1.355 818 E+00

To convert from	to	Multiply by
horsepower (550 ft · lbf/s)	watt (W)	7.456 999 E+02
horsepower (boiler)	watt (W)	9.809 50 E+03
horsepower (electric)	watt (W)	7.460 000*E+02
horsepower (metric)	watt (W)	7.354 99 E+02
horsepower (water)	watt (W)	7.460 43 E+02
horsepower (UK)	watt (W)	7.457 0 E+02
kilocalorie (thermochemical)/min	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/s	watt (W)	4.184 000*E+03
ton of refrigeration (12 000 Btu/h)	watt (W)	3.517 E+03
PRESSURE or STRESS (FORCE PER UNIT AREA)		
atmosphere (standard)	pascal (Pa)	1.013 250*E+05
atmoshpere (technical = 1 kgf/cm^2)	pascal (Pa)	9.806 650*E+04
bar	pascal (Pa)	1.000 000*E+05
centimeter of mercury (0 °C)	pascal (Pa)	1.333 22 E+03
centimeter of water (4 °C)	pascal (Pa)	9.806 38 E+01
dyne/cm^2	pascal (Pa)	1.000 000*E−01
foot of water (39.2 °F)	pascal (Pa)	2.988 98 E+03
gram-force/cm^2	pascal (Pa)	9.806 650*E+01
inch of mercury (32 °F)[18]	pascal (Pa)	3.386 38 E+03
inch of mercury (60 °F)[18]	pascal (Pa)	3.376 85 E+03
inch of water (39.2 °F)	pascal (Pa)	2.490 82 E+02
inch of water (60 °F)	pascal (Pa)	2.488 4 E+02
kgf/cm^2	pascal (Pa)	9.806 650*E+04
kgf/m^2	pascal (Pa)	9.806 650*E+00
kgf/mm^2	pascal (Pa)	9.806 650*E+06
kip/in^2 (ksi)	pascal (Pa)	6.894 757 E+06
millibar	pascal (Pa)	1.000 000*E+02
millimeter of mercury (0 °C)[18]	pascal (Pa)	1.333 22 E+02
poundal/ft^2	pascal (Pa)	1.488 164 E+00
lbf/ft^2	pascal (Pa)	4.788 026 E+01
lbf/in^2 (psi)	pascal (Pa)	6.894 757 E+03
psi	pascal (Pa)	6.894 757 E+03
tor (mmHg, 0 °C)[18]	pascal (Pa)	1.333 22 E+02
RADIOLOGY		
curie	becquerel (Bq)	3.700 000*E+10
rad (absorbed dose)	gray (Gy)	1.000 000*E−02
rem (dose equivalent)	sievert (Sv)	1.000 000*E−02
roentgen	coulomb per kilogram (C/kg)	2.58 E−04
SPEED (See VELOCITY)		
STRESS (See PRESSURE)		
TEMPERATURE		
degree Celsius	kelvin (K)	$T_K = t_{°C} + 273.15$
degree Fahrenheit	degree Celsius (°C)	$t_{°C} = (t_{°F} - 32)/1.8$
degree Fahrenheit	kelvin (K)	$T_K = (t_{°F} + 459.67)/1.8$
degree Rankine	kelvin (K)	$T_K = T_{°R}/1.8$
kelvin	degree Celsius (°C)	$t_{°C} = T_K - 273.15$

To convert from	to	Multiply by
TEMPERATURE INTERVAL		
degree Celsius	kelvin (K)	1.000 000*E+00
degree Fahenheit	kelvin (K)	5.555 556 E−01
degree Fahrenheit	degree Celsius (°C)	5.555 556 E−01
degree Rankine	kelvin (K)	5.555 556 E−01
TIME		
day (mean solar)	second (s)	8.640 000*E+04
day (sidereal)	second (s)	8.616 409 E+04
hour	second (s)	3.600 000*E+03
hour (sidereal)	second (s)	3.590 170 E+03
minute	second (s)	6.000 000*E+01
minute (sidereal)	second (s)	5.983 617 E+01
second (sidereal)	second (s)	9.972 696 E−01
shake	second (s)	1.000 000*E−08
year (365 days)	second (s)	3.153 600*E+07
year (sidereal)	second (s)	3.155 815 E+07
year (tropical)	second (s)	3.155 693 E+07
TORQUE (See BENDING MOMENT)		
VELOCITY (Includes SPEED)		
ft/h	meter per second (m)	8.466 667 E−05
ft/min	meter per second (m)	5.080 000*E−03
ft/s	meter per second (m)	3.048 000*E−01
in/s	meter per second (m)	2.540 000*E−02
km/h	meter per second (m)	2.777 778 E−01
knot (international)	meter per second (m)	5.144 444 E−01
mi/h (international)	meter per second (m)	4.470 400*E−01
mi/min (international)	meter per second (m)	2.682 240*E+01
mi/s (international)	meter per second (m)	1.609 344*E+03
mi/h (international)	kilometer per hour (km/h)[28]	1.609 344*E+00
VISCOSITY		
centipoise	pascal second (Pa · s)	1.000 000*E−03
centistokes	meter^2 per second (m^2/s)	1.000 000*E−06
ft^2/s	meter^2 per second (m^2/s)	9.290 304*E−02
poise	pascal second (Pa · s)	1.000 000*E−01
poundal · s/ft^2	pascal second (Pa · s)	1.488 164 E+00
lb/ft · h	pascal second (Pa · s)	4.133 789 E−04
lb/ft · s	pascal second (Pa · s)	1.488 164 E+00
lbf · s/ft^2	pascal second (Pa · s)	4.788 026 E+01
lbf · s/in^2	pascal second (Pa · s)	6.894 757 E+03
rhe	1 per pascal second (1/Pa · s)	1.000 000*E+01
stokes	meter^2 per second (m^2/s)	1.000 000*E−04
VOLUME (Includes CAPACITY)		
acre-foot[14]	meter^3 (m^3)	1.233 5 E+03
barrel (oil, 42 gal)	meter^3 (m^3)	1.589 873 E−01
board foot	meter^3 (m^3)	2.359 737 E−03
bushel (US)	meter^3 (m^3)	3.523 907 E−02
cup	milliliter (mL)	2.366 E+02

[28] Although speedometers may read km/h, the SI unit is m/s.

To convert from	to	Multiply by
fluid ounce (US)	meter^3 (m^3)	2.957 353 E−05
ft^3	meter^3 (m^3)	2.831 685 E−02
gallon (Canadian liquid)	meter^3 (m^3)	4.546 090 E−03
gallon (UK liquid)	meter^3 (m^3)	4.546 092 E−03
gallon (US liquid)	meter^3 (m^3)	3.785 412 E−03
gill (UK)	meter^3 (m^3)	1.420 654 E−04
gill (US)	meter^3 (m^3)	1.182 941 E−04
in^3 [see footnote 19]	meter^3 (m^3)	1.638 706 E−05
liter [see footnote 21]	meter^3 (m^3)	1.000 000*E−03
ounce (UK fluid)	meter^3 (m^3)	2.841 307 E−05
ounce (US fluid)	meter^3 (m^3)	2.957 353 E−05
peck (US)	meter^3 (m^3)	8.809 768 E−03
pint (US dry)	meter^3 (m^3)	5.506 105 E−04
pint (US liquid)	meter^3 (m^3)	4.731 765 E−04
quart (US dry)	meter^3 (m^3)	1.101 221 E−03
quart (US liquid)	meter^3 (m^3)	9.463 529 E−04
stere	meter^3 (m^3)	1.000 000*E+00
tablespoon	milliliter (mL)	1.479 E+01
teaspoon	milliliter (mL)	4.929 E+00
ton (register)	meter^3 (m^3)	2.831 685 E+00
yd^3	meter^3 (m^3)	7.645 549 E−01

VOLUME PER UNIT TIME (Includes FLOW)

ft^3/min	meter^3 per second (m^3/s)	4.719 474 E−04
ft^3/s	meter^3 per second (m^3/s)	2.831 685 E−02
gal (US liquid)/(hp · h) (SFC, specific fuel consumption)	meter^3 per joule (m^3/J)	1.410 089 E−09
in^3/min	meter^3 per second (m^3/s)	2.731 177 E−07
yd^3/min	meter^3 per second (m^3/s)	1.274 258 E−02
gal (US liquid)/day	meter^3 per second (m^3/s)	4.381 264 E−08
gal (US liquid)/min	meter^3 per second (m^3/s)	6.309 020 E−05

WORK (See ENERGY)

APPENDIX D

MASS, FORCE, AND WEIGHT[29]

The principal departure of SI from the gravimetric system of metric engineering units is the use of explicitly distinct units for mass and force. In SI, the name kilogram is restricted to the unit of mass, and the kilogram-force (from which the suffix *force* was in practice often erroneously dropped) should not be used. In its place, the SI unit of force, the newton, is used. Likewise, the newton rather than the kilogram-force is used to form derived units which include force, for example, pressure or stress ($N/m^2 = Pa$), energy ($N \cdot m = J$), and power ($N \cdot m/s = W$).

Considerable confusion exists in the use of the term *weight* as a quantity to mean either *force* or *mass*. In commercial and everyday use, the term *weight* nearly always means *mass*; thus, when one speaks of a person's weight, the quantity referred to is mass. This nontechnical use of the term weight in everyday life will probably persist.

In science and technology, the term *weight* of a *body* has usually meant the force that, if applied to the body, would give it an acceleration equal to the local acceleration of free fall. The adjective "local" in the phrase "local acceleration of free fall" has usually meant a location on the surface of the earth; in this context the "local acceleration of free fall" has the symbol g (commonly referred to as "acceleration of gravity") with observed values of g differing by over 0.5 percent at various points on the earth's surface. The use of *force of gravity* (mass times acceleration of gravity) instead of *weight* with this meaning is recommended.

Because of the dual use of the term weight as a quantity, this term should be avoided in technical practice except under circumstances in which its meaning is completely clear. When the term is used, it is important to know whether mass or force is intended and to use SI units properly, i.e., by using kilograms for mass or newtons for force.

[29] Reprinted from IEEE Std 268-1982, *IEEE Standard Metric Practice*, © 1982 by the Institute of Electrical and Electronics Engineers, Inc. with permission of the IEEE.

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This document is very similar to the English language version of the document above [1].

[3] *Style Manual*, U.S. Government Printing Office (1984), Washington, DC.

[4] *SI Units and Recommendations For the Use of Their Multiples and of Certain Other Units*, ISO 1000–1981, The International Organization for Standardization, Geneva, Switzerland. (Routine revision of this standard is in progress; the new publication date is expected to be 1991.)

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Quantities and Units of Mechanics, ISO 31/3–1978;

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Standard Practice for the Use of the International System of Units: The Modernized Metric System, E 380–89a (1989), American Society for Testing and Materials, Philadelphia, Pa.

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[12] Federal Register, Vol. 40, No. 23, page 5954, February 3, 1975.

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