Second Committee Draft (2CD)

Project:	Revision of OIML Document (OIML D 2:2007)
Title:	Legal units of measurement
Date:	03 August 2021
Document number:	TC2_P1_N004 (clean version)
Supersedes document:	TC2_P1_N001
Project Group:	TC 2/p 1
Convenership:	Austria
Convener:	Dr. Michael Matus
BIML contact:	Mr. Paul Dixon

Circulated to P- and O-members and liaison international bodies and external organizations for:

☐ Discussion at (date and place of meeting):

☐ Comments by:

☒ Vote (P-members only) and comments by: **03 November 2021**

INTERNATIONAL
DOCUMENT

OIML D 2

Edition 202x (E)

TC2_P1_N004
2CD Revision of D 2 (clean)

Legal units of measurement

Unités de mesure légales

OIML D 2 Edition 202x (E)

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

Contents

Foreword

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States.

The main categories of OIML publications are:

- **International Recommendations (OIML R),** which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity. OIML Member States shall implement these Recommendations to the greatest possible extent;
- **International Documents (OIML D),** which are informative in nature and which are intended to harmonize and improve work in the field of legal metrology;
- **International Guides (OIML G),** which are also informative in nature and which are intended to give guidelines for the application of certain requirements to legal metrology; and
- **International Basic Publications (OIML B),** which define the operating rules of the various OIML structures and systems.

OIML Draft Recommendations, Documents and Guides are developed by Technical Committees or Subcommittees which comprise representatives from the Member States. Certain international and regional institutions also participate on a consultation basis. Cooperative agreements have been established between the OIML and certain institutions, such as ISO and the IEC, with the objective of avoiding contradictory requirements. Consequently, manufacturers and users of measuring instruments, test laboratories, etc. may simultaneously apply OIML publications and those of other institutions.

International Recommendations, Documents, Guides and Basic Publications are published in English (E) and translated into French (F) and are subject to periodic revision.

Additionally, the OIML publishes or participates in the publication of **Vocabularies (OIML V)** and periodically commissions legal metrology experts to write **Expert Reports (OIML E)**. Expert Reports are intended to provide information and advice, and are written solely from the viewpoint of their author, without the involvement of a Technical Committee or Subcommittee, nor that of the CIML. Thus, they do not necessarily represent the views of the OIML.

This publication – reference OIML D 2 Edition 202x (E) – was developed by Project Group 1 of the OIML Technical Committee TC 2 *Units of measurement*. It was approved by the International Committee of Legal Metrology in 202x and is aligned with the 9th edition of the International System of Units (2019, BIPM). It supersedes the previous Edition 2007.

OIML Publications may be downloaded from the OIML web site in the form of PDF files. Additional information on OIML Publications may be obtained from the Organization's headquarters:

Bureau International de Métrologie Légale
11, rue Turgot - 75009 Paris - France
Telephone: 33 (0)1 48 78 12 82
Fax: 33 (0)1 42 82 17 27
E-mail: biml@oiml.org
Internet: www.oiml.org

Legal units of measurement

Introduction

The purpose of this International Document is to facilitate the drafting of national regulations relating to legal units of measurement.

This International Document is drawn up according to the following principles:

1 The International System of Units (SI), adopted by the General Conference on Weights and Measures (CGPM), is used as the basis for national regulations concerning legal units of measurement.

2 As a general rule, units other than SI units should be eliminated; however, for practical reasons it is sometimes necessary to use other units as legal units of measurement (e.g. the kilowatt hour (kW · h)).

3 Those definitions which have been provided or ratified by the CGPM have been reproduced exactly. (See subclauses 2.2.1, 2.2.6, 2.3.1, 2.3.5, 2.3.10, 2.3.11, 2.4.1, 2.5.1, 2.5.2, 2.5.3, 2.5.5, 2.5.7, 2.5.8, 2.5.9, 2.6.1, 2.7.2 and 2.7.4).

For the requirements of legal metrology, other definitions are given here in their most usually accepted form.

This International Document is divided into the following clauses:

1 General provisions

Classification and fields of use of legal units of measurement.

2 SI units

Catalogue of the SI units. The list of derived units may be supplemented or reduced as required.

3 Decimal multiples and sub-multiples of SI units

Catalogue of SI prefixes. Rules for the formation of decimal multiples and sub-multiples of SI units by means of the SI prefixes.

4 Other units

List of units outside the scope of the International System of Units which continue to be used for practical reasons[1]. The list is not standardized internationally although most of these units are recognized by the CIPM. Nonetheless it is desirable to consider it as restrictive in order to facilitate the extension of the International System of Units.

[1] *"There are many more non-SI units, which are either of historical interest, or are still used in specific fields (for example, the barrel of oil) or in particular countries (the inch, foot and yard). The CIPM can see no case for continuing to use these units in modern scientific and technical work. However, it is clearly a matter of importance to be able to recall the relation of these units to the corresponding SI units and this will continue to be true for many years." (Source: SI Brochure - The International System of Units (SI), 9th edition, 20 May 2019, page 146). Some OIML Recommendations apply to these specific fields which still commonly use "traditional units" and this is why non-SI units are used.*

Annex A

Annex A lists those units of measurement and denominations which may be used temporarily up to a date which remains to be fixed by national regulations, but which shall not be introduced where they are not in use.

Annex B

Annex B lists those units of measurement and denominations whose use must be discontinued as soon as possible where they are currently in use and which shall not be introduced where they are not in use.

The lists in the Annexes must be completed in accordance with the needs or customs of each country.

1 General provisions

1.1 The legal units of measurement are:

1.1.1 The SI units named and defined in clauses 2 and 3.

1.1.2 The other units named and defined in clause 4.

1.1.3 The compound units formed by combining the units in subclauses 1.1.1 and 1.1.2.

1.2 The units of measurement mentioned in the Annexes may be used up to dates which are to be fixed by national or regional regulations.

1.3 The obligation to use the legal units of measurement refers to measuring instruments, results of measurements and indications of quantity values where used in the economic field, in the area of public health and safety, in education, in standardization and in operations of an administrative character.

1.4 This Document shall not affect the use of units, other than those it renders obligatory, which are laid down in international conventions or agreements between governments in the fields of navigation by sea, air traffic and rail transport.

1.5 A legal unit of measurement may be expressed only:

- either by its legal name or by its legal symbol specified in this Document,
- or by using legal names or legal symbols of units, combined according to the definitions of the unit concerned.

It is not permitted to add any kind of adjective or sign to the legal names or legal symbols of units. (For example, electrical power is expressed in watts, W, not in electrical watts, W_e).

1.6 The symbols of the units are printed in upright type. These symbols are not followed by a full stop (period); they do not change in the plural.

2 SI units

2.1 General provisions

2.1.1 The SI units belong to the International System of Units, the international abbreviation of which is SI.

2.1.2 The SI units are:

- Set of coherent SI units
  - base units;
  - coherent derived units.
- Decimal multiples and sub-multiples of this set.

2.1.3 The names and symbols of the base units are:

			Defined in subclause
For time	second	m	2.2.1
For length	metre	m	2.2.7
For mass	kilogram	kg	2.3.1
For electric current	ampere	A	2.4.1
For thermodynamic temperature	kelvin	K	2.5.1
For amount of substance	mole	mol	2.6.1
For luminous intensity	candela	cd	2.7.2

2.1.4 The derived units are expressed algebraically in terms of base units by means of the mathematical symbols of multiplication and division. Certain derived units have been assigned special names and symbols.

2.1.5 Dimensionless derived units for plane angle and solid angle have the following names and symbols respectively:

			Defined in subclause
For plane angle	radian	rad	2.2.2
For solid angle	steradian	sr	2.2.3

The names and symbols of these dimensionless derived units may, but need not, be used in expressions for other SI derived units, as convenient (20$^{\text{th}}$ CGPM, 1995).

2.2 Space and time

2.2.1 Time: second (symbol: s)

The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{\text{Cs}}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1} (26$^{\text{th}}$ CGPM, 2018).

2.2.2 Frequency: hertz (symbol: Hz)

The hertz is the frequency of a periodic phenomenon, the period of which is 1 second.

$1\ \text{Hz} = 1\ \text{s}^{-1}$

2.2.3 Angular velocity: radian per second (symbol: rad/s or $\text{rad} \cdot \text{s}^{-1}$)

The radian per second is the angular velocity of a body that rotates uniformly about a fixed axis through 1 radian in 1 second.

$$1\ \text{rad/s} = \frac{1\ \text{rad}}{1\ \text{s}}$$

2.2.4 Angular acceleration: radian per second squared (symbol: rad/s^2 or $\text{rad} \cdot \text{s}^{-2}$)

The radian per second squared is the angular acceleration of a body, rotating about a fixed axis with uniform acceleration, whose angular velocity changes by 1 radian per second in 1 second.

$$1\ \text{rad/s}^2 = \frac{1\ \text{rad/s}}{1\ \text{s}}$$

2.2.5 Velocity: metre per second (symbol: m/s or $\mathrm{m \cdot s^{-1}}$)

The metre per second is the velocity of a point that moves through 1 metre in 1 second with uniform motion.

$$1\ \mathrm{m/s} = \frac{1\ \mathrm{m}}{1\ \mathrm{s}}$$

2.2.6 Acceleration: metre per second squared (symbol: $\mathrm{m/s^2}$ or $\mathrm{m \cdot s^{-2}}$)

The metre per second squared is the acceleration of a body, animated by a uniformly varied movement whose velocity varies in 1 second by 1 metre per second.

$$1\ \mathrm{m/s^2} = \frac{1\ \mathrm{m/s}}{1\ \mathrm{s}}$$

2.2.7 Length: metre (symbol: m)

The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299 792 458 when expressed in the unit $\mathrm{m \cdot s^{-1}}$, where the second is defined in terms of $\Delta\nu_{\mathrm{Cs}}$ (26th CGPM, 2018).

2.2.8 Plane angle: radian (symbol: rad)

The radian is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

$$1\ \mathrm{rad} = \frac{1\ \mathrm{m}}{1\ \mathrm{m}} = 1$$

2.2.9 Solid angle: steradian (symbol: sr)

The steradian is the solid angle of a cone which, having its vertex in the center 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.

$$1\ \mathrm{sr} = \frac{1\ \mathrm{m^2}}{1\ \mathrm{m^2}} = 1$$

2.2.10 Area: square metre (symbol: $\mathrm{m^2}$)

The square metre is the area of a square of side 1 metre.

$$1\ \mathrm{m^2} = 1\ \mathrm{m} \cdot 1\ \mathrm{m}$$

2.2.11 Volume: cubic metre (symbol: $\mathrm{m^3}$)

The cubic metre is the volume of a cube of side 1 metre.

$$1\ \mathrm{m^3} = 1\ \mathrm{m} \cdot 1\ \mathrm{m} \cdot 1\ \mathrm{m}$$

2.3 Mechanics

2.3.1 Mass: kilogram (symbol: kg)

The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be $6.626\ 070\ 15 \cdot 10^{-34}$ when expressed in the unit J s, which is equal to $\mathrm{kg\ m^2\ s^{-1}}$, where the metre and the second are defined in terms of c and $\Delta\nu_{\mathrm{Cs}}$ (26th CGPM, 2018).

2.3.2 Lineic mass, linear density: kilogram per metre (symbol: kg/m or $kg \cdot m^{-1}$)

The kilogram per metre is the lineic mass of a homogeneous body of uniform section having a mass of 1 kilogram and a length of 1 metre.

$$1\ \text{kg/m} = \frac{1\ \text{kg}}{1\ \text{m}}$$

2.3.3 Areic mass, surface density: kilogram per square metre (symbol: kg/m^2 or $kg \cdot m^{-2}$)

The kilogram per square metre is the areic mass of a homogeneous body of uniform thickness having a mass of 1 kilogram and an area of 1 square metre.

$$1\ \text{kg/m}^2 = \frac{1\ \text{kg}}{1\ \text{m}^2}$$

2.3.4 Density (mass density): kilogram per cubic metre (symbol: kg/m^3 or $kg \cdot m^{-3}$)

The kilogram per cubic metre is the density of a homogeneous body having a mass of 1 kilogram and a volume of 1 cubic metre.

$$1\ \text{kg/m}^3 = \frac{1\ \text{kg}}{1\ \text{m}^3}$$

2.3.5 Force: newton (symbol: N)

The newton is the force which gives to a mass of 1 kilogram an acceleration of 1 metre per second, per second.

$$1\ \text{N} = \frac{1\ \text{kg}}{1\ \text{m/s}^2}$$

2.3.6 Moment of force: newton metre (symbol: $N \cdot m$)

The newton metre is a moment of force about a point which is equal to the vector product of a radius vector with a length of 1 metre from this point to a point on the line of action of the force, and the force equivalent to 1 N.

$$1\ \text{N} \cdot \text{m} = \frac{1\ \text{kg}}{1\ \text{m}^2/\text{s}^2}$$

2.3.7 Pressure, stress: pascal (symbol: Pa)

The pascal is the uniform pressure that, when acting on a plane surface of 1 square metre, exerts perpendicularly to that surface a total force of 1 newton. It is also the uniform stress that, when acting on a plane surface of 1 square metre, exerts on that surface a total force of 1 newton.

$$1\ \text{Pa} = \frac{1\ \text{N}}{1\ \text{m}^2}$$

2.3.8 Dynamic viscosity: pascal second (symbol: $Pa \cdot s$)

The pascal second is the dynamic viscosity of a homogeneous fluid in which the velocity varies uniformly in a direction normal to that of the flow with a variation of 1 metre per second over a distance of 1 metre, and in which there is a shear stress of 1 pascal.

$$1\ \text{Pa} \cdot \text{s} = \frac{1\ \text{Pa} \cdot 1\ \text{m}}{1\ \text{m/s}}$$

2.3.9 Kinematic viscosity: metre squared per second

(symbol: m^2/s or $m^2 \cdot s^{-1}$)

The metre squared per second is the kinematic viscosity of a fluid whose dynamic viscosity is 1 pascal second and whose density is 1 kilogram per cubic metre.

$$1\ m^2/s = \frac{1\ Pa \cdot s}{1\ kg/m^3}$$

2.3.10 Energy flow rate, heat flow rate, power: watt (symbol: W)

The watt is the power which in 1 second gives rise to energy of 1 joule.

$$1\ W = \frac{1\ J}{1\ s}$$

2.3.11 Volume flow rate: cubic metre per second (symbol: m^3/s or $m^3 \cdot s^{-1}$)

The cubic metre per second is the volume flow rate such that a substance having a volume of 1 cubic metre passes through the cross section considered in 1 second.

$$1\ m^3/s = \frac{1\ m^3}{1\ s}$$

2.3.12 Mass flow rate: kilogram per second (symbol: kg/s or $kg \cdot s^{-1}$)

The kilogram per second is the mass flow rate of a uniform flow such that a substance having a mass of 1 kilogram passes through the cross section considered in a time of 1 second.

$$1\ kg/s = \frac{1\ kg}{1\ s}$$

2.4 Electricity and magnetism

2.4.1 Electric current: ampere (symbol: A)

The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be $1.602\ 176\ 634 \cdot 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\Delta\nu_{Cs}$ (26th CGPM, 2018).

2.4.2 Quantity of electricity, electric charge: coulomb (symbol: C)

The coulomb is the quantity of electricity carried in 1 second by a current of 1 ampere.

$$1\ C = 1\ A \cdot 1\ s$$

2.4.3 Electric potential, electric tension, electromotive force: volt (symbol: V)

The volt is the potential difference between two points of a conducting wire carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

$$1\ V = \frac{1\ W}{1\ A}$$

2.4.4 Electric field strength: volt per metre (symbol: V/m)

The volt per metre is the strength of the electric field which exercises a force of 1 newton on a body charged with a quantity of electricity of 1 coulomb.

$$1\ V/m = \frac{1\ N}{1\ C}$$

2.4.5 Electric resistance: ohm (symbol: Ω)

The ohm is the electrical resistance between two points of a conductor when a constant potential difference of 1 volt, applied to these points, produces in the conductor a current of 1 ampere, the conductor not being the seat of any electromotive force.

$$1\ \Omega = \frac{1\ \mathrm{V}}{1\ \mathrm{A}}$$

2.4.6 Conductance: siemens (symbol: S)

The siemens is the conductance of a conductor having an electrical resistance of 1 ohm.

$$1\ \mathrm{S} = 1\ \Omega^{-1}$$

2.4.7 Electric capacitance: farad (symbol: F)

The farad is the capacitance of a capacitor between the plates of which there appears a potential difference of 1 volt when it is charged by a quantity of electricity of 1 coulomb.

$$1\ \mathrm{F} = \frac{1\ \mathrm{C}}{1\ \mathrm{V}}$$

2.4.8 Inductance: henry (symbol: H)

The henry is the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at the rate of 1 ampere per second.

$$1\ \mathrm{H} = \frac{1\ \mathrm{V} \cdot 1\ \mathrm{s}}{1\ \mathrm{A}}$$

2.4.9 Magnetic flux: weber (symbol: Wb)

The weber is the magnetic flux which, linking a circuit of one turn, would produce in it an electromotive force of 1 volt, if it were reduced to zero at a uniform rate in 1 second.

$$1\ \mathrm{Wb} = 1\ \mathrm{V} \cdot 1\ \mathrm{s}$$

2.4.10 Magnetic flux density, magnetic induction: tesla (symbol: T)

The tesla is the magnetic flux density produced within a surface of 1 square metre by a uniform magnetic flux of 1 weber perpendicular to this surface.

$$1\ \mathrm{T} = \frac{1\ \mathrm{Wh}}{1\ \mathrm{m}^2}$$

2.4.11 Magnetomotive force: ampere (symbol: A)

The magnetomotive force of 1 ampere is caused along any closed curve that passes once around an electric conductor through which an electric current of 1 ampere is passing.

2.4.12 Magnetic field strength: ampere per metre (symbol: A/m or $\mathrm{A} \cdot \mathrm{m}^{-1}$)

The ampere per metre is the strength of the magnetic field produced in vacuum along the circumference of a circle of 1 metre in circumference by an electric current of 1 ampere, maintained in a straight conductor of infinite length, of negligible circular cross section, forming the axis of the circle mentioned.

$$1\ \mathrm{A/m} = \frac{1\ \mathrm{A}}{1\ \mathrm{m}}$$

2.5 Heat

2.5.1 Thermodynamic temperature, interval of temperature: kelvin (symbol: K)

The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380 649 · 10^{-23} when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$ (26th CGPM, 2018).

Note: In addition to the thermodynamic temperature (symbol T), expressed in kelvins, use is also made of Celsius temperature (symbol t) defined by the equation:

$$t = T - T_0$$

where T_0 = 273.15 K by definition. To express Celsius temperature, the unit "degree Celsius" (symbol: °C) which is equal to the unit "kelvin" is used; in this case, "degree Celsius" is a special name used in place of "kelvin". An interval or difference of Celsius temperature can, however, be expressed in kelvins as well as in degrees Celsius.

2.5.2 Work, energy, quantity of heat: joule (symbol: J)

The joule is the work done when the point of application of 1 newton moves a distance of 1 metre in the direction of the force.

1 J = 1 N ·1 m

2.5.3 Entropy: joule per kelvin (symbol: J/K or J · K^{-1})

The joule per kelvin is the increase in the entropy of a system receiving a quantity of heat of 1 joule at the constant thermodynamic temperature of 1 kelvin, provided that no irreversible change takes place in the system.

$$1\ \text{J/K} = \frac{1\ \text{J}}{1\ \text{K}}$$

2.5.4 Massic heat capacity, specific heat capacity: joule per kilogram kelvin

(symbol: J/(kg · K) or J · kg^{-1} · K^{-1})

The joule per kilogram kelvin is the massic heat capacity of a homogeneous body at constant pressure or constant volume having a mass of 1 kilogram in which the addition of a quantity of heat of 1 joule produces a rise in temperature of 1 kelvin.

$$1\ \text{J/(kg}\cdot\text{K)} = \frac{1\ \text{J}}{1\ \text{kg}\cdot 1\ \text{K}}$$

2.5.5 Thermal conductivity: watt per metre kelvin (symbol: W/(m · K) or W · m^{-1} · K^{-1})

The watt per metre kelvin is the thermal conductivity of a homogeneous body in which a difference of temperature of 1 kelvin between two parallel planes having a surface of 1 square metre and which are 1 metre apart produces a heat flow rate of 1 watt between these planes.

$$1\ \text{W/(m}\cdot\text{K)} = \frac{1\ \text{W/m}^2}{1\ \text{K/m}}$$

2.6 Physical chemistry and molecular physics

2.6.1 Amount of substance: mole (symbol: mol)

2.6.1.1 The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.022\,140\,76 \cdot 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called Avogadro number (26th CGPM, 2018).

2.6.1.2 When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles (14th CGPM, 1971).

2.6.2 Catalytic activity: katal (symbol: kat)[2]

2.6.2.1 The katal is the activity of a catalyst which causes a catalysed conversion rate of one mole of substrate per second.

2.6.2.2 It is recommended that when the katal is used, the measurand be specified by reference to the measurement procedure; the measurement procedure must identify the indicator reaction (21st CGPM, 1999).

$$1\ \text{kat} = \frac{1\ \text{mol}}{1\ \text{s}}$$

2.7 Radiation and light

2.7.1 Radiant intensity: watt per steradian (symbol: W/sr or $W \cdot sr^{-1}$)

The watt per steradian is the radiant intensity of a point source emitting uniformly a radiant flux of 1 watt in a solid angle of 1 steradian.

$$1\ \text{W/sr} = \frac{1\ \text{W}}{1\ \text{sr}}$$

2.7.2 Luminous intensity: candela (symbol: cd)

The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency $540 \cdot 10^{12}$ Hz, K_{cd}, to be 683 when expressed in the unit $lm\,W^{-1}$, which is equal to $cd\,sr\,W^{-1}$, or $cd\,sr\,kg^{-1}\,m^{-2}\,s^3$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$ (26th CGPM, 2018).

2.7.3 Luminance: candela per square metre (symbol: cd/m^2 or $cd \cdot m^{-2}$)

The candela per square metre is the luminance perpendicular to the plane surface of 1 square metre of a source of which the luminous intensity perpendicular to that surface is 1 candela.

$$1\ \text{cd/m}^2 = \frac{1\ \text{cd}}{1\ \text{m}^2}$$

2.7.4 Luminous flux: lumen (symbol: lm)

The lumen is the luminous flux emitted in a unit solid angle of 1 steradian by a uniform point source having a luminous intensity of 1 candela.

$$1\ \text{lm} = 1\ \text{cd} \cdot 1\ \text{sr}$$

[2] Especially for the fields of medicine and biochemistry

2.7.5 Illuminance: lux (symbol: lx)

The lux is the illuminance of a surface receiving a luminous flux of 1 lumen, uniformly distributed over 1 square metre of the surface.

$$1\ \mathrm{lx} = \frac{1\ \mathrm{lm}}{1\ \mathrm{m}^2}$$

2.8 Ionizing radiations

2.8.1 Activity (of a radioactive source): becquerel (symbol: Bq)

The becquerel is the activity of a radioactive source in which the quotient of the expectation value of a number of spontaneous nuclear transitions or isomeric transitions and the time interval in which these transitions take place tends to the limit 1/s.

$$1\ \mathrm{Bq} = \frac{1}{1\ \mathrm{s}}$$

2.8.2 Absorbed dose, kerma: gray (symbol: Gy)

The gray is the absorbed dose or the kerma in an element of matter of 1 kilogram mass to which the energy of 1 joule is imparted by ionizing radiations (absorbed dose), or in which the sum of the initial kinetic energies of 1 joule is liberated by charged ionizing particles (kerma), each under a condition of constant energy fluence.

$$1\ \mathrm{Gy} = \frac{1\ \mathrm{J}}{1\ \mathrm{kg}}$$

2.8.3 Dose equivalent: sievert (symbol: Sv)[3]

The sievert is the dose equivalent in an element of tissue of 1 kilogram mass to which the energy of 1 joule is imparted by ionizing radiations whose value of the quality factor, which weights the absorbed dose for the biological effectiveness of the charged particles producing the absorbed dose, is 1 and whose energy fluence is constant.

$$1\ \mathrm{Sv} = \frac{1\ \mathrm{J}}{1\ \mathrm{kg}}$$

2.8.4 Exposure: coulomb per kilogram (symbol: C/kg or $\mathrm{C} \cdot \mathrm{kg}^{-1}$)

The coulomb per kilogram is the exposure of a photonic ionizing radiation that can produce, in a quantity of air of 1 kilogram mass, ions of one sign carrying a total electric charge of 1 coulomb when all the electrons (negatrons and positrons) liberated by photons in the air are completely stopped in air, the energy fluence being uniform in the quantity of air.

$$1\ \mathrm{C/kg} = \frac{1\ \mathrm{C}}{1\ \mathrm{kg}}$$

[3] The dose equivalent, H, is the product of Q and D at a point in tissue, where D is the absorbed dose and Q is the quality factor at that point, thus $H = Q \cdot D$ (ICRU Report 51, 1993).

3 Decimal multiples and sub-multiples of SI units

3.1 The decimal multiples and sub-multiples of SI units are formed by means of the decimal numerical factors set out below, by which SI unit concerned is multiplied.

3.2 The names of the decimal multiples and sub-multiples of the SI units are formed by means of SI prefixes designating the decimal numerical factors.

Factor		SI Prefix	Symbol
1 000 000 000 000 000 000 000 000	$= 10^{24}$	yotta	Y
1 000 000 000 000 000 000 000	$= 10^{21}$	zetta	Z
1 000 000 000 000 000 000	$= 10^{16}$	exa	E
1 000 000 000 000 000	$= 10^{12}$	peta	P
1 000 000 000 000	$= 10^{9}$	tera	T
1 000 000 000	$= 10^{6}$	giga	G
1 000 000	$= 10^{5}$	mega	M
1 000	$= 10^{3}$	kilo	k
100	$= 10^{2}$	hecto	h
10	$= 10^{1}$	deca	da
0.1	$= 10^{-1}$	deci	d
0.01	$= 10^{-2}$	centi	c
0.001	$= 10^{-3}$	millo	m
0.000 001	$= 10^{-6}$	micro	µ
0.000 000 001	$= 10^{-9}$	nano	n
0.000 000 000 001	$= 10^{-12}$	pico	p
0.000 000 000 000 001	$= 10^{-15}$	femto	f
0.000 000 000 000 000 001	$= 10^{-18}$	atto	a
0.000 000 000 000 000 000 001	$= 10^{-21}$	zepto	z
0.000 000 000 000 000 000 000 001	$= 10^{-24}$	yocto	y

3.3 A prefix is considered to be combined with the name of the unit to which it is directly attached.

3.4 The symbol of the prefix must be placed before the symbol of the unit without an intermediate space; the whole forms the symbol of the multiple or sub- multiple of the unit. The symbol of the prefix is therefore considered to be combined with the symbol of the unit to which it is directly attached, forming with it a new unit symbol which can be raised to a positive or negative power and which can be combined with other unit symbols to form the symbols for compound units.

3.5 Compound prefixes, formed by the juxtaposition of several SI prefixes, are not allowed.

3.6 The kilogram is the only coherent SI unit, whose name and symbol, for historical reasons, include a prefix. The names and the symbols of the decimal multiples and sub-multiples of the unit of mass are formed by the addition of the SI prefixes to the word "gram" (symbol: g).

1 g = 0.001 kg = 10^{-3} kg

3.7 To designate the decimal multiples and sub-multiples of a derived unit which is expressed in the form of a fraction, a prefix can be attached indifferently to the units which appear either in the numerator, or in the denominator, or in both of these terms. In standardization the general advice is not to use prefixes in the denominator.

4 Other units

4.1 Time

4.1.1 minute (symbol: min)

1 min = 60 s

4.1.2 hour (symbol: h)

1 h = 60 min = 3 600 s

4.1.3 day (symbol: d)[4]

1 d = 24 h = 86 400 s

4.2 Plane angle

4.2.1 degree (symbol: °)

$$1° = \frac{\pi}{180}\ \text{rad}$$

4.2.2 minute (symbol: ′)

$$1' = \left(\frac{1}{60}\right)^{\circ} = \frac{\pi}{10800}\ \text{rad}$$

4.2.3 second (symbol: ″)

$$1'' = \left(\frac{1}{60}\right)' = \frac{\pi}{648000}\ \text{rad}$$

4.2.4 gon (symbol: gon)

$$1\ \text{gon} = \frac{\pi}{200}\ \text{rad}$$

4.3 Volume

4.3.1 litre (symbol: l or L)

and the multiples and sub-multiples of the litre formed according to subclause 3.2.

1 l = 1 L = 1 dm^3 = 10^3 m^3

4.4 Mass

4.4.1 tonne (symbol: t)

and the multiples of the tonne formed according to subclause 3.2.

1 t = 1 Mg = 10^3 kg

[4] According to the Gregorian calendar, established in 1582, the year (symbol: a) consists of 365 days with a leap-year of 366 days every 4 years, whereas of the centenary years only those exactly divisible by 400 should be counted as leap-years.

4.4.2 dalton (symbol: Da) is equal to the fraction 1/12 of the mass of an atom of the nuclide carbon 12, at rest and in its ground state. The dalton and the unified atomic mass unit (symbol: u) are alternative names (and symbols) for the same unit.

Approximate value:

1 Da = 1.660 539 066 60(50) yg = 1.660 539 066 60(50) $\cdot$ 10^{-27} kg

Its use is authorized only in chemistry and physics.

4.5 Work, energy, quantity of heat

4.5.1 watt hour (symbol: W · h)

and the multiples and sub-multiples of the watt hour formed according to subclause 3.2.

1 W · h = 3.6 kJ = 3.6 $\cdot$ 10^3 J

4.5.2 electronvolt (symbol: eV)

equal to the kinetic energy acquired by an electron in passing through a potential difference of 1 volt in vacuum, and the multiples and sub-multiples of the electronvolt formed according to subclause 3.2.

Approximate value:

1 eV ≈ 160.217 7 zJ = 1.602 177 $\cdot$ 10^{-19} J

Its use is authorized only in specialized fields.

4.6 Logarithmic quantities

4.6.1 Field level, e.g. sound pressure level and logarithmic decrement

Units[5]: neper (symbol: Np)[6] [7]
bel (symbol: B)[8]

$$L_F = \ln\left(\frac{F}{F_0}\right) = \ln\left(\frac{F}{F_0}\right) \text{Np} = 2 \lg(F/F_0) \text{ B}$$

The neper is the level of a field quantity F when $F/F_0 = \mathrm{e}$, where F_0 is a reference quantity of the same kind, i.e.:

$$1 \text{ Np} = \ln (F/F_0) = \ln \mathrm{e} = 1$$

The bel is the level of a field quantity F when $F/F_0 = 10^{1/2}$, where F_0 is a reference quantity of the same kind, i.e.:

$$1 \text{ B} = \ln\left(\frac{F}{F_0}\right) = \ln 10^{1/2} \text{ Np} = \left(\frac{1}{2}\right) \ln 10 \text{ Np} = 2 \lg 10^{1/2} \text{ B}$$

4.6.2 Power level, e.g. power attenuation

Units[5]: neper (symbol: Np) [6] [7]
bel (symbol: B)[8]

[5] In using these units it is particularly important that the quantity be specified. The unit must be used to imply the quantity.

[6] The neper is coherent with the SI, but not yet adopted by the CGPM as an SI unit.

[7] To obtain the numerical values of quantities expressed in nepers, the natural logarithm must be used.

[8] To obtain the numerical values of quantities expressed in bels, decimal logarithms (logarithm to the base 10) must be used. The sub-multiple decibel is commonly used.

$$L_P = (1/2)\ \ln\left(\frac{P}{P_0}\right) = (1/2)\ \ln\left(\frac{P}{P_0}\right) \text{Np} = 2\ \lg(P/P_0)\ \text{B}$$

The neper is the level of a power quantity P when $P/P_0 = \mathrm{e}^2$, where P_0 is a reference power, i.e.:

$$1\ \text{Np} = (1/2)\ \ln\ (F/F_0) = (1/2)\ \ln\ \mathrm{e}^2 = 1$$

The bel is the level of a power quantity P when $P/P_0 = 10$, where P_0 is a reference power, i.e.:

$$1\ \text{B} = (1/2) \ln\left(\frac{P}{P_0}\right) = (1/2)\ \ln 10\ \ \text{Np} = \lg 10\ \text{B}$$

Annex A

Units of measurement and denominations which may be used temporarily up to a date which remains to be fixed by national regulations, but which shall not be introduced where they are not in use

A.1 Area

barn (symbol: b)

$1\ \mathrm{b} = 100\ \mathrm{fm}^2 = 10^{-28}\ \mathrm{m}^2$

Its use is authorized only in atomic and nuclear physics.

A.2 Dynamic viscosity

poise (symbol: P)

$1\ \mathrm{P} = 0.1\ \mathrm{Pa} \cdot \mathrm{s} = 10^{-1}\ \mathrm{Pa} \cdot \mathrm{s}$

centipoise (symbol: cP)

$1\ \mathrm{cP} = 1\ \mathrm{mPa} \cdot \mathrm{s} = 10^{-3}\ \mathrm{mPa} \cdot \mathrm{s}$

A.3 Kinematic viscosity

stokes (symbol: St)

$1\ \mathrm{St} = 100\ \mathrm{mm}^2/\mathrm{s} = 10^{-4}\ \mathrm{m}^2/\mathrm{s}$

centistokes (symbol: cSt)

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

A.4 Activity (of a radioactive source)

curie (symbol: Ci)

and the multiples and sub-multiples of the curie formed according to subclause 3.2.

$1\ \mathrm{Ci} = 37\ \mathrm{GBq} = 3.7 \cdot 10^{10}\ \mathrm{Bq}$

A.5 Absorbed dose

rad (symbol: rad)

and the multiples and sub-multiples of the rad formed according to subclause 3.2.

$1\ \mathrm{rad} = 0.01\ \mathrm{Gy} = 10^{-2}\ \mathrm{Gy}$

A.6 Exposure

röntgen (symbol: R)

and the multiples and sub-multiples of the röntgen formed according to subclause 3.2.

$1\ \mathrm{R} = 0.258\ \mathrm{mC/kg} = 2.58 \cdot 10^{4}\ \mathrm{C/kg}$

A.7 Pressure

millimetre of mercury (symbol: mmHg)

1 mmHg = 133.322 Pa

Its use is authorized only in specialized fields.

bar (symbol: bar)

and the multiples and sub-multiples of the bar formed according to subclause 3.2.

1 bar = 100 kPa = 10^5 Pa

A.8 Plane angle

revolution (turn), (symbol: r)

1 r = 2π rad

A.9 Vergency of optical systems

diopter

1 diopter = 1 m^{-1}

A.10 Area of farmland and estates

are (symbol: a)

1 a = 100 m^2= 10^2 m^2

hectare (symbol: ha)

1 ha = 0.01 km^2= 10^4 m^2

A.11 Metric carat (symbol: ct)[9]

1 ct = 0.2 g = $2 \cdot 10^{-4}$ kg

Its use is authorized only for indicating the mass of pearls and precious stones.

[9] The symbol "ct" is authorized neither by the CIPM nor by ISO, but is commonly used.

Annex B

Units of measurement and denominations whose use must be discontinued as soon as possible where they are currently in use and which shall not be introduced where they are not in use

B.1 Length

ångström (symbol: Å)

1 Å = 0.1 nm = 10^{-10} m

inch (symbol: in)

1 in = 2.54 cm = $2.54 \cdot 10^{-2}$ m

B.2 Volume (forestry management and timber trade)

stere (symbol: st) 1 st = 1 m^3

1 st = 1 m^3

B.3 Mass

quintal (symbol: q)

1 q = 100 kg = 10^2 kg

pound (symbol: lb)

1 lb = 453 592 g = 0.453 592 kg

B.4 Force

kilogram-force (symbol: kgf);
kilopond (symbol: kp)

and their decimal multiples and sub-multiples.

1 kgf = 1 kp = 9.806 65 N

B.5 Pressure

standard atmosphere (symbol: atm)

1 atm = 101.325 kPa = $1.013\,25 \cdot 10^5$ Pa

technical atmosphere (symbol: at)

1 at = 98.066 5 kPa = $0.980\,665 \cdot 10^5$ Pa

torr (symbol: Torr)

$$1\ \text{Torr} = \frac{101\,325}{760}\ \text{Pa}$$

metre of water (symbol: mH_2O)

1 mH_2O = 9.806 65 kPa = $9.806\,65 \cdot 10^3$ Pa

B.6 Work, energy, quantity of heat

kilogram force metre (symbol: kgf · m);
kilopond metre (symbol: kp· m)

1 kgf · m = 1 kp · m = 9.806 65 J

calorie (symbol: cal)

and its decimal multiples and sub-multiples.

1 cal = 4.186 8 J

B.7 Power

metric horsepower (cheval-vapeur)

1 metric horsepower = 0.735 498 75 kW = 735.498 75 W

B.8 Luminance

stilb (symbol: sb)

1 sb = 10 kcd/m^2 = 10^4 cd/m^2

Bibliography

- The International System of Units, 9th edition, 20 May 2019, BIPM
- ISO/IEC 80000 Series on Quantities and units