IEEE Standard Definitions for Selected Quantities, Units, and Related Terms, with Special Attention to the International System of Units (SI)

IEEE Standards Coordinating Committee 14

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(SCC14)

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Quantities, Units, and Letter Symbols Committee
of the
Standards Coordinating Committee 14 (SCC14)

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Abstract: The definitions for physical quantities and units commonly used in applied science and technology, and for related terms that concern systems of measurement, are included in this standard. Particular emphasis is placed on the International System of Units (*Le Système International d'Unités,* SI).

Keywords: International System of Units, measurement, metric, quantities, SI, units

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The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Introduction

This introduction is not part of IEEE Std 270-2006, IEEE Standard Definitions for Selected Quantities, Units, and Related Terms, with Special Attention to the International System of Units (SI).

This standard supersedes IEEE Std 270-1966. Since the 1966 standard was approved, significant changes have occurred in the International System of Units (SI). Corresponding updates have been issued for some of the documents referred to in this standard. Significantly, those updates represent a movement toward greater formalism in dealing with quantities and values—an area that has become known as the quantity calculus. Those updates also represent a movement toward global consensus, necessary for international harmonization of standards, which is needed for an increasingly global economy.

The global community has made great strides toward universally recognized and used units that transcend language groups, fields of study, and industries. The once common use of thousands of units, some arcane and used only in small fields, others more popularly used but varying in definition, has been replaced by a very small set of simple and well-defined units, the SI. Those defined units are based on fundamental physical quantities. The SI is a practical system. The Eighth Edition of the BIPM brochure [B1][a] on the International System of Units states "The definitions of the base units of the SI were adoped in a context that takes no account of relativistic effects. When such account is taken, it is clear that the definitions apply only in a small spatial domain sharing the motion of the standards that realize them."

The SI includes simple rules that provide robust means by which to combine that small set of units to meet nearly every need in commerce, science, engineering, and technology. Necessarily, the parsimonious nature of this system requires exacting compliance with the rules provided for using those units—a "grammar" that is as tight as its vocabulary is "succinct."

The global movement toward universally recognized and used quantities is paralleling the progress made on units, but it is not as greatly advanced. Nonetheless, great strides have been made and, increasingly, international consensus is consolidating the thousands of variants for quantity names and symbols to a smaller set. This consolidation of system of quantities, too, requires the use of rigid rules of the quantity calculus's "grammar" to ensure universal understanding and usefulness. It is appropriate, therefore, that the IEEE make this standard available to describe quantities commonly used or encountered in its community.

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[a] The numbers in brackets correspond to those of the bibliography in Annex B.

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Bruce B. Barrow
James R. Frysinger
Barry N. Taylor
Ambler Thompson
John T. Scott

The following members of the balloting committee voted on this standard as individuals. Balloters may have voted for approval, disapproval, or abstention.

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Gordon Aubrecht
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Contents

IEEE Standard Definitions for Selected Quantities, Units, and Related Terms, with Special Attention to the International System of Units (SI)

1. Overview

This standard is divided into the following three clauses: Clause 1 provides the scope and purpose of this standard and the methodology used in devising it; Clause 2 references IEEE Std 260.1™ and IEEE/ASTM SI 10; and Clause 3 provides definitions.[1] The definitions represent the bulk of the standard's material and the purpose of the revision. Annex A provides information on an alternative approach to the terms used in electricity and magnetism.

1.1 Scope

This standard includes definitions for physical quantities and units commonly used in applied science and technology, and related terms that concern systems of measurement. Particular emphasis is placed on the International System of Units (SI).

1.2 Purpose

IEEE Std 270-1966 attempted to cover not only quantities and units, but also the much broader area implied in its title, "General (Fundamental and Derived) Electrical and Electronics Terms." This scope proved to be far too broad, and the standard could not be maintained. The purpose of this revision is to present authoritative definitions of physical quantities and units and other terms relating to measurement systems, with particular emphasis on the vocabulary used in IEEE/ASTM SI 10.

1.3 Methodology

In the preparation of this standard, it was sometimes found that a formal definition is understandable only by the relatively few persons who are familiar with a particular branch of physics, mathematics, or other specialized field of knowledge. This standard will be referred to by many individuals who are not experts in a particular field; consequently, the Definitions Working Group (SCC14.2) decided that a simplified definition should occasionally accompany the more formal definition.

[1] For information on references, see Clause 2.

Definitions are meant to clarify selected terms. Occasionally, terms used in some definitions are defined themselves.

In the preparation of this standard, several references were consulted, as listed in the Bibliography (see Annex B). Many definitions in this standard reflect the wording used in these sources.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 260.1™, IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units).[2, 3]

IEEE/ASTM SI 10™, American National Standard for Use of the International System of Units (SI): The Modern Metric System.

3. Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B10][4] should be referenced for terms not defined in this clause.

- A -

3.1 A: Symbol for ampere, the SI unit of current.

3.2 absorbed dose: The mean energy imparted to an element of irradiated matter, for any ionizing radiation, divided by the mass of this element.

NOTE—The symbol for this quantity is D, and its SI unit is the gray (Gy).[5]

3.3 absorbed dose rate: The time rate of change of absorbed dose.

NOTE—The symbol for this quantity is $\mathrm{d}D/\mathrm{d}t$, and its SI unit is the gray per second (Gy/s).

3.4 acceleration: The time rate of change of velocity, $\mathrm{d}v/\mathrm{d}t$.

NOTE—The symbol for this quantity is a, and its SI unit is the meter per second squared (m/s^2).

3.5 acceleration of free fall; acceleration due to gravity: The acceleration experienced by an object in free fall, i.e., influenced only by the local gravitational field. *See:* **free fall; reference frame.**

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[2] The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.
[3] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[4] The numbers in brackets correspond to those of the bibliography in Annex B.
[5] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

NOTE 1—Specification of this quantity requires a reference frame. In many applications the reference frame is fixed to the surface of the rotating earth. Satellites and other space applications, however, use “inertial reference frames” that are fixed with respect to distant celestial bodies.

NOTE 2—In 1901, the CGPM defined a standard acceleration due to gravity, 9.806 65 m/s^2, that was used to define the now obsolete unit kilogram-force and similar force units. The local, but variable, acceleration of free fall at the surface of the Earth is close to this standard acceleration.

NOTE 3—The symbol for the standard acceleration due to gravity is g_n.

3.6 accuracy of measurement: The closeness of agreement between the result of a measurement and the true value of the measurand. *See:* **measurand; precision of measurement; uncertainty of measurement; true value.**

3.7 activity (of a radionuclide): The average number of spontaneous nuclear transitions from a particular energy state occurring in an amount of a radionuclide in a small time interval, divided by that interval.

NOTE—The symbol for this quantity is A, and its SI unit is the becquerel (Bq).

3.8 admittance: The ratio of the effective current I flowing in the circuit divided by the effective voltage E across its terminals. Voltage and current must be sinusoidal quantities of the same frequency. *See:* **effective current; effective voltage; sinusoidal quantity.**

NOTE—The symbol for this quantity is Y, and its SI unit is the siemens (S).

3.9 amount of substance: A physical quantity that is defined to be proportional to the number of specified elementary entities in a sample, the proportionality constant being a universal constant, which is the same for all samples. The elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles. *See:* **mole.**

NOTE—The symbol for this quantity is n, and its SI base unit is the mole (mol).

3.10 ampacity: The current in amperes that a conductor can carry continuously under the conditions of use for which it was designed, without exceeding its temperature rating.

3.11 ampere: That constant current that, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.

NOTE—The ampere, unit of electric current, is one of the seven base units of the SI.

3.12 ampere-turn: *See:* **magnetomotive force.**

NOTE—In the SI, the product of the current in a coil times the number of turns is expressed in amperes, not in ampere-turns.

3.13 amplitude (of a sinusoidal quantity): *See:* **sinusoidal quantity.**

3.14 angle (plane): A measure of the divergence of intersecting straight lines. The angle between two intersecting half-lines is defined as the ratio of the length of the included arc of a circle (with its center at the point of intersection) to the radius of that circle.

NOTE—The SI unit for plane angle is the radian (rad).

3.15 angle (solid): A measure of the divergence of a conical surface defined in three-dimensional space. The solid angle of a cone is defined as the ratio of the area cut out on a spherical surface (with its center at the apex of that cone) to the square of the radius of the sphere.

NOTE—The symbol for this quantity is Ω, and its SI unit is the steradian (sr).

3.16 ångström: A non-SI unit of length.

NOTE—The symbol for this unit is Å. Equivalent value in SI units: 1 Å = 10^{-10} m = 0.1 nm.

3.17 angular acceleration: The time rate of change of angular velocity, $\mathrm{d}\omega/\mathrm{d}t$.

NOTE—The symbol for this quantity is α and its SI unit is the radian per second squared ($\mathrm{rad/s^2}$).

3.18 angular frequency: The product of 2π rad and the frequency f of a sinusoidal periodic function.

NOTE—The symbol for this quantity is ω, and its SI unit is the radian per second (rad/s).

3.19 angular momentum: A quantity equal to the vector product of the radius vector from the origin of the chosen coordinate system and the linear momentum ($\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p}$) for a particle in motion.

NOTE 1—For a body in motion, angular momentum is the vector sum of the angular momenta of its constituent particles.

NOTE 2—The SI unit of angular momentum is the kilogram meter squared per second ($\mathrm{kg{\cdot}m^2/s}$).

NOTE 3—The angular momentum of a rigid body rotating around a fixed axis is equal to the product of the moment of inertia and the angular velocity vector.

3.20 angular velocity: The time rate of change of plane angle, $\mathrm{d}\theta/\mathrm{d}t$.

NOTE—The symbol for this quantity is ω, and its SI unit is the radian per second (rad/s).

3.21 ANSI: Abbreviation for American National Standards Institute.

3.22 area: Any particular extent of surface S defined by the double integral of $\mathrm{d}s_1\,\mathrm{d}s_2$ where s_1 and s_2 are perpendicular contours on the surface. In the special case of a planar surface, the contours are defined by the Cartesian coordinates, $s_1 = x$ and $s_2 = y$. In simpler terms, it is the size of that portion of a surface within a specified boundary.

NOTE—The symbol for area is A and its SI unit is the square meter ($\mathrm{m^2}$).

3.23 ASTM: Abbreviation for ASTM International.

NOTE—ASTM International, originally known as the American Society for Testing and Materials, was formed over a century ago and is one of the largest voluntary standards development organizations in the world.

3.24 atto: SI prefix that denotes multiplication by 10^{-18}.

3.25 AWG: Abbreviation for American Wire Gage.

NOTE—ASTM Std B258 assigns, at 20 °C, a diameter of 460 mils to AWG 4/0 conductor and a diameter of 5 mils to AWG 36 solid round wires used as electrical conductors. The diameters of the intervening conductors decrease in size by the ratio $(460/5)^{1/39} = 1.1229$. This factor is also used to extrapolate beyond the two defining sizes. *See:* **ASTM; mil.**

- B -

3.26 B: The symbol B stands for bel, a unit for level. *See:* **bel; level; decibel.**

3.27 bar: A non-SI unit of pressure. Equivalent value in SI units: 1 bar = 10^5 Pa = 100 kPa.

3.28 base quantity: One of the several quantities that, in a system of quantities, are conventionally accepted as independent of one another.

NOTE—The SI comprises seven base quantities: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity.

3.29 base unit (of measurement): A specific defined amount of a base quantity in a given system of quantities.

NOTE—In any coherent system of units, there is only one base unit for each base quantity. Thus, a base unit is the specific, defined magnitude of a base quantity. The SI possesses the following seven base units: the meter, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. They correspond, respectively, to specific, defined, magnitudes of the base quantities of length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity.

3.30 becquerel: A special name for the reciprocal second, to be used as the SI unit of activity of a radionuclide. *See:* **activity.**

NOTE—The symbol for becquerel, the SI unit of activity, is Bq.

3.31 bel (field level): A unit of level of a field quantity when logarithm to the base 10 is used. The level of a field quantity L_F is defined by $L_F = 2 \log_{10} (F/F_0)$, where F and F_0 represent amplitudes of the same kind, and F_0 is the reference amplitude. Thus, 1 B corresponds to a field ratio $F/F_0 = \sqrt{10}$. *See also:* **level; field quantity; decibel; neper.**

NOTE 1—The symbol for bel is B.

NOTE 2—The submultiple decibel is more commonly used (1 dB = 0.1 B).

3.32 bel (power level): A unit of level of a power quantity when logarithm to the base 10 is used. The level of a power quantity L_p is defined by $L_p = \log_{10}(P/P_0)$, where P is the power quantity of interest and P_0 is a reference power. Thus, 1 B corresponds to a power ratio $P/P_0 = 10$. *See also:* **level; level of a power quantity; level of a field quantity; neper**.

NOTE 1—The submultiple decibel is more commonly used (1 dB = 0.1 B).

NOTE 2—The bel may also be used to express the ratio of two field quantities. To obtain the same numerical value as for the corresponding power ratio, the logarithm of the field quantity ratio is multiplied by the factor 2. This calculation is valid provided that the power quantity is proportional to the square of the field quantity.

3.33 *BH* curve: A magnetization curve representing magnetic flux density (***B***) as a function of magnetic field strength (***H***).

NOTE—See the discussion of alternative terms in Annex A.

3.34 BIPM: Internationally used abbreviation for International Bureau of Weights and Measures (Bureau International des Poids et Mesures).

3.35 Bq: Symbol for becquerel, the SI unit of activity.

3.36 Btu: Symbol for British thermal unit, a non-SI unit of thermal energy.

NOTE—The Btu is the thermal energy required to increase the temperature of one pound of water by 1 °F. Measurements at different temperatures have produced a range of defined Btu values from 1054.35 J to 1059.67 J

- C -

3.37 C: Symbol for coulomb, the SI unit of electric charge.

3.38 calorie: A non-SI unit of thermal energy.

NOTE 1—The calorie is the thermal energy required to increase the temperature of one gram of water by 1 °C. Measurements at different temperatures have produced a range of energy values from 4.181 90 J to 4.190 02 J.

NOTE 2—The “calorie” used in nutrition is actually one kilocalorie.

3.39 candela: The SI unit of luminous intensity, one of the seven SI base units.

NOTE—The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz, and that has a radiant intensity in that direction of 1/683 W/sr.

3.40 capacitance: The electric charge carried by two bodies divided by the potential difference between them.

NOTE—The symbol for this quantity is C, and its SI unit is the farad (F).

3.41 cd: The symbol cd stands for candela, the SI unit of luminous intensity.

3.42 Celsius temperature: Temperature that is defined in terms of the thermodynamic temperature (*T*) by the numerical equation $\{t\}_{°C} = \{T\}_K - 273.15$.

NOTE—The symbol for Celsius temperature is *t*.

Example

A thermodynamic temperature of 300 K yields $\{t\}_{°C} = \{T\}_K - 273.15 = 300 - 273.15 = 26.85$. Thus, a thermodynamic temperature $T = 300$ K is equal to a Celsius temperature $t = 26.85$ °C.

3.43 centi: SI prefix that denotes multiplication by 10^{-2}.

3.44 centigrade: *See:* **degree centigrade.**

3.45 CGPM: Internationally used abbreviation for General Conference on Weights and Measures (Conférence Générale des Poids et Mesures).

3.46 cgs units: Units from systems that use the centimeter, gram, and second as base units. These systems of units are now obsolete.

3.47 cgs system: Several systems of units (now obsolete) constructed by using length, mass, and time as base quantities and the centimeter, gram, and second as base units. *See:* **system of units.**

3.48 circular mil: A non-SI unit of area used for the measurement of wire sizes. Equivalent value in SI units: 1 cmil = 506.71×10^{-12} m^2 (506.71 μm^2).

NOTE 1—The symbol for a circular mil is cmil.

NOTE 2—1 cmil is equal to the area of a circle having a diameter of 0.001 in. Thus, 1 cmil = $(\pi/4) \times (0.001 \text{ in})^2$.

NOTE 3—The symbol for 1000 cmil is kcmil.

3.49 CIPM: Internationally used abbreviation for International Committee for Weights and Measures (Comité International des Poids et Mesures).

3.50 coherent system of units (of measurement): A system in which all the derived units can be expressed as products of powers of the base units. *See:* **equation between numerical values; equation between quantities.**

Examples

In the field of mechanics, the following units (expressed by their symbols) form part of the coherent system of units of the International System of Units, SI.

m	m^2	m^3	kg	s	$m \cdot s^{-1}$	$m \cdot s^{-2}$	$kg \cdot m^{-3}$
$Hz = s^{-1}$		$N = kg \cdot m \cdot s^{-2}$		$J = kg \cdot m^2 \cdot s^{-2}$		$Pa = kg \cdot m^{-1} \cdot s^{-2}$	

NOTE—A coherent system of units is one wherein the equations between numerical values have the same form as the equations between physical quantities.

3.51 coherent (derived) unit (of measurement): A unit of measurement that is expressed as the product of powers of base units with the proportionality factor 1. *See:* **equation between quantities**.

NOTE—Coherence can be determined only with respect to the base units of a particular system of units. A unit may be coherent with respect to one system but not to another.

3.52 concentration of B: A component of a mixture, equal to the amount of substance of B divided by the volume of the mixture.

NOTE—The symbol for this quantity is c_B, and its SI unit is the mole per cubic meter (mol/m^3).

3.53 conductance (electric): *See:* **electric conductance.**

3.54 coulomb: Equal to the quantity of electricity, or charge, carried in 1 s by a current of 1 A as it passes a given point.

NOTE 1—The unit symbol for the coulomb is C.

NOTE 2—The coulomb is a special name for the SI unit, ampere second (C = A·s).

3.55 current density: A vector quantity, the integral of which over a given surface is equal to the electric current flowing through that surface. In simpler terms, it is the electric current flowing in a conductor divided by the cross-sectional area of the conductor.

NOTE—The SI unit of current density is the ampere per square meter (A/m^2).

3.56 current, electrical: *See:* **electric current.**

3.57 cycle: One full sequence of events that is repeated. It may be based on time, distance, or any other variable. *See:* **period.**

- D -

3.58 d: The symbol d stands for day.

3.59 day: A non-SI unit of time, recognized for use with the SI.

NOTE 1—The symbol d stands for day.

NOTE 2—Defined value in SI units: 1 d = 86 400 s.

3.60 deci: One of the SI prefixes that denotes multiplication by 10^{-1}.

3.61 decibel: A submultiple of the bel; 1 dB = 0.1 B. *See:* **bel; level; field quantity.**

NOTE—The symbol for decibel is dB.

3.62 degree (of angle): A non-SI unit of plane angle, recognized for use with the SI.

NOTE 1—The symbol for degree is °.

NOTE 2—Defined value in terms of SI units: 1° = (π /180) rad.

3.63 degree Celsius: A unit of temperature. *See:* **Celsius temperature.**

NOTE 1—The unit symbol for degree Celsius is °C.

NOTE 2—By definition, an interval of 1 °C is equal to an interval of 1 K.

3.64 degree centigrade: A unit of temperature that has been replaced by degree Celsius, which is defined in terms of thermodynamic principles. *See:* **degree Celsius.**

3.65 degree Fahrenheit: A unit of temperature. *See:* **Fahrenheit temperature.**

NOTE 1—The unit symbol for degree Fahrenheit is °F

NOTE 2—By definition, an interval of 1.8 °F is equal to an interval of 1 °C.

3.66 deka: One of the SI prefixes that denotes multiplication by 10.

NOTE—The symbol for the prefix deka is da.

3.67 density of charge (area): Electric charge expressed in coulombs per square meter (C/m^2).

3.68 density of charge (linear): Electric charge expressed in coulombs per meter (C/m).

3.69 density of charge (volume): Electric charge expressed in coulombs per cubic meter (C/m^3).

3.70 density (mass): Mass divided by volume.

NOTE—The symbol for this quantity is ρ, and its SI unit is the kilogram per cubic meter (kg/m^3).

3.71 derived quantity: A quantity defined, in a system of quantities, as a function of base quantities of that system. *See:* **equation between quantities.**

NOTE—A derived quantity is a quantity that is expressible in terms of the base quantities of a system of measurement. However, a derived quantity is often expressed in terms of other derived quantities. The physical relationship between the derived quantity and the base quantities (and/or other derived quantities) is expressed by means of equations between quantities.

Example

In a system having base quantities length, mass, and time, the derived quantity velocity is expressed by the equation between quantities: velocity equals length divided by time. Similarly, the quantity force is given by the equation between quantities: force equals mass times acceleration, which in turn can be expressed, in terms of base quantities, as force equals mass times length divided by time squared.

3.72 derived unit (of measurement): A unit of a derived quantity in a given system of measurement.

NOTE 1—Sometimes derived units are given special names. In the SI, a total of 22 derived units have been given special names and symbols approved by the CGPM. These derived units are listed alphabetically in Table 1.

NOTE 2—A derived unit is a specific, defined magnitude of a derived quantity. Derived units are formed by combining base units in accordance with the equations between quantities.

Table 1—SI derived units with special names and symbols

Special name	Unit symbol	Special name	Unit symbol
becquerel	Bq	newton	N
coulomb	C	ohm	Ω
degree Celsius	°C	pascal	Pa
farad	F	radian	rad
gray	Gy	siemens	S
henry	H	steradian	sr
hertz	Hz	sievert	Sv
joule	J	tesla	T
katal	kat	volt	V
lumen	lm	watt	W
lux	lx	weber	Wb

3.73 derived unit (with special name): A unit whose name and symbol have been approved by the CGPM.

3.74 dielectric constant: *See:* **permittivity (relative).**

3.75 digit: In a number system, a character that is used to express numbers of any value. In the decimal number system, a digit is one of the ten numerals (0 to 9). In the binary number system, a digit is usually 0 or 1. A digit may also indicate a position in a number.

3.76 digit (significant): A significant digit is any digit in a number that is necessary to define a numerical value, without regard to the position of the decimal point. *See:* **numerical value.**

NOTE 1—Significant digits of a number begin with the first digit on the left that is not zero and end with the last digit to the right that is not zero, or is a zero that is considered to be significant.

NOTE 2—The identification of significant digits is only possible through knowledge of the circumstances. For example, the number 1000 may be the result of rounding from 965, in which case only one zero is significant, or it may be rounded from 999.7, in which case all four digits are significant.

3.77 dimension (of a base quantity): Expresses the intrinsic nature of the base quantity, rather than its magnitude. Represented by a roman uppercase sans serif letter, and is distinct from the symbol for the base quantity. The respective quantity symbols and dimension symbols of the seven base quantities of the SI are shown in Table 2.

Table 2—Quantity and dimension symbols of SI base quantities

Quantity	Quantity symbol	Dimension symbol
Length	l	L
Mass	m	M
Time	t	T
Electric current	I	I
Thermodynamic temperature	T	θ
Amount of substance	n	N
Luminous intensity	I_v	J

3.78 dimension (of a derived quantity): S*implest* algebraic expression in terms of the powers of the dimensions of the base quantities.

Example

In a system having base quantities length, mass, and time, whose dimensional symbols are denoted by L, M, and T, respectively, LMT^{-2} is the dimension of force.

NOTE 1—Quantities of entirely different kind may share the same dimension. For example, precipitation, in cubic meters per square meter and per year, is dimensionally expressible by $\mathsf{L}^3/(\mathsf{L}^2\,\mathsf{T})$. However, by reducing it to its simplest algebraic form, we obtain the dimension LT^{-1}. This dimension is the same as that of speed (LT^{-1}), and yet the two quantities, precipitation and speed, have quite different meanings.

NOTE 2—The dimension of a quantity, when reduced to its simplest algebraic form, frequently yields the number 1. For example, the efficiency of a motor, expressed as mechanical power output divided by electric power input has a dimension of one (1). The reason is that the numerator and denominator can each be expressed in terms of the same dimension, namely $\mathsf{L}^2\mathsf{MT}^{-3}$. Consequently, when reduced to their simplest form, the exponents of the individual base dimensions are all zero, yielding the number 1 for the dimension of efficiency.

NOTE 3—The SI dimensions of several quantities are given in Table 3.

NOTE 4—The use of dimensional expressions is further elaborated in Part 31-0 of the ISO Standards Handbook, *Quantities and Units*, Third Edition [B15].

Table 3—SI dimensions of quantities

Acceleration	LT^{-2}
Power	$\mathsf{L}^2\mathsf{MT}^{-3}$
Plane angle	$\mathsf{L}\,\mathsf{L}^{-1}$ [= 1]
Magnetic flux	$\mathsf{L}^2\,\mathsf{M}\,\mathsf{T}^{-2}\mathsf{I}^{-1}$
Illuminance	$\mathsf{J}\,\mathsf{L}^{-2}$
Specific heat	$\mathsf{L}^2\mathsf{T}^{-2}\theta^{-1}$

3.79 dimension (geometric): A geometric element in a design, such as length or angle, or the magnitude of such a quantity.

3.80 dimensionless quantity: *See:* **quantity of dimension one.**

3.81 displacement: *See:* **electric flux density.**

3.82 dose equivalent: Dose equivalent is the product of D, Q, and N, at the point of interest in tissue, where D is the absorbed dose, Q is the quality factor, and N is the product of any other modifying factors.

NOTE—The symbol for this quantity is H, and its SI unit is the sievert (Sv).

3.83 dynamic viscosity: *See:* **viscosity.**

3.84 dyne: A cgs unit of force. Equivalent value in SI units: 1 dyne = 10^{-5} N = 10 μN.

- E -

3.85 effective current: The square root of the mean of the square of the current during one cycle.

NOTE—The effective value of a current that varies sinusoidally with time is equal to the amplitude of the current divided by $\sqrt{2}$.

3.86 effective voltage: The square root of the mean of the square of the voltage during one cycle.

NOTE—The effective value of a voltage that varies sinusoidally with time is equal to the amplitude of the voltage divided by $\sqrt{2}$.

3.87 electric charge: The integral of electric current over time.

NOTE—The symbol for electric charge is Q and its SI unit is the coulomb (C).

3.88 electric conductance: The reciprocal of electric resistance. *See:* **electric resistance.**

NOTE—The symbol for this quantity is G, and its SI unit is the siemens (S).

3.89 electric constant: A scalar constant such that, in vacuum, its product with the electric field strength E is equal the electric flux density D, thus, $D = \varepsilon_0 E$. *See also:* **magnetic constant.**

NOTE 1—The symbol for electric constant is ε_0. The value of $\varepsilon_0 = 8.854\ 187 \times 10^{-12}$ F/m.

NOTE 2—The electric constant is also called permittivity of vacuum, or permittivity of free space.

3.90 electric current: One of the seven SI base quantities. *See:* **ampere.**

NOTE—The quantity symbol for electric current is *I*, and its SI base unit is the ampere (A).

3.91 electric field strength: The force exerted by an electric field on an electric point charge divided by the electric charge.

NOTE 1—The symbol for electric field strength is *E*, and its SI unit is the volt per meter (V/m).

NOTE 2—The volt per meter (V/m) can also be expressed as newton per coulomb (N/C).

NOTE 3—See alternative term for *electric field strength* in Annex A.

3.92 electric flux density: A vector quantity, the divergence of which is equal to the volume density of charge.

NOTE—The symbol for this quantity is ***D***, and its SI unit is the coulomb per square meter (C/m^2).

3.93 electric hysteresis: A dielectric is an irreversible variation of the electric flux density, associated with a change in the electric field strength. *See:* **hysteresis.**

3.94 electric potential difference: Between two points in any medium, the line integral of the electric field strength along any path connecting those points. It is equal to the work done per unit charge to move a charge between the two points, and thus the difference in potential energy per unit charge.

NOTE—The SI unit for electric potential difference, the joule per coulomb, is given the special name volt (V).

3.95 electric resistance: The electric potential difference between two points of a conductor divided by the current flowing therein, the conductor not being the seat of any electromotive force.

NOTE—The symbol for this quantity is *R*, and its SI unit is the ohm (Ω).

3.96 electromotive force: The electric potential difference at the terminals of a source of electricity having zero internal resistance.

NOTE—The symbol for this quantity is *E*, and its SI unit is the volt (V), and the abbreviation is EMF.

3.97 electronvolt: A non-SI unit of energy. It is the kinetic energy acquired by an electron in passing through a potential difference of 1 V, in vacuum.

NOTE 1—The symbol for electronvolt is eV.

NOTE 2—The electronvolt is a unit in use with the SI.

NOTE 3—The value of the electronvolt is obtained experimentally. This value, in SI units, is 1 eV = $1.602\,176\,462(63) \times 10^{-19}$ J.

3.98 EMF: Abbreviation for electromotive force. *See:* **electromotive force.**

3.99 energy: This term characterizes the ability of a physical system to do work. *See:* **work.**

NOTE 1—The SI unit for energy is the joule (J).

NOTE 2—Energy has different forms, all of which may be transformed, in part or fully, into one another.

3.100 entropy: When a small quantity of heat dQ is received by a system, the thermodynamic temperature of which is T, the entropy of the system is increased by dQ/T, provided that no irreversible change takes place in the system. The symbol for this quantity is S, and its SI unit is the joule per kelvin (J/K).

3.101 equation between numerical values: A transformed version of an equation between quantities wherein each letter symbol represents only the {numerical value} of a specified quantity rather than {numerical value} × [unit]. Consequently, in a numerical equation the unit associated with each letter symbol must be specified.

NOTE—An equation between numerical values strongly resembles the corresponding equation between quantities, with the exception that it often carries a numerical coefficient that differs from the numerical coefficient in the equation between quantities. When the units are *coherent* (as they are in the SI), the said coefficient (usually 1) is the same in both types of equations. For this reason, in the SI, the equations between quantities and the corresponding equations between numerical values have the same form.

Example

The expression $F = ma$ is an equation between quantities. If we use newtons, kilograms, and feet per second squared as the units for force, mass, and acceleration, respectively, we can derive the following equation between numerical values. We begin with the quantity equation:

$F = ma$

$\{F\} \times [\text{newton}] = \{m\} \times [\text{kg}] \times \{a\} \times [\text{ft/s}^2]$

from which

$\{F\} = \{m\}\{a\} \times [\text{kg}]\ [\text{ft/s}^2] / [\text{newton}]$

converting feet (ft) to SI units, we obtain the following equation:

$\{F\} = \{m\}\{a\} \times [\text{kg}]\ [0.3048\ \text{m/s}^2]/ [\text{newton}]$

but since, by definition, $[\text{kg}]\ [\text{m/s}^2] = [\text{newton}]$

we obtain the equation between numerical values as follows:

$\{F\}_{\text{N}} = 0.3048\ \{m\}_{\text{kg}}\{a\}_{\text{ft/s2}}$

The symbols $\{F\}_{\text{N}}$, $\{m\}_{\text{kg}}$, and $\{a\}_{\text{ft/s2}}$ represent numerical values: $\{F\}_{\text{N}}$ = *number* of newtons; $\{m\}_{\text{kg}}$ = *number* of kilograms; $\{a\}_{\text{ft/s2}}$ = *number* of feet per second squared.

The numerical coefficient 0.3048 that appears in this numerical equation results from the particular units that were chosen; with other choices the coefficient would be different.

3.102 equation between quantities: Expresses the physical, mathematical, definitional, and/or geometric equality between quantities. Such an equation consists of letter symbols that denote the quantities that are entailed and dimensionless coefficients. Each symbol implicitly represents the product of a {numerical value} × [unit]. An equation between quantities has the merit of permitting any appropriate units to be used for its individual quantities.

Example

$F = ma$ is an equation between quantities

where

F	is the force
m	is the mass
a	is the acceleration

In applying $F = ma$, any appropriate units are acceptable for its several quantities.

Thus, if mass $m = 0.2$ kg and acceleration $a = 40$ ft/s^2, then

$F = 0.2 \text{ kg} \times 40 \text{ ft/s}^2 = 8 \text{ kg·ft/s}^2$.

Converting feet to SI units yields the following equation:

$F = 8 \times \text{kg} \times 0.3048 \text{ m/s}^2 = 2.44 \text{ kg·m/s}^2 = 2.44 \text{ N}$

NOTE—The unusual mixture of units in this example illustrates the freedom to use any system of units for the individual components of an equation between quantities.

3.103 eV: The symbol eV stands for electronvolt.

3.104 exa: The SI prefix that denotes multiplication by 10^{18}.

3.105 exposure (X- and gamma rays): The X- or gamma radiation, the total electric charge of the ions of the same sign produced when all the electrons (negative and positive) liberated by photons in an element of air are stopped in air, divided by the mass of that element. The symbol for this quantity is X, and its SI unit is the coulomb per kilogram (C/kg).

- F -

3.106 F: The symbol F stands for farad, the SI unit of capacitance.

3.107 Fahrenheit temperature: Temperature defined by the numerical equation $\{t\}_{°F} = 1.8\{t\}_{°C} + 32$. By convention, the symbol $\{t\}_{°F}$ represents the number of degrees Fahrenheit and $\{t\}_{°C}$ represents the number of degrees Celsius.

Example

A Celsius temperature of 300 °C corresponds to a Fahrenheit temperature whose numerical value is given as follows:

$\{t\}_{°F} = 1.8\{t\}_{°C} + 32 = 1.8 \times 300 + 32 = 572.$

Therefore 300 °C corresponds to a temperature of 572 °F.

NOTE—Fahrenheit temperature is related to Celsius temperature. By definition, 32 °F corresponds to 0 ºC, and 212 °F corresponds to 100 °C. Hence, an interval of 1.8 ºF corresponds to an interval of 1 ºC.

3.108 farad: The SI unit of capacitance. It is the capacitance of a capacitor between the plates of which there appears a difference of potential of 1 V when it is charged by a quantity of electric charge equal to 1 C.

NOTE 1—The symbol for farad, the SI unit of capacitance, is F.

NOTE 2—The farad is the special name for coulomb per volt (F = C/V).

3.109 femto: The SI prefix that denotes multiplication by 10^{-15}.

3.110 field quantity: A scalar, vector, or tensor quantity, existing at each point of a defined region and depending on the position of the point.

NOTE 1—A field quantity may be a function of time.

NOTE 2—A field quantity is also used to denote a quantity such as voltage, current, sound pressure, electric field strength, the square of which, in linear systems, is proportional to power.

3.111 footcandle: A non-SI unit of illuminance equal to one lumen per square foot (lm/ft^2).

NOTE—Equivalent value in SI units: 1 footcandle = 10.7639 lux.

3.112 force: The push or pull exerted on a body or on an electric charge.

NOTE 1—The symbol for this quantity is F, and its SI unit is the newton (N).

NOTE 2—A force is always an *interaction* between objects or electric charges.

3.113 frame of reference: *See:* **reference frame.**

3.114 free fall: The motion of an object influenced only by gravity at the position of the object. The conditions of free fall are realized in vacuum and in the absence of all force fields other than the gravitational field.

3.115 frequency (of a periodic phenomenon): The reciprocal of the period. The frequency expresses the number of cycles that occur in a given time interval. *See:* **cycle; period.**

NOTE—The symbol for this quantity is f, and its SI unit is the hertz (Hz).

- G -

3.116 gallon (imperial): A non-SI unit of volume that is part of the British Imperial System of units.

NOTE—Defined value in SI units: 1 gallon (Imperial) = $4.546\ 09 \times 10^{-3}\ m^3$.

3.117 gallon (US): A non-SI unit of volume that is used in the United States. Defined value in SI units: 1 gallon (US) = $3.785\ 411\ 784 \times 10^{-3}\ m^3$.

3.118 gauss: A cgs unit of magnetic flux density. Equivalent value in SI units: 1 gauss = 10^{-4} T.

3.119 General Conference on Weights and Measures: Consists of delegates from the member nations of the Treaty of the Meter and meets, at present, every four years. *See also:* **Meter Convention; International Committee for Weights and Measures.**

NOTE—The abbreviation for Conférence Générale des Poids et Mesures (General Conference on Weights and Measures) is CGPM.

3.120 giga: The SI prefix that denotes multiplication by 10^9.

3.121 gram: A submultiple of the kilogram equal to 1/1000 kg.

3.122 gray: The SI unit of absorbed dose; it is a special name for joule per kilogram, used in connection with radiation health for (1) specific energy imparted, and (2) absorbed dose (Gy = J/kg).

NOTE—The symbol for gray, the SI unit of absorbed dose, is Gy.

3.123 Gy: The symbol Gy stands for gray, the SI unit of absorbed dose.

- H -

3.124 h: The symbol h stands for hour.

3.125 H: The symbol H stands for henry, the SI unit of inductance.

3.126 ha: The symbol ha stands for hectare. *See:* **hectare.**

3.127 half-life: The average time required for the decay of one half of the atoms of a sample of a radioactive nuclide. *See:* **mean life.**

3.128 heat: Energy in transit from one body to another as a result of a difference in temperature.

NOTE 1—The SI unit of heat is the joule (J).

NOTE 2—It is incorrect to speak of the heat of a body, because heat is restricted to describe energy being transferred.

3.129 heat capacity (of a body): The quantity $\mathrm{d}Q/\mathrm{d}T$, where $\mathrm{d}T$ is the increase in temperature of a body that results from the addition of a small quantity of thermal energy $\mathrm{d}Q$.

NOTE—The symbol for heat capacity is C and its SI unit is the joule per kelvin (J/K).

3.130 heat flow rate: The rate at which heat crosses a given surface.

NOTE—The symbol for this quantity is φ, and its SI unit is the watt (W).

3.131 hectare: A non-SI unit of area, recognized for use with the SI. Defined value in SI units: 1 ha = 10 000 m^2.

NOTE—The symbol for hectare is ha.

3.132 hecto: The SI prefix that denotes multiplication by 10^2.

3.133 henry: The inductance of a closed circuit in which an electromotive force of 1 V is produced when the electric current in the circuit varies uniformly at a rate of 1 A/s.

NOTE 1—The symbol for henry, the SI unit of inductance, is H.

NOTE 2—The henry is a special name for volt second per ampere.

3.134 hertz: The SI unit of frequency of a periodic process. It is the frequency for which the period is 1 s. Thus, hertz is a special name for the unit s^{-1}.

NOTE—The symbol for hertz, the SI unit of frequency, is Hz.

3.135 hour: A non-SI unit of time, formally recognized for use with the SI. Defined value in SI units: 1 h = 3600 s.

NOTE—The symbol for hour is h.

3.136 hysteresis: A phenomenon represented by a closed characteristic curve that has a branch, called ascending branch, for increasing values of the input variable, and a different branch, called descending branch, for decreasing values of the input variable. The area between branches does not close as the time rate of change between inceasing and decreasing values of the input variable tends toward zero (quasistatic condition).

3.137 Hz: The symbol Hz stands for hertz, the SI unit of frequency.

- I -

3.138 IEC: Internationally used abbreviation for International Electrotechnical Commission.

3.139 IEEE: Internationally used abbreviation for Institute of Electrical and Electronics Engineers.

3.140 illuminance:, The luminous flux incident on an element of the surface, divided by the area of that element, at a point on a surface.

NOTE—The symbol for this quantity is *E*, and its SI unit is the lumen per square meter, given the special name lux (lx).

3.141 impedance: The ratio of the effective voltage *E* across the terminals of an electric circuit to the effective current *I* flowing through it. The voltage and current must both be alternating sinusoidally at the same frequency. *See:* **effective voltage; effective current.**

NOTE—The symbol for this SI quantity is *Z* and its unit is the ohm (Ω).

3.142 inductance (mutual): The ratio of the voltage that is induced in a circuit to the rate of change of current in another circuit.

NOTE—The symbol for this quantity is *M*, and its SI unit is the henry (H).

3.143 inductance (self): The ratio of the voltage that is induced in a circuit to the rate of change of current in the same circuit.

NOTE—The symbol for this quantity is *L*, and its SI unit is the henry (H).

3.144 inertia: Refers to that property of matter by virtue of which any material body continues its state of movement or rest in the absence of an external force.

NOTE—Inertia is not a quantity; consequently, it does not have a unit.

3.145 International Bureau of Weights and Measures: Ensures worldwide unification of physical measurements. *See also:* **International Committee for Weights and Measures; General Conference on Weights and Measures.**

NOTE 1—The abbreviation for Bureau International des Poids et Mesures (International Bureau of Weights and Measures) is BIPM.

NOTE 2—The BIPM operates under the exclusive supervision of the International Committee for Weights and Measures, which, itself, comes under the authority of the General Conference on Weights and Measures.

3.146 International Committee for Weights and Measures: Body responsible for supervision of the International Bureau of Weights and Measures, the preparation of an annual report to provide administrative and financial information to the governments of the member nations of the Meter Convention, and the operations of a number of technical Consultative Committees. *See also:* **General Conference on Weights and Measures; International Bureau of Weights and Measures.**

NOTE 1—The internationally used abbreviation for International Committee for Weights and Measures is CIPM (Comité International des Poids et Mesures).

NOTE 2—The International Committee for Weights and Measures functions under the authority of the General Conference on Weights and Measures. It consists of 18 members, each belonging to a different nation. At present, it meets every year.

3.147 International System of Units: A coherent system of units developed and maintained by the General Conference on Weights and Measures and intended as a basis for worldwide standardization of measurement units. The SI constitutes the modern metric system of units. *See also:* **Système International d'Unités (Le)**.

NOTE—The abbreviation for International System of Units/Le Système International d'Unités is SI. The abbreviation SI is used throughout the world, in all languages.

3.148 irradiance:, The radiant energy flux incident on an element of the surface, divided by the area of that element, at a point on a surface.

NOTE—The symbol for this quantity is E and its SI unit is the watt per square meter (W/m^2).

3.149 ISO: Internationally used abbreviation for International Organization for Standardization.

- J -

3.150 J: The symbol J stands for joule, the SI unit of energy or work.

3.151 joule: The joule (J) is the SI unit of energy or work. It is the work done when the point of application of a force of 1 N is displaced a distance of 1 m in the direction of the force. The joule is a special name for newton meter (J = N·m).

NOTE—The symbol for joule, the SI unit of energy or work, is J.

- K -

3.152 K: The symbol K stands for kelvin, the SI unit of thermodynamic temperature.

3.153 kat: The symbol kat stands for katal, the SI unit of catalytic activity.

3.154 katal: The katal is the SI unit of catalytic activity. The katal is a special name for 1 mol/s.

NOTE 1—The symbol kat stands for katal, the SI unit of catalytic activity.

NOTE 2—The special name *katal* was adopted by Resolution 12 of the 21st General Conference of Weights and Measures in October 1999.

3.155 kcmil: This is a symbol for one thousand circular mils. *See:* **circular mil.**

3.156 kelvin: The SI unit of thermodynamic temperature, one of the seven SI base units. It is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. *See:* **triple point of water.**

NOTE—The symbol for kelvin, the SI unit of thermodynamic temperature, is K.

3.157 kerma:, The sum of the initial energies of all charged particles liberated in an element of matter, divided by the mass of that element, for indirectly ionizing (uncharged) particles.

NOTE 1—The symbol for this quantity is K, and its SI unit is the gray (Gy).

NOTE 2—The name kerma is an acronym for kinetic energy released in matter.

3.158 kg: The symbol kg stands for kilogram, the SI unit of mass.

3.159 kilo: The SI prefix that denotes multiplication by 10^3.

3.160 kilogram: The kilogram is the SI unit of mass, one of the seven SI base units. The kilogram is equal to the mass of the international prototype of the kilogram, an artifact that is conserved at the International Bureau of Weights and Measures, near Paris.

NOTE—The symbol for kilogram, the SI unit of mass, is kg.

3.161 kilogram-force: A non-SI unit of force. Defined value in SI units: 1 kgf = 9.806 65 N.

NOTE—The abbreviation of kilogram-force is kgf.

3.162 kilowatt-hour: A widely used non-SI unit for the measurement of electric energy. Defined value in SI units: 1 kWh = 3.6 MJ.

NOTE—kWh (or kW·h) is the generally accepted symbol for kilowatt-hour.

3.163 kinematic viscosity: *See:* **viscosity (kinematic).**

3.164 knot: A non-SI unit of speed equal to one nautical mile per hour. Defined value in SI units: 1 knot = (1852/3600) m/s.

3.165 kWh (or kW·h): The kWh is the generally accepted symbol for kilowatthour.

- L -

3.166 L: The symbol L stands for liter.

3.167 lb: The unit symbol lb stands for pound. *See:* **pound.**

3.168 lbf: The symbol lbf stands for pound-force. *See:* **pound-force.**

3.169 length: One of the seven base quantities of the SI.

NOTE—The quantity symbol for length is l, and its SI unit is the meter (m).

3.170 level: This term is given to the logarithm of the ratio of a given quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

NOTE—The kind of level is indicated by use of a compound term such as sound power level or sound pressure level.

3.171 level of a field quantity ($\log_{10}$-based): Defined by the following expression: $L_F = 2 \log_{10} (F/F0)$, where F and F_0 represent two amplitudes of the same kind, F_0 being a reference amplitude. *See:* **level; field quantity; bel.**

NOTE—The symbol for this quantity is L_F, and its unit is the bel (B).

Example

Given $F = 25$ V and $F_0 = 0.15$ V, the level of the field quantity is $L_F = 2 \log_{10} (F/F_0) = 2 \log_{10} (25/0.15) = 4.44$ B = 44.4 dB.

3.172 level of a field quantity ($\log_e$-based): This term is defined by the following expression: $L_F = \log_e (F/F_0)$, where F and F_0 represent two amplitudes of the same kind, F_0 being a reference amplitude. *See:* level; field quantity; neper.

NOTE—The symbol for this quantity is L_F, and its unit is the neper (Np).

Example

Given $F = 25$ V and $F_0 = 0.15$ V, the level of the field quantity is $L_F = 2 \log_e (F/F_0) = \log_e (25/0.15) = 5.12$ Np.

3.173 level of a power quantity ($\log_{10}$-based): This term is defined by the following expression: $L_p = \log_{10} (P/P_0)$, where P and P_0 represent two powers, P_0 being a reference power. *See:* **level; field quantity; bel.**

NOTE—The symbol for this quantity is L_p, and its unit is the bel (B).

Example

Given $P = 25$ W and $P_0 = 0.15$ W, the level of the power quantity is $L_p = \log_{10} (P/P_0) = \log_{10} (25/0.15) = 2.22$ B = 22.2 dB.

3.174 level of a power quantity ($\log_e$-based): This term is $\log_e$-based is defined by the following expression: $L_p = (1/2) \log_e (P/P_0)$, where P and P_0 represent two powers, P_0 being a reference power. *See:* **level; field quantity; neper.**

NOTE—The symbol for this quantity is L_p, and its unit is the neper (Np).

Example

Given $P = 25$ W and $P_0 = 0.15$ W, the level of the power quantity is $L_p = (1/2)\log_e (P/P_0) = (1/2)\log_e (25/0.15) = 2.56$ Np.

3.175 light year: A non-SI unit of length used in astronomy. Equivalent value in SI units: 1 light year = $9.460\,528 \times 10^{15}$ m.

3.176 liter: An alternative name for the cubic decimeter. It is not an SI name, but it is accepted for use with the SI. Equivalent value in SI units: 1 L = 1 $dm^3 = 10^{-3}$ m^3. The term is used to express volumetric capacity, dry measure, and measure of fluids (both liquids and gases).

NOTE 1—The symbol for liter is L.

NOTE 2—An alternative spelling for liter is litre.

3.177 lm: The symbol lm stands for lumen, the SI unit of luminous flux.

3.178 load: In a *mechanical* context the term is related to either mass, force, or pressure, depending on its intended use. In an *electrical* context the term means (a) a device that absorbs power or (b) the power delivered by a source. The term comprises all the electrical and/or mechanical quantities that signify the demand to be made at a given instant on a rotating machine, an electric circuit, a mechanism, or a structure.

NOTE—For example, the term "load" is expressible in the following SI units: kilograms, newtons, pascals, kilowatts, kilovolt amperes, newtons per meter, kilograms per square meter, and so forth, depending upon the intended meaning of the term.

3.179 lumen: The SI unit of luminous flux. It is the luminous flux emitted in a solid angle of one steradian by a point source having a uniform intensity of one candela. The lumen is a special name for candela steradian (lm = cd·sr).

NOTE—The symbol for lumen, the SI unit of luminous flux, is lm.

3.180 luminance: The luminous intensity of an element of the surface divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction, at a point of a surface and in a given direction.

NOTE—The symbol for this quantity is L and its unit of measurement is the candela per square meter (cd/m^2), a derived unit in the SI.

3.181 luminous flux: The quantity $d\Phi$ that is equal to $I\, d\Omega$, where I is a source of luminous intensity in an element of solid angle $d\Omega$.

NOTE—The symbol for luminous flux is Φ and its SI unit is the lumen (lm).

3.182 luminous intensity: The base SI quantity required for the study of light. It is one of the seven SI base quantities.

NOTE—The quantity symbol for luminous intensity is I_v, and its base SI unit is the candela (cd).

3.183 lux: The SI unit of illuminance, equal to one lumen per square meter.

3.184 lx: The symbol lx stands for lux, the SI unit of illuminance.

- M -

3.185 m: The symbol m stands for meter, the SI unit of length.

3.186 magnetic constant: A scalar constant such that, in vacuum, its product with the magnetic field strength H is equal to the magnetic flux density B; thus, $B = \mu_0 H$. The value of $\mu_0 = 4\pi \times 10^{-7}$ H/m.

NOTE 1—The symbol for magnetic constant is μ_0.

NOTE 2—The magnetic constant is also called permeability of vacuum, or permeability of free space.

NOTE 3—The reciprocal square root of the product of the magnetic constant μ_0 and the electric constant ε_0 is equal to the speed of light in vacuum c, expressed in m/s. Symbolically, $c = 1/\sqrt{(\mu_0\varepsilon_0)}$.

3.187 magnetic field strength: A vector quantity obtained at a given point by subtracting the magnetization $\boldsymbol{M}$ from the magnetic flux density $\boldsymbol{B}$ divided by the magnetic constant μ_0: $\boldsymbol{H} = \boldsymbol{B}/\mu_0 - \boldsymbol{M}$.

NOTE 1—The symbol for magnetic field strength is $\boldsymbol{H}$.

NOTE 2—The SI unit of magnetic field strength is ampere per meter (A/m).

NOTE 3—In vacuum, the magnetic field strength is at all points equal to the magnetic flux density divided by the magnetic constant: $\boldsymbol{H} = \boldsymbol{B}/\mu_0$.

NOTE 4—The curl of the magnetic field strength is the total current density curl $\boldsymbol{H} = \boldsymbol{J}_\mathbf{t}$.

3.188 magnetic flux: The integral of the scalar product of the magnetic flux density, across a surface area, and the surface element $\Phi = \int \boldsymbol{B} \cdot d\boldsymbol{A}$. In simpler terms, it is an SI-derived quantity that may be defined as follows: an elementary magnetic flux is the product of a small surface area and the component of the magnetic flux density that is perpendicular to it. The sum of these elementary fluxes crossing a given area is equal to the magnetic flux.

NOTE—The symbol for magnetic flux is Φ and its SI unit is the weber (Wb).

3.189 magnetic flux density: A vector quantity such that the force F exerted on an element of electric current $I\mathrm{d}\boldsymbol{r}$ is equal to the vector product of this element and the magnetic flux density, $\mathrm{d}\boldsymbol{F} = I\mathrm{d}\boldsymbol{r} \times \boldsymbol{B}$ where $\mathrm{d}\boldsymbol{r}$ is in the direction of the current. In simpler terms, it is a quantity that may be defined as follows: consider an electric current I flowing in a straight conductor having a length l immersed in a magnetic field of uniform flux density $\boldsymbol{B}$ and oriented at right angles thereto. The conductor will be subjected to a force $\boldsymbol{F}$. The flux density of the magnetic field where the length of conductor is located is given by the expression: $B = F/(Il)$. Flux density can therefore be expressed in terms of newtons per ampere meter (N/(A·m)).

NOTE 1—The symbol for magnetic flux density is $\boldsymbol{B}$ and its SI unit is the tesla (T).

NOTE 2—See the discussion of alternative terms in Annex A.

3.190 magnetic hysteresis: A ferromagnetic or ferrimagnetic substance is the incompletely reversible variation of the magnetic flux density or magnetization that is associated with the change of magnetic field strength and is independent of the rate of change. *See:* **hysteresis.**

3.191 magnetic permeability: The ratio of magnetic flux density $\boldsymbol{B}$ to magnetic field strength $\boldsymbol{H}$.

NOTE 1—The symbol for this quantity is μ, and its SI unit is the henry per meter (H/m).

NOTE 2—The term magnetic permeability is sometimes called absolute magnetic permeability to distinguish it from the dimensionless quantity μ/μ_0, which is called relative permeability.

3.192 magnetomotive force: The scalar line integral of the magnetic field strength ($\boldsymbol{H}$) along a closed path.

NOTE 1—The symbol for magnetomotive force is F_m and its SI unit is the ampere (A).

NOTE 2—The magnetomotive force is equal to the total electric current through any surface bounded by that path.

NOTE 3—In the SI, the product of the current in a coil times the number of turns is expressed in amperes, not in ampere-turns.

3.193 mass: An SI base quantity.

NOTE 1—The quantity symbol for mass is m, and its SI unit is the kilogram (kg).

NOTE 2—Mass is the defining property of matter; it determines the acceleration that a free body will have when acted upon by a given force.

3.194 maxwell: A cgs unit of magnetic flux. Equivalent value in SI units: 1 maxwell = 10^{-8} Wb.

3.195 mean life: For an exponentially decaying population of particles, it is the time duration for the number of particles to decrease to 1/e of the initial value, where e is the base of natural logarithms (e = 2.718 28...). *See:* **half-life.**

3.196 measurement: Refers to a set of operations having the object of determining the value of a quantity.

3.197 measurand: A particular quantity, subject to measurement.

3.198 measured value of a quantity: That value measured under actual conditions using a proven method. The measured value will, to some extent, differ from the true value, owing to the limited precision and less-than-perfect accuracy of any real method of measurement. *See:* **uncertainty; true value.**

3.199 mega: The SI prefix that denotes multiplication by 10^6.

NOTE—The symbol for the prefix mega is M.

3.200 meter: The SI unit of length, one of the seven SI base units. It is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

NOTE 1—The symbol for meter, the SI unit of length, is m.

NOTE 2—Metre is an alternative spelling of meter.

3.201 Meter Convention: The Meter Convention (Convention du Mètre), also called “Treaty of the Meter”, was signed in Paris on 20 May 1875 by seventeen nations (including the United States) during the final session of the Diplomatic Conference of the Meter. This Convention was amended in 1921. *See also:* **General Conference of Weights and Measures; International Committee for Weights and Measures.**

3.202 metric system: Any of a number of decimal systems of units, including, for example, the centimeter-gram-second (cgs) system, the meter-kilogram-second system (MKS), the electrostatic system of units (esu), the electromagnetic system of units (emu), the practical system of units, and the International System of Units (SI).

NOTE—With the exception of the International System of Units (SI), the above-mentioned metric systems are all obsolete.

3.203 metric ton: A unit of mass. It is not an SI unit, but it is accepted for use with the SI. Defined value in SI units: 1 t = 1000 kg = 1 Mg.

NOTE—The symbol for metric ton is t.

3.204 micro: The SI prefix that denotes multiplication by 10^{-6}.

NOTE—The symbol for the prefix micro is μ.

3.205 mil: A non-SI unit of length equal to 0.001 in. Equivalent value in SI units: 1mil = 25.4 μm.

3.206 milli: The SI prefix that denotes multiplication by 10^{-3}.

NOTE—The symbol for the prefix milli is m.

3.207 min: The symbol min stands for minute, a unit of time.

3.208 minute: A unit of time, formally recognized for use with the SI. Defined value in SI units: 1 min = 60 s.

NOTE—The symbol for minute, a unit of time, is min.

3.209 minute (of angle): A unit of plane angle, formally recognized for use with the SI. Defined value in SI units: 1' = (π/10 800) rad.

NOTE—The symbol for minute of angle is '.

3.210 mol: The symbol mol stands for mole, the SI unit of amount of substance.

3.211 molar heat capacity: Heat capacity divided by amount of substance.

NOTE—The symbol for this quantity is C_{m}, and its SI unit is the joule per mole kelvin (J/(mol·K)).

3.212 molar thermodynamic energy: Thermodynamic energy divided by amount of substance.

NOTE—The symbol for this quantity is U_{m}, and its SI unit is the joule per mole (J/mol).

3.213 molar entropy: Entropy divided by amount of substance.

NOTE—The symbol for this quantity is S_{m}, and its SI unit is the joule per mole kelvin (J/(mol·K)).

3.214 mole: The SI unit of amount of substance, one of the seven SI base units. It is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kg of carbon-12. *See:* **amount of substance.**

NOTE 1—The symbol for mole, the SI unit of amount of substance, is mol.

NOTE 2—When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, photons, other particles, or specified groups of such particles.

3.215 mole fraction of B: The ratio of the amount of substance of B to the amount of substance of the mixture. It is a quantity that has the dimension of mol/mol, hence a dimension of 1.

NOTE—Mole fraction provides a way of being precise and is preferable to the non-SI designations ppm (parts per million) and ppb (parts per billion).

3.216 moment of force: The vector product $\boldsymbol{M}$ of the force $\boldsymbol{F}$ and any radius vector $\boldsymbol{r}$ from the point of reference to a point on the line of action of the force ($\boldsymbol{M} = \boldsymbol{r} \times \boldsymbol{F}$). Often called torque. *See:* **torque.**

NOTE—The symbol for this quantity is M, and its SI unit is the newton meter (N·m).

3.217 moment of inertia: Property of a body about an axis of rotation equal to the sum of the products of the elementary masses that make up the body and the squares of their distances from the axis: $J = \int r^2 \mathrm{d}m$.

NOTE 1—The symbol for the moment of inertia is *J*.

NOTE 2—The SI unit for moment of intertia is the kilogram meter squared ($kg{\cdot}m^2$).

3.218 momentum: The product of the mass of a body and its velocity.

NOTE—The symbol for this vector quantity is ***p*** and its SI unit is the kilogram meter per second (kg·m/s).

- N -

3.219 N: The symbol N stands for newton, the SI unit of force.

3.220 nano: The SI prefix that denotes multiplication by 10^{-9}.

NOTE—The symbol for the SI prefix nano is n.

3.221 National Institute of Standards and Technology: The name of the national standards laboratory of the United States.

NOTE 1—The abbreviation for the National Institute of Standards and Technology is NIST

NOTE 2—Before 1988, NIST was known as the National Bureau of Standards (NBS).

3.222 nautical mile: A unit of length employed for marine and aerial navigation to express distances.

NOTE 1—Defined value in SI units: 1 nautical mile = 1852 m. [First International Extraordinary Hydrographic Conference, Monaco, 1929.]

NOTE 2—The nautical mile is not an SI unit, but is in use with the SI.

3.223 NBS: *See:* **National Institute of Standards and Technology.**

3.224 neper (field level): A unit of level of a field quantity when logarithm to the base e is used. The level of a field quantity L_F is defined by $L_F = \log_e (F/F_0)$, where F and F_0 represent two amplitudes of the same kind, F_0 being a reference amplitude. 1 neper is the level of a field quantity when $\log_e (F/F_0) = 1$. Thus, 1 Np corresponds to a field ratio $F/F_0 = 2.718\ 2818$. *See also:* **level; field quantity; bel.**

NOTE—The symbol for neper is nP.

3.225 neper (power level): A unit of level of a power quantity when logarithm to the base e is used. The level of a power quantity L_p is defined by $L_p = (1/2) \log_e (P/P_0)$, where P is the power of interest and P_0 is a reference power. Thus, 1 neper corresponds to a power ratio $P/P_0 = 7.38905$. *See also:* **level; field quantity; bel.**

NOTE 1—The submultiple decineper (dNp) is occasionally used (1 dNp = 0.1 Np).

NOTE 2—The neper may also be used to express the ratio of two field quantities. To obtain the same numerical value as for the corresponding power ratio, the logarithm of the field quantity ratio is multiplied by the factor 2. This calculation is valid provided that the power quantity is proportional to the square of the field quantity.

3.226 newton: The SI unit of force. This force, when applied to a body having a mass of one kilogram, gives it an acceleration of 1 m/s^2. It is a special name for the SI unit $kg\cdot m/s^2$ ($N = kg\cdot m/s^2$).

NOTE—The symbol for newton, the SI unit of force, is N.

3.227 NIST: The abbreviation NIST stands for National Institute of Standards and Technology, the name of the national standards laboratory of the United States.

3.228 numerical equation: *See:* **equation between numerical values.**

3.229 numerical value (of a quantity): The quotient of the value of a quantity and the unit used in its expression.

NOTE 1—The numerical value is a number that, when multiplied by a unit, yields the value or magnitude of a quantity.

NOTE 2—In the formal development of equations between numerical values, the numerical value is enclosed in braces, for example, {26.789} or $\{Q_n\}$ where Q_n represents the numerical value of a particular quantity.

NOTE 3—When appropriate, or for greater clarity, the unit is added as a subscript to the numerical value of the quantity. For example, the symbol $\{Q_n\}_{mm}$ indicates the numerical value is Q_n and that the unit is the millimeter.

- O -

3.230 oersted: A cgs unit of magnetic field strength. Equivalent value in SI units: 1 oersted = $(250/\pi)$ A/m.

3.231 ohm: The SI unit of electric resistance. It is the resistance between two points of a conductor when a constant potential difference of 1 V, applied to these points, produces in the conductor a current of 1 A, the conductor not being the seat of any electromotive force.

NOTE—The symbol for ohm, the SI unit of electric resistance, is Ω.

- P -

3.232 Pa: The symbol Pa stands for pascal, the SI unit of pressure or stress.

3.233 pascal: The SI unit of pressure or stress. It is the special name for newton per square meter ($Pa = N/m^2$).

NOTE—The symbol for pascal, the SI unit of pressure or stress, is Pa.

3.234 period: The time required for a repetitive quantity to undergo one cycle. *See:* **cycle; frequency.**

NOTE—The symbol for this quantity is T, and its SI unit is the second (s).

3.235 permeability (magnetic): *See:* **magnetic permeability.**

3.236 permeability (relative): The ratio of magnetic permeability μ to the magnetic constant μ_0. The ratio is a pure number.

NOTE—The symbol for relative permeability is μ_r.

3.237 permeability of free space: *See:* **magnetic constant.**

3.238 permittivity: The ratio of electric flux density D to electric field strength E.

NOTE—The symbol for this quantity is ε, and its SI unit is the farad per meter (F/m).

3.239 permittivity of free space: *See:* **electric constant.**

3.240 permittivity (relative): The ratio of permittivity ε to the electric constant ε_0. The ratio is a pure number.

NOTE 1—The symbol for relative permittivity is ε_r.

NOTE 2—Relative permittivity is sometimes called dielectric constant.

3.241 peta: The SI prefix that denotes multiplication by 10^{15}.

NOTE—The symbol for the SI prefix peta is P.

3.242 phase: *See:* **sinusoidal quantity.**

3.243 physical quantity: *See:* **quantity.**

3.244 pico: The SI prefix denotes multiplication by 10^{-12}.

NOTE—The symbol for the SI prefix pico is p.

3.245 plane angle: *See:* **angle (plane).**

3.246 pound: The pound (lb) is a non-SI unit of mass. Defined value in SI units: 1 lb = 0.453 592 37 kg.

NOTE—The unit symbol for pound is lb.

3.247 pound-force: A non-SI unit of force. Defined value in SI units: 1 lbf = 0.453 592 37 × 9.806 65 N. Approximate value in SI units 1 lbf = 4.448 222 N.

NOTE—The symbol for pound-force is lbf.

3.248 power: The rate at which work is done or the rate of energy transfer. *See:* **watt.**

NOTE—The symbol for this quantity is P, and its SI unit is the watt (W).

3.249 power, active: Used in electrotechnology, corresponds to the basic definition of power and expresses the rate at which work is done or energy is transferred. It must be distinguished from reactive power (Q) and apparent power (S).

NOTE 1—The SI unit of active power is the watt (W).

NOTE 2—For a circuit with a sinusoidal voltage (E) and current (I) the active power is given by $P = EI_p$, where I_p is the in-phase component of I.

3.250 power, apparent: Used in electrotechnology in conjunction with active power (P) and reactive power (Q). The three quantities are related by the expression $S^2 = P^2 + Q^2$.

NOTE 1—The symbol for apparent power is S, and the SI unit of apparent power is the volt ampere (V·A).

NOTE 2—The apparent power S associated with an electric circuit subsumes a sinusoidal voltage having an effective value E and a sinusoidal current having an effective current I. The apparent power is given by $S = EI$.

NOTE 3—In the specialized field of electric power, the symbol VA is generally used as a symbol for the unit of apparent power.

3.251 power, reactive: Describes power that flows back and forth in an ac circuit without being consumed. The term is used in electrotechnology to distinguish it from active power (P). For a circuit with a sinusoidal voltage (E) and current (I) the reactive power is given by $Q = EI_q$, where I_q is the in-quadrature component of I. *See:* **var.**

NOTE 1—The symbol for reactive power is Q, and the SI unit of reactive power is the volt ampere (V·A).

NOTE 2—In the specialized field of electric power, the var is the generally used unit name and symbol for reactive power. Equivalent value in SI units: 1 var = 1 V·A.

NOTE 3—The IEC and IEEE have adopted the name and symbol var for the volt ampere as unit for reactive power.

NOTE 4—Owing to its practical importance in the specialized field of electric power, the var is generally used along with SI units.

3.252 power factor: The ratio of active power (P) to apparent power (S): $F_p = P/S$. Power factor is a pure number, sometimes expressed in percent.

NOTE—The symbol for power factor is F_p.

3.253 precision of measurement: The closeness of agreement of the results of repeated measurements carried out over a short period of time and under the same conditions. *See:* **accuracy of measurement; uncertainty of measurement.**

3.254 prefix (unit): An attachment to a unit to denote multiplication or division of the unit by a specified power of 10.

NOTE 1—The names and symbols for SI prefixes have been standardized by the CGPM.

NOTE 2—The prefix name is attached to the unit name.

NOTE 3—The prefix symbol is attached to the unit symbol.

3.255 pressure: Force divided by area.

NOTE—The symbol for this quantity is p, and its SI unit is the pascal (Pa).

- Q -

3.256 quantity: The term, as used in this standard, refers to a physical attribute of a phenomenon, body, or substance that may be distinguished qualitatively and determined quantitatively.

NOTE—A quantity is expressed as the product of a numerical value and a unit: quantity = {numerical value} × [unit]. The term physical quantity is sometimes used.

3.257 quantity (derived): *See:* **derived quantity.**

3.258 quantity equation: *See:* **equation between quantities.**

3.259 quantity of dimension one: The term, often called a dimensionless quantity, is a physical quantity whose dimensional components, when reduced to their simplest expression, all possess exponents that are zero. *See:* **dimension of a base quantity.**

NOTE 1—Linear strain, friction factor, Mach number, and refractive index are examples of quantities that have dimension one.

NOTE 2—When expressing the values of quantities of dimension one, the underlying meaning of the one (1) should be known, or made clear.

3.260 quantity symbol: A conventional sign designating a physical quantity.

NOTE—A quantity symbol is usually a single letter of the Latin or Greek alphabet, printed in italic type, sometimes with a subscript or other modifying sign.

Examples

B is the vector symbol for magnetic flux density
m is the symbol for mass.

- R -

3.261 rad: The symbol rad stands for the radian, the SI unit of plane angle.

3.262 radian: The SI unit of plane angle. It is the angle between two radii of a circle that cut off on the circumference an arc equal in length to the radius.

NOTE 1—The symbol for the radian, the SI unit of plane angle, is rad.

NOTE 2—The symbol rad is omitted in compound units when radian is not relevant. For example, in the expression $v = \omega r$ relating peripheral speed v to rotational speed ω (rad/s) and radius r (m), the peripheral speed is expressed in m/s, not in m·rad/s.

3.263 radiance: At a point on a surface and in a given direction, the radiant intensity of an element of the surface, divided by the area of the orthogonal projection of the surface element on a plane perpendicular to the given direction.

NOTE—The symbol for radiance is L and its SI unit is the watt per square meter steradian ($W/(m^2 \cdot sr)$).

3.264 radiant flux: Power emitted, transmitted, or received in the form of radiation.

NOTE—The symbol for this quantity is Φ, and its SI unit is the watt (W).

3.265 radiant intensity: In a given direction from a source, the radiant energy flux leaving the source, or an element of the source, in an element of solid angle containing the given direction, divided by that element of solid angle.

NOTE—The symbol for this quantity is I, and its SI unit is the watt per steradian (W/sr).

3.266 reactance (capacitive): The ratio of the effective voltage across the terminals of a capacitor to the effective current flowing through it. The voltage and current must be alternating sinusoidally at the same frequency.

NOTE—The symbol for capacitive reactance is X_C, and the SI unit for this quantity is the ohm (Ω).

3.267 reactance (inductive): The ratio of the effective voltage across the terminals of an inductance to the effective current flowing through it. The voltage and current must be alternating sinusoidally at the same frequency.

NOTE—The symbol for inductive reactance is X_L, and the SI unit for this quantity is the ohm (Ω).

3.268 reference frame: A system of coordinates that makes it possible to specify the unambiguous position of an object of interest.

NOTE—A reference frame may be in motion with respect to other reference frames. It may be convenient to use a reference frame that is fixed to a room in a building, a moving elevator, an accelerating vehicle, a satellite in orbit, or any other conceptual frame.

3.269 resistance (to direct current): *See:* **electric resistance.**

3.270 resistivity: The rationalized electrical resistance of a material, expressed in ohm meters (Ω·m). It is numerically equal to the electrical resistance of a sample of the material having a length of one meter and a cross section of 1 square meter.

NOTE—The symbol for resistivity is ρ.

3.271 revolution: A unit equal to one complete turn around an axis of rotation.

NOTE 1—The symbol for revolution is r.

NOTE 2—The revolution is equivalent to a plane angle of 2π radians (r = 2π rad).

- S -

3.272 s: The symbol s stands for second, the SI unit of time.

3.273 S: The symbol S stands for siemens, the SI unit of electric conductance.

3.274 scalar quantity: A physical quantity that has a magnitude but no direction.

NOTE—Mass, temperature, electric charge, and volume are examples of scalar quantities.

3.275 scale of a measuring instrument: The scale of a measuring instrument is an ordered set of marks, together with any associated numbering, forming part of a displaying device of a measuring instrument.

3.276 second: The SI unit of time, one of the seven SI base units. The second is equal to the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

NOTE— The symbol for second, the SI unit of time, is s.

3.277 SI: The abbreviation SI stands for *Le Système International d'Unités*, the International System of Units. The abbreviation SI is used throughout the world, in all languages.

3.278 siemens: The SI unit of electric conductance. It is defined as the conductance of a conductor in which a current of one ampere is produced by an electric potential difference of one volt. *See:* **conductance.**

NOTE 1—The symbol S stands for siemens, the SI unit of electric conductance.

NOTE 2—The siemens is a special name for the SI unit ampere per volt (S = A/V).

3.279 sievert: The SI unit of dose equivalent. It is the dose imparted by x or gamma radiation when the absorbed dose is one joule per kilogram (Sv = J/kg). *See:* **dose equivalent.**

NOTE—The symbol Sv stands for sievert, the SI unit of dose equivalent.

3.280 significant digit: *See:* **digit (significant)**.

3.281 sinusoidal current: An electric current that varies periodically with time according to the expression $i = I_{max} \sin (2\pi ft + \theta)$, where I_{max} is the amplitude of the current, f is the frequency, t is the time, and θ is a phase angle. *See:* **sinusoidal quantity**.

NOTE 1—The quantity f is the reciprocal of the period T of one cycle.

NOTE 2—The effective value I of a sinusoidal current is equal to $I_{max} /\sqrt{2}$.

3.282 sinusoidal quantity: A quantity q that varies periodically with time or space according to the expression $q = Q_{max} \sin (2\pi ft + 2\pi x/\lambda + \theta)$, where Q_{max} is the amplitude of the quantity, f is the frequency, t is the time, x is the path distance, λ is the wavelength, and θ is a phase angle.

NOTE 1—The quantity f is the reciprocal of the period T of one cycle.

NOTE 2—Two sinusoidal quantities are said to be *in phase* when their frequencies and phase angles, respectively, possess the same values.

NOTE 3—Two sinusoidal quantities are said to be *out of synchronization* when their frequencies or phase angles are different.

NOTE 4—The quantity $2\pi f$ is often represented by the symbol ω, which stands for angular frequency.

3.283 sinusoidal voltage: A voltage e that varies according to the expression $e = E_{max} \sin (2\pi ft + \theta)$, where E_{max} is the amplitude of the voltage, f is the frequency, t is the time, and θ is a phase angle. *See:* **sinusoidal quantity.**

NOTE 1—The quantity f is the reciprocal of the period T of one cycle.

NOTE 2—The effective value E of a sinusoidal voltage is equal to $E_{max}/\sqrt{2}$.

3.284 solid angle (of a cone): The ratio of the area cut out on the surface of a sphere (with its center at the apex of the cone) to the square of the radius of the sphere. *See:* **solid angle and steradian.**

NOTE—The unit of solid angle is the steradian (sr).

3.285 specific entropy: Entropy divided by mass.

NOTE—The symbol for this quantity is s, and its SI unit is the joule per kilogram kelvin (J/(kg·K)).

3.286 specific energy imparted: For any ionizing radiation, the energy imparted to an element of irradiated matter divided by the mass of this element.

NOTE—The symbol for this quantity is *Z* and its SI unit is the gray (Gy), a special name for the joule per kilogram (J/kg).

3.287 specific heat capacity: Heat capacity divided by mass.

NOTE—The symbol for this quantity is *c* and its SI unit is the joule per kilogram kelvin [J/(kg·K)].

3.288 specific energy: Energy divided by mass.

NOTE—The symbol for this quantity is *e* and its SI unit is the joule per kilogram (J/kg).

3.289 specific volume: Volume divided by mass.

NOTE—The symbol for this quantity is *v* and its SI unit is the cubic meter per kilogram (m^3/kg).

3.290 speed: Distance traveled divided by the time required to travel that distance.

NOTE—The SI unit of speed is the meter per second (m/s).

3.291 sr: The symbol sr stands for steradian, the SI unit of solid angle.

3.292 standard acceleration due to gravity: *See:* **acceleration of free fall** (NOTE 1 and NOTE 2).

3.293 steradian: The SI unit of solid angle. It is the solid angle that, having its vertex at the center of a sphere, cuts off an area on the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere. The steradian is a quantity that has a dimension of m^2/m^2, which reduces to a dimension of 1.

NOTE—The symbol for steradian, the SI unit of solid angle, is sr.

3.294 stress: The force per unit area acting upon a body.

NOTE—The symbol for this quantity is σ, and its SI unit is the pascal (Pa).

3.295 substance, amount of: *See:* **mole.**

3.296 surface tension: The force perpendicular to a line element in a surface, divided by the length of the line element.

NOTE—The symbol for this quantity is γ, and its SI unit is the newton per meter (N/m).

3.297 Sv: The symbol Sv stands for sievert, the SI unit of dose equivalent.

3.298 Système International d'Unités (Le): The official French name (and spelling) for the International System of Units.

3.299 system of quantities: A set of quantities among which defined relationships exist.

3.300 system of units (of measurement): A set of base units, together with derived units, defined in accordance with given rules, for a given system of quantities.

Examples

a) International System of Units (SI)

b) Electromagnetic cgs system of units

- T -

3.301 t: The symbol t stands for metric ton. *See:* **tonne.**

3.302 T: The symbol T stands for tesla, the SI unit of magnetic flux density.

3.303 temperature (Celsius): *See:* **Celsius temperature.**

3.304 temperature (Fahrenheit): *See:* **Fahrenheit temperature.**

3.305 temperature interval: The difference between two temperatures using the same scale.

3.306 temperature (thermodynamic): *See:* **thermodynamic temperature.**

3.307 tera: The SI prefix that denotes multiplication by 10^{12}.

NOTE—The symbol for the prefix tera is T.

3.308 tesla: The SI unit of magnetic flux density. It is the special name for weber per square meter (T = Wb/m^2).

NOTE 1—The symbol for tesla, the SI unit of magnetic flux density, is T.

NOTE 2—See the discussion of alternative terms in Annex A.

3.309 thermal conductivity: The heat flow rate divided by area and the temperature gradient.

NOTE—The symbol for this quantity is λ, and its SI unit is the watt per meter kelvin [W/(m·K)] or, equivalently, the watt per meter degree Celsius [W/(m·°C)].

3.310 thermodynamic temperature: One of the seven SI base quantities. It is a state variable proportional to the thermal energy of a given body at equilibrium. *See:* **triple point of water.**

NOTE—The quantity symbol for thermodynamic temperature is *T*, and its SI base unit is the kelvin (K).

3.311 time: One of the seven SI base quantities. *See:* **second.**

NOTE 1—The quantity symbol for time is t, and its SI base unit is the second (s).

NOTE 2—The term “time” is sometimes used to mean “time interval” or “duration.”

NOTE 3—Among its other attributes, time is a factor that determines the degradation of a radioactive substance.

3.312 time constant: A function that decreases exponentially in time is the duration required for the function to decrease from a value u to a value u/e, where e = 2.718 281 8 · · ·.

NOTE—The symbol for time constant is τ.

3.313 tonne: A name that is used in many countries for metric ton. Equivalent value in SI units: 1 t = 1000 kg.

NOTE—The symbol for metric ton is t.

3.314 torque: The vector product of any radius vector $\boldsymbol{r}$ and a force $\boldsymbol{F}$, the radius vector being taken from this point to a point on the line of action of the force ($\boldsymbol{T} = \boldsymbol{r} \times \boldsymbol{F}$). In simpler terms, the magnitude of a torque due to a force about a point is the component of that force perpendicular to the line connecting the point of application of the force and the point about which the torque is taken, multiplied by the length separating those two points.

NOTE 1—The symbol for torque is $\boldsymbol{T}$ and its SI unit is the newton meter (N·m).

NOTE 2—In SI, torque and work share the same dimension (ML^2T^{-2}), despite the fact that they are different quantities.

NOTE 3—In the case of torque, the joule is not permitted as a special name for newton meter.

3.315 triple point of water: The temperature and pressure at which the solid, liquid, and gas phases may coexist in equilibrium. A temperature of 273.16 K has been assigned to the triple point of water, and this assignment defines thermodynamic temperature in the SI. The pressure at the triple point of water is approximately 611.29 Pa.

NOTE—273.16 K corresponds to 0.01 ºC.

3.316 true value of a quantity: The value consistent with the definition of a given particular quantity and that would be attained by a perfect measurement.

- U -

3.317 u: The symbol u stands for the unified atomic mass unit.

3.318 uncertainty of measurement: A parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand. *See:* **accuracy of measurement; measurand; precision of measurement.**

3.319 unified atomic mass unit: Equals 1/12 of the mass of an atom of the nuclide ^{12}C (carbon-12). It is a unit in use with SI.

NOTE 1—The symbol u stands for the unified atomic mass unit.

NOTE 2—The value of the unified atomic mass unit is obtained experimentally. Equivalent value in SI units: 1 u = 1.660 540 2 × 10^{-27} kg.

3.320 unit (of measurement): A chosen amount of a quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitudes relative to that amount.

NOTE 1—In the formal development of equations between numerical values, the unit is sometimes enclosed in brackets, for example, [kilogram].

NOTE 2—Units of quantities having the same dimension may have the same names and symbols, even when the quantities are not of the same kind. For example, the sheet output of a paper mill expressed in square meters per second has the same unit and symbol (m^2/s) as the kinematic viscosity of a fluid (m^2/s).

3.321 unit (derived): *See:* **derived unit.**

3.322 unit (coherent): *See:* **coherent unit.**

3.323 unit symbol: A conventional sign designating a unit of measurement.

NOTE—Roman (upright) type, in general lower case, is used for symbols of units; however, if the symbols are derived from proper names, capital roman type is used for the initial letter.

- V -

3.324 V: The symbol V stands for volt, the SI unit of potential difference and of electromotive force.

3.325 vacuum: A space wherein the amount of substance is nil. *See:* **amount of substance.**

3.326 value (of a quantity): The magnitude of a particular quantity, expressed as a number multiplied by a unit of measurement. It may be positive, zero, or sometimes negative.

3.327 var: A name commonly used for the SI unit of reactive power, the volt ampere (V.A).

NOTE—The name var and the unit symbol var have been accepted by the IEC and the IEEE but have not been adopted by the CGPM.

3.328 vector quantity: A quantity that has both magnitude and direction.

NOTE—Velocity, force, magnetic flux density, and momentum are examples of vector quantities.

3.329 velocity: The rate of change of position with time.

NOTE—The symbol for this vector quantity is v and its SI unit is the meter per second (m/s).

3.330 viscosity: Defined by the expression $\tau_{xz} = \eta \, dv_x/dz$ where τ_{xz} is the shear stress in a fluid moving with a velocity gradient dv_x/dz perpendicular to the plane of shear.

NOTE 1—The symbol for viscosity is η, and its SI unit is the pascal second (Pa·s).

NOTE 2—Viscosity was formerly called dynamic viscosity.

3.331 viscosity (kinematic): The viscosity of a fluid divided by its mass density.

NOTE—The symbol for this quantity is ν, and its SI unit is the meter squared per second (m^2/s).

3.332 volt: The SI unit of electric potential difference and electromotive force. It is the difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.

NOTE 1—The symbol V stands for volt, the SI unit of potential difference and of electromotive force.

NOTE 2—The volt is a special name for joule per coulomb (V = J/C).

3.333 voltage: The general term that expresses a difference of potential, or an electromotive force, between any two points.

NOTE 1—The SI unit of voltage is the volt.

NOTE 2—The voltage may be specified as being ac, dc, effective, peak, sinusoidal, triangular, trapezoidal, fundamental, 27th harmonic, etc.

NOTE 3—Voltage is sometimes called tension; e.g., high-tension line instead of high-voltage line.

3.334 volume: The triple integral of $dx dy dz$ within defined limits, where x, y, and z are Cartesian coordinates. In simpler terms, it is a defined portion of three-dimensional space.

NOTE—The symbol for volume is V and its SI unit is the cubic meter (m^3).

- W -

3.335 W: The symbol W stands for watt, the SI unit of power.

3.336 watt: The SI unit of power equal to a rate of energy transfer (or the rate at which work is done), of one joule per second.

NOTE 1—The symbol for watt, the SI unit of power, is W.

NOTE 2—The watt is a special name for joule per second (W = J/s).

3.337 wavelength: The distance along the direction of propagation of a periodic wave between two successive points where, at a given time, the phase is the same.

NOTE—The symbol for this quantity is λ, and its SI unit is the meter (m).

3.338 wavenumber: The reciprocal of wavelength.

NOTE—The symbol for this quantity is k, and its SI unit is 1 per meter (m^{-1}).

3.339 Wb: Wb is the symbol for weber, the SI unit of magnetic flux.

3.340 weber: The SI unit of magnetic flux. It is the magnetic flux that, linking a circuit of one turn, produces in it an electromotive force of one volt as the flux is reduced to zero at a uniform rate, in one second.

NOTE 1—Wb is the symbol for weber, the SI unit of magnetic flux.

NOTE 2—The weber is a special name for the volt second (Wb = V·s).

3.341 weight: The force that gives a body an acceleration equal to the acceleration of free fall in that reference frame.

NOTE 1—The SI unit of weight is the newton (N).

NOTE 2—In commercial and everyday use, the term "weight" is often used as a synonym for mass, for which the SI unit is the kilogram. The verb "to weigh" means to determine the mass of. Nevertheless, in scientific and technical practice, the term "weight" should not be used to mean mass.

3.342 work: The scalar product of the force on a body and the displacement of the body. In simpler terms, it is force on a body times the distance the body moves in the direction of the force.

NOTE 1—The symbol for work is W and its SI unit is the joule (J).

NOTE 2—The joule is the special name for newton meter (N·m) when the newton meter implies work. The joule is not permitted as a special name for newton meter, the unit of torque.

- Y -

3.343 yard: A non-SI unit of length. Defined value in terms of SI units: 1 yd = 0.9144 m.

NOTE—The symbol for yard is yd.

3.344 yocto: The SI prefix that denotes multiplication by 10^{-24}.

NOTE—The symbol for the prefix yocto is y.

3.345 yotta: The SI prefix that denotes multiplication by 10^{24}.

NOTE—The symbol for the prefix yotta is Y.

- Z -

3.346 zepto: The SI prefix that denotes multiplication by 10^{-21}.

NOTE—The symbol for the prefix zepto is z.

3.347 zetta: The SI prefix that denotes multiplication by 10^{21}.

NOTE—The symbol for the prefix zetta is Z.

Annex A

(informative)

Alternative terms in electricity and electromagnetism

Many current textbooks on physics[6] have adopted terms relating to electromagnetism that differ from those used nationally and internationally. The following list shows the relationship between the two terminologies.

ISO, IEEE, IEC terms and symbols	**Physics textbook terms and symbols**
Magnetic flux density ($\boldsymbol{B}$)	Magnetic field ($\boldsymbol{B}$)
Magnetic field strength ($\boldsymbol{H}$)	Not addressed
Magnetomotive force (F_m)	Not addressed
B-H curve (B vs H) (See NOTE 1)	B-B_0 curve (B vs B_0) (See NOTE 2)
Electric field strength (E)	Electric field ($\boldsymbol{E}$)
Magnetic constant (μ_0)	Permeability of free space (μ_0)
Electric constant (ε_o)	Permittivity of free space (ε_o)

NOTE 1—B is the magnetic flux density (teslas) in a magnetic material; H is the magnetic field strength (A/m) that gives rise to B.

NOTE 2—B is the magnetic field (teslas) in a magnetic material; B_0 is the magnetic field (teslas) in vacuum defined by $B_0 = \mu_0 nI$, where n = turns per unit length of a solenoid and I = electric current.

[6] *Fundamentals of Physics*, Sixth Edition by Halliday/Resnick/Walker, © 2001, John Wiley and Sons, Inc. *Physics*, Third Edition by Douglas C. Giancoli, © 1991, Prentice-Hall.

Annex B

(informative)

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[B2] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML, *International Vocabulary of Basic and General Terms in Metrology*, Second Edition, Geneva, ISO, 1993.

[B3] IEC 60027-1-1992-12 (Corr. 1995-03), Letter Symbols to be Used in Electrical Technology—Part 1: General.[7]

[B4] IEC 60027-1-am1-1997-05, Letter Symbols to be Used in Electrical Technology—Part 1: General.

[B5] IEC 60027-2-2000-11, Letter Symbols to be Used in Electrical Technology—Part 2: Telecommunications and Electronics.

[B6] IEC 60027-3-2002-07, Letter Symbols to be Used in Electrical Technology—Part 3: Logarithmic and Related Quantities, and Their Units.

[B7] IEC 60027-4-1985-09, Letter Symbols to be Used in Electrical Technology—Part 4: Symbols for Quantities to be Used for Rotating Electrical Machines.

[B8] IEC, Multilingual Dictionary of Electricity, Electronics and Telecommunications, Volume 1, Geneva, 1992.

The Multilingual Dictionary is based on nearly 70 chapters of the International Electrotechnical Vocabulary, IEC Publication 50. Chapter 301, General Terms on Measurements in Electricity is included. The definitions of terms point to IEV Chapters and the corresponding chapter numbers are identified in this document.

[B9] IEC, Multilingual Dictionary of Electricity, Electronics and Telecommunications, Volume 2, Geneva, 1992.

The Multilingual Dictionary is based on nearly 70 chapters of the International Electrotechnical Vocabulary, IEC Publication 50. Chapter 301, General Terms on Measurements in Electricity is included. The definitions of terms point to IEV Chapters and the corresponding chapter numbers are identified in this document.

[B10] IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.[8, 9]

[B11] IEEE Std 145™-1993, IEEE Standard Definitions of Terms for Antennas.

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[7] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.
[8] The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.
[9] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[B12] IEEE Std 211™-1997 (Reaff 2003), IEEE Standard Definitions of Terms for Radio Wave Propagation.

[B13] IEEE Std 280™-1985, IEEE Standard Letter Symbols for Quantities used in Electrical Science and Electrical Engineering.

[B14] IEEE Std 945™-1984 (Reaff 1997), IEEE Recommended Practice for Preferred Metric Units for Use in Electrical and Electronics Science and Technology.

[B15] ISO Standards Handbook, *Quantities and Units*, Third Edition, Geneva, 1993.[10]

[B16] NIST Special Publication 330-2001, The International System of Units (SI).

[10] ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iso.ch/). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).