



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

Sponsor

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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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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of units, some arcane and used only in small fields, others more popularly used but varying in definition, has been replaced by a very small set of simple and well-defined units, the SI.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 adopted 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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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 dD/dt , and its SI unit is the gray per second (Gy/s).

3.4 acceleration: The time rate of change of velocity, dv/dt .

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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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, $9.806\,65\text{ m/s}^2$, 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: $1 \text{ Å} = 10^{-10} \text{ m} = 0.1 \text{ nm}$.

3.17 angular acceleration: The time rate of change of angular velocity, $d\omega/dt$.

NOTE—The symbol for this quantity is α and its SI unit is the radian per second squared (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 ($\mathbf{L} = \mathbf{r} \times \mathbf{p}$) 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 ($\text{kg}\cdot\text{m}^2/\text{s}$).

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, $d\theta/dt$.

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 $ds_1 ds_2$ 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 (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 $\{t\}_{\text{C}} = \{T\}_{\text{K}} - 273.15$.

NOTE—The symbol for Celsius temperature is t .

Example

A thermodynamic temperature of 300 K yields $\{t\}_{\text{C}} = \{T\}_{\text{K}} - 273.15 = 300 - 273.15 = 26.85$. 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: $1 \text{ cmil} = 506.71 \times 10^{-12} \text{ m}^2$ ($506.71 \mu\text{m}^2$).

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, $1 \text{ cmil} = (\pi/4) \times (0.001 \text{ in})^2$.

NOTE 3—The symbol for 1000 cmil is kmil.

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·s ⁻¹	m·s ⁻²	kg·m ⁻³
Hz = s ⁻¹		N = kg·m·s ⁻²		J = kg·m ² ·s ⁻²		Pa = kg·m ⁻¹ ·s ⁻²	