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Quantities and units —

Part 6:
Electromagnetism

Grandeurs et unités —

Partie 6: Électromagnétisme

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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QUANTITIES AND UNITS –

Part 6: Electromagnetism

FOREWORD

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International Standard IEC 80000-6 has been prepared by IEC technical committee 25: Quantities and units, and their letter symbols in close cooperation with ISO/TC 12, Quantities, units, symbols, conversion factors.

This second edition of IEC 80000-6 cancels and replaces the first edition published in 2008.

The text of this standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or

- amended.

IEC 80000 consists of the following parts, under the general title *Quantities and units*:

– *Part 6: Electromagnetism*
– *Part 13: Information science and technology*
– *Part 15: Logarithmic and related quantities, and their units*
– *Part 16: Printing and writing rules*
– *Part 17: Time dependency*

The following parts are published by ISO:

– *Part 1: General*
– *Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*
– *Part 3: Space and time*
– *Part 4: Mechanics*
– *Part 5: Thermodynamics*
– *Part 7: Light*
– *Part 8: Acoustics*
– *Part 9: Physical chemistry and molecular physics*
– *Part 10: Atomic and nuclear physics*
– *Part 11: Characteristic numbers*
– *Part 12: Condensed matter physics*

0 Introduction

0.1 Arrangements of the tables

Where the numbering of an item has been changed in the revision of a part of IEC 80000 or ISO 80000, the number in the preceding edition is shown in parenthesis on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

0.2 Tables of quantities

The names in English of the most important quantities within the field of this document are given together with their symbols and, in most cases, their definitions. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed in Table 1; they are not intended to be complete.

The scalar, vectorial or tensorial character of quantities is pointed out, especially when this is needed for the definitions.

In most cases only one name and only one symbol for the quantity are given; where two or more names or two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When two types of italic letters exist (for example as with ϑ and θ; φ and ϕ; a and a; g and g) only one of these is given. This does not mean that the other is not equally acceptable. It is recommended that such variants should not be given different meanings. A symbol within parenthesis implies that it is a reserve symbol, to be used when, in a particular context, the main symbol is in use with a different meaning.

0.3 Units

0.3.1 General

The names of units for the corresponding quantities are given together with the international symbols and the definitions. These unit names are language-dependent, but the symbols are international and the same in all languages. For further information, see the SI Brochure (9th edition 2019) from BIPM and ISO 80000-1.

The units are arranged in the following way:

a) The coherent SI units are given first. The SI units have been adopted by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM). The use of coherent SI units, and their decimal multiples and submultiples formed with the SI prefixes are recommended, although the decimal multiples and submultiples are not explicitly mentioned. The order of the units is kg, m, s, A, K, mol, cd.

b) Some non-SI units are then given, being those accepted by the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM), or by the International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), or by ISO and IEC, for use with the SI.

c) Non-SI units that are not recommended are given only in annexes in some parts of ISO 80000 and IEC 80000. These annexes are informative, in the first place for the conversion factors, and are not integral parts of the standard. These deprecated units are arranged in two groups:

   1) units in the CGS system with special names;

   2) units based on the foot, pound, and some other related units.

0.3.2 Remark on units for quantities of dimension one, or dimensionless quantities

The coherent unit for any quantity of dimension one, also called a dimensionless quantity, is the number one, symbol 1. When the value of such a quantity is expressed, the unit symbol 1 is generally not written out explicitly.

EXAMPLE

Refractive index n = 1,53 × 1 = 1,53

Prefixes shall not be used to form multiples or submultiples of this unit. Instead of prefixes, powers of 10 are recommended.

EXAMPLE

Reynolds number Re = 1,32 × 10^3

Considering that plane angle is generally expressed as the ratio of two lengths and solid angle as the ratio of two areas, in 1995 the CGPM specified that, in the SI, the radian, symbol rad, and steradian, symbol sr, are dimensionless derived units. This implies that the quantities plane angle and solid angle are considered as derived quantities of dimension one. The units radian and steradian are thus equal to one; they may either be omitted, or they may be used in expressions for derived units to facilitate distinction between quantities of different kinds but having the same dimension.

0.4 Numerical statements in this standard

The sign = is used to denote “is exactly equal to” and the sign ≈ is used to denote “is approximately equal to”.

Numerical values of physical quantities that have been experimentally determined always have an associated measurement uncertainty. This uncertainty should always be specified. In this standard, the magnitude of the uncertainty is represented as in the following example.

EXAMPLE

l = 2,347 82(32) m

In this example, l = $a(b)$ m, the numerical value of the uncertainty b indicated in parentheses is assumed to apply to the last (and least significant) digits of the numerical value a of the length l. This notation is used when b represents one standard uncertainty (estimated standard deviation) in the last digits of a. The numerical example given above may be interpreted to mean that the best estimate of the numerical value of the length l, when l is expressed in the unit metre, is 2,347 82 and that the unknown value of l is believed to lie between (2,347 82 −0,000 32) m and (2,347 82 +0,000 32) m with a probability determined by the standard uncertainty 0,000 32 m and the probability distribution of the values of l.

0.5 Special remarks

The items given in IEC 80000-6 are generally in conformity with the International Electrotechnical Vocabulary (IEV), especially IEC 60050-121 and IEC 60050-131. For each quantity, the reference to IEV is given in the form: “See IEC 60050-121, item 121-xx-xxx.”.

The font used for text is sans serif; that used for quantities is serif

0.5.1 System of quantities

For electromagnetism, several different systems of quantities have been developed and used depending on the number and the choice of base quantities on which the system is based. However, in electromagnetism and electrical engineering, only the International System of Quantities, ISQ, and the associated International System of Units, SI, are acknowledged and are reflected in the standards of ISO and IEC. The SI has seven base units, among them kilogram (kg), metre (m), second (s), and ampere (A).

0.5.2 Sinusoidal quantities

For quantities that vary sinusoidally with time, and for their complex representations, the IEC has standardized two ways to build symbols. Capital and lowercase letters are generally used for electric current (item 6-1) and for voltage (item 6-11.3), and additional marks for other quantities. These are given in IEC 60027-1.

EXAMPLE 1

The sinusoidal variation with time of an electric current (item 6-1) can be expressed in real representation as

$$i = \sqrt{2}\, I \cos(\omega t - \phi)$$

and its complex representation (termed phasor) is expressed as

$$\underline{i} = I\mathbf{e}^{-j\varphi}$$

where $\underline{i}$ is the instantaneous value of the current, I, is its root-mean-square (rms) value (subclause 0.5.2), $(\omega t - \varphi)$ is the phase, φ is the initial phase, and j is the imaginary unit ($j^2 = -1$), in mathematics often denoted by i..

EXAMPLE 2

The sinusoidal variation with time of a magnetic flux (item 6-22.1) can be expressed in real representation as

$$\Phi = \hat{\Phi}\cos(\omega t - \phi) = \sqrt{2}\,\Phi_{\text{eff}}\cos(\omega t - \phi)$$

where Φ is the instantaneous value of the flux, $\hat{\Phi}$ is its peak value and Φ_{eff} is its rms value.

0.5.3 Root-mean-square value, rms value

For a time-depending quantity a, the positive square root of the mean value of the square of the quantity taken over a given time interval is called root-mean-square value, i.e.

$$\sqrt{\frac{1}{T}\int_0^T a^2\,\mathrm{d}t}$$

The root-mean-square value of a periodic quantity is usually taken over an integration interval the range of which is the period multiplied by a natural number. For a sinusoidal quantity $a(t) = \hat{A}\cos(\omega t + \varphi)$, the root-mean-square value is $\hat{A}/\sqrt{2}$.

The root-mean-square value of a quantity may be denoted by adding one of the subscripts eff or rms to the symbol of the quantity. In electrical technology, the root-mean-square values of electric current $i(t)$ and voltage $u(t)$ are usually denoted I and U, respectively.

QUANTITIES AND UNITS –

Part 6: Electromagnetism

1 Scope

This part of IEC 80000 gives names, symbols, and definitions for quantities and units of electromagnetism. Where appropriate, conversion factors are also given.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027-1:1992, *Letter symbols to be used in electrical technology – Part 1: General*

IEC 60050-111, *International electrotechnical vocabulary – Part 111: Physics and chemistry*

IEC 60050-121, *International electrotechnical vocabulary – Part 121: Electromagnetism*

IEC 60050-131, *International electrotechnical vocabulary – Part 131: Circuit theory*

ISO 80000-3, *Quantities and units – Part 3: Space and time*

ISO 80000-4:2006, *Quantities and units – Part 4: Mechanics*

3 Names, symbols, definitions and units of quantities

The names, symbols, and definitions for quantities and units of electromagnetism are given in the tables on the following pages.

NOTE In general, these quantities can depend on time even when not explicitly noted. All surfaces are assumed to be oriented surfaces (see IEC 60050-102, item102-04-37)

NOTE: The font in the formulas is different from the font of the main text.

241 **Table 1 – Quantities and units in electromagnetism**

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition	Symbol	
6-1 (6-*1*)	electric current	I i	scalar quantity equal to the quotient of the net quasi-infinitesimal (see IEC 60050-121, item 121-11-06) electric charge dQ (item 6-2) transferred thorough a surface during a quasi-infinitesimal (see IEC 60050-121, item 121-11-06) time interval dt and the duration of that interval; $I = \mathrm{d}Q/\mathrm{d}t$	A	Electric current is one of the base quantities in the International System of Quantities, ISQ, on which the International System of Units, SI, is based. Electric current I through a surface S can also be written as $I = \int_S \boldsymbol{J} \cdot \boldsymbol{e}_n \mathrm{d}A$ where $\boldsymbol{e}_n \mathrm{d}A$ is vector surface element. Electric current produces a magnetic field, see item 6-25. For a more complete definition, see item 6-8 and IEC 60050-121, item 121-11-13.
6-2 (6-*2*)	electric charge	Q q	additive scalar property of discrete particles and their agglomerations exhibiting forces (ISO 80000-4) by means of electric fields (item 6-10)	C A s s A	Electric charge can be positive, negative or zero. The sign convention is such that the elementary electric charge, e, of the proton, is positive. See IEC 60050-121, item121-11-01. To denote a point charge q is often used, and that is done in the present document. The coherent SI unit of charge is coulomb, C. Another frequently used unit is the ampere-hour Ah mentioned in IEC 60050-313, item 313-01-16, widely used for battery characteristics.

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition	Symbol	
6-3 (6-*3*)	electric charge density, volumic (electric) charge	ρ	scalar quantity representing the spatial distribution of electric charge, $\rho(\boldsymbol{r}) = \frac{\mathrm{d}Q}{\mathrm{d}V}$ where $\mathrm{d}Q$ is quasi-infinitesimal 121-11-06] electric charge (item 6-2) contained in an quasi-infinitesimal (see IEC 60050-121, item 121-11-06) domain located at position $\boldsymbol{r}$ and $\mathrm{d}V$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) volume (ISO 80000-3) of this domain	C / m^3 m^{-3} s A	See IEC 60050-121, item 121-11-07.
6-4 (6-4)	surface density of electric charge, areic (electric) charge	σ	scalar quantity representing the areal distribution of electric charge, $\sigma = \sigma(\boldsymbol{r}) = \frac{\mathrm{d}Q}{\mathrm{d}A}$ where $\mathrm{d}Q$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) electric charge (item 6-2) contained in an quasi-infinitesimal (see IEC 60050-121, item 121-11-06) domain located at position $\boldsymbol{r}$ and $\mathrm{d}A$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) area (ISO 80000-3) of this domain	C / m^2 m^{-2} s A	See IEC 60050-121, item 121-11-08.
6-5 (6-*5*)	linear density of electric charge, lineic (electric) charge	τ	scalar quantity representing the linear distribution of electric charge, $\tau = \tau(\boldsymbol{r}) = \frac{\mathrm{d}Q}{\mathrm{d}l}$ where $\mathrm{d}Q$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) electric charge (item 6-2) contained in an quasi-infinitesimal (see IEC 60050-121, item 121-11-06) domain located at position $\boldsymbol{r}$ and $\mathrm{d}l$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) length (ISO 80000-3) of this domain	C / m m^{-1} s A	See IEC 60050-121, item121-11-09.

Item No.	Quantity			Unit	Remarks
	Name	Symbol	Definition	Symbol	
6-6 (6-*14*)	electric dipole moment	$\boldsymbol{p}$	vector quantity given by $\boldsymbol{p} = q(\boldsymbol{r}_+ - \boldsymbol{r}_-)$ where $\boldsymbol{r}_+$ and $\boldsymbol{r}_-$ are the position vectors (ISO 80000-3) to carriers of electric charges q and $-q$ (item 6-2), respectively	C m m s A	The electric dipole moment of a substance within a domain is the vector sum of electric dipole moments of all electric dipoles contained in the domain. See IEC 60050-121, items 121-11-35 and 121-11-36.
6-7 (6-*13*)	electric polarization	$\boldsymbol{P}$	vector quantity representing the spatial distribution of electric dipole moment, $\boldsymbol{P}(\boldsymbol{r}) = \frac{d\boldsymbol{p}}{dV}$ where $d\boldsymbol{p}$ is quasi-infinitesimal (see IEC 60050-121, item 121-11-06) electric dipole moment (item 6-6) of a substance in an quasi-infinitesimal (see IEC 60050-121, item 121-11-06) domain at position $\boldsymbol{r}$ and dV is volume (ISO 80000-3) of this domain	C / m^2 m^{-2} s A	See IEC 60050-121, item 121-11-37.
6-8 (6-*15*)	electric current density	$\boldsymbol{J}$	vector quantity given by the volumic density of charge carriers forming an electric current (item 6-1), given by; $\boldsymbol{J}(\boldsymbol{r}) = \boldsymbol{J} = \rho\boldsymbol{v}$ where ρ is electric charge density (item 6-3) at position $\boldsymbol{r}$ and $\boldsymbol{v}$ is velocity (ISO 80000-3) of the charge carriers there	A / m^2 m^{-2} A	There can be different charge carriers with different velocities. Electric current I (item 6-1) through a surface S is $I = \int_S \boldsymbol{J} \cdot \boldsymbol{e}_n dA$ where $\boldsymbol{e}_n dA$ is vector surface element. See IEC 60050-121, item 121-11-11.
6-9 (—)	linear electric current density	$\boldsymbol{J}_S$	vector quantity given by the areic density of electric charge carriers forming an electric surface current (item 6-1), given by $\boldsymbol{J}_S(\boldsymbol{r}) = \boldsymbol{J}_S = \rho\boldsymbol{v}$ where σ is surface density of electric charge (item 6-4) at position $\boldsymbol{r}$ and $\boldsymbol{v}$ is velocity (ISO 80000-3) of the charge carriers there	A / m m^{-1} A	See IEC 60050-121, item 121-11-12.