IEC 80000-6

Edition 1.0 2008-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Quantities and units –
Part 6: Electromagnetism

Grandeurs et unités –
Partie 6: Electromagnétisme

IEC 80000-6:2008

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

QUANTITIES AND UNITS –

Part 6: Electromagnetism

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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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 first edition of IEC 80000-6 cancels and replaces the second edition of ISO 31-5, published in 1992, and its amendment 1 (1998).

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

FDIS	Report on voting
25/370/FDIS	25/376/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- withdrawn,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 14: Telebiometrics related to human physiology*

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: Solid state physics*

0 Introduction

0.1 Arrangements of the tables

The tables of quantities and units in ISO/IEC 80000 are arranged so that the quantities are presented on the left-hand pages and the units on the corresponding right-hand pages.

All units between two full lines on the right-hand pages belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of an item has been changed in the revision of a part of ISO 31, 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 and in French of the most important quantities within the field of this document are given together with their symbols and, in most cases, their definitions. These names and symbols are recommendations. The definitions are given for identification of the quantities in the International System of Quantities (ISQ), listed on the left hand pages of 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 *ɑ*; *g* and *ɡ*) 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.

In this English edition the quantity names in French are printed in an italic font, and are preceded by *fr*. The gender of the French name is indicated by (m) for masculine and (f) for feminine, immediately after the noun in the French name.

0.3 Tables of 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 (8th edition 2006) from BIPM and ISO 80000-1 (under preparation).

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.

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.

Such units are separated from the SI units in the item by use of a broken line between the SI units and the other units.

c) Non-SI units currently accepted by the CIPM for use with the SI are given in small print (smaller than the text size) in the “Conversion factors and remarks” column.

d) Non-SI units that are not recommended are given only in annexes in some parts of ISO/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, second, and some other related units.

e) Other non-SI units given for information, especially regarding the conversion factors are given in another informative annex.

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 $n = 1{,}53 \times 1 = 1{,}53$

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

EXAMPLE

Reynolds number $Re = 1{,}32 \times 10^3$

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”, the sign ≈ is used to denote “is approximately equal to”, and the sign := is used to denote “is by definition 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 ISO 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.”.

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 metre, symbol m, kilogram, symbol kg, second, symbol s, and ampere, symbol 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

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

and its complex representation (termed phasor) is expressed as

$$\underline{I} = I\, \mathrm{e}^{-\mathrm{j}\varphi}$$

where i is the instantaneous value of the current, I is its root-mean-square (rms) value, $(\omega t - \varphi)$ is the phase, φ is the initial phase.

EXAMPLE 2

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

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

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

QUANTITIES AND UNITS –

Part 6: Electromagnetism

1 Scope

In IEC 80000-6 names, symbols, and definitions for quantities and units of electromagnetism are given. Where appropriate, conversion factors are also given.

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) 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 31-0:1992, *Quantities and units – Part 0: General principles (under revision)*

ISO 80000-3:2006, *Quantities and units – Part 3: Space and time*

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

3 Names, symbols, and definitions

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

ELECTROMAGNETISM				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
6-1 (*5-1*)	electric current *fr* *courant* (m) *électrique*	I, i	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 is the quantity that can often be measured with an ammeter. The electric current through a surface is the quotient of the electric charge (item 6-2) transferred through the surface during a time interval by the duration of that interval. For a more complete definition, see item 6-8 and IEC 60050-121, item 121-11-13.
6-2 (*5-2*)	electric charge *fr* *charge* (f) *électrique*	Q, q	$\mathrm{d}Q = I\mathrm{d}t$ where I is electric current (item 6-1) and t is time (ISO 80000-3, item 3-7)	Electric charge is carried by discrete particles and can be positive or negative. The sign convention is such that the elementary electric charge e, i.e. the charge 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.
6-3 (*5-3*)	electric charge density, volumic electric charge *fr* *charge* (f) *électrique volumique*	ρ, ρ_V	$\rho = \frac{\mathrm{d}Q}{\mathrm{d}V}$ where Q is electric charge (item 6-2) and V is volume (ISO 80000-3, item 3-4)	See IEC 60050-121, item 121-11-07.
6-4 (*5-4*)	surface density of electric charge, areic electric charge *fr* *charge* (f) *électrique surfacique*	ρ_A, σ	$\rho_A = \frac{\mathrm{d}Q}{\mathrm{d}A}$ where Q is electric charge (item 6-2) and A is area (ISO 80000-3, item 3-3)	See IEC 60050-121, item 121-11-08.

UNITS				ELECTROMAGNETISM
Item No.	**Name**	**Inter-national symbol**	**Definition**	**Conversion factors and remarks**
6-1.a	ampere	A	ampere is that constant electric current which, if maintained in two parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length [9th CGPM (1948)]	This definition implies that the magnetic constant μ_0 (item 6-26.1) is exactly $4\pi \times 10^{-7}$ H/m. In this definition "force" is used instead of "lineic force" or "force per length". Accordingly the last unit should be "newton per metre" without "of length".
6-2.a	coulomb	C	1 C := 1 A · s	The unit ampere hour, is used for electrolytic devices, such as storage batteries. 1 A · h = 3,6 kC
6-3.a	coulomb per cubic metre	C/m^3		
6-4.a	coulomb per square metre	C/m^2		

ELECTROMAGNETISM				QUANTITIES
Item No.	**Name**	**Symbol**	**Definition**	**Remarks**
6-5 *(5-5)*	linear density of electric charge, lineic electric charge *fr* *charge* (f) *électrique linéique*	ρ_l, τ	$\rho_l = \frac{\mathrm{d}Q}{\mathrm{d}l}$ where Q is electric charge (item 6-2) and l is length (ISO 80000-3, item 3-1.1)	See IEC 60050-121, item121-11-09.
6-6 *(5-14)*	electric dipole moment *fr* *moment* (m) *électrique* *moment* (m) *de dipôle électrique*	$\boldsymbol{p}$	$\boldsymbol{p} = q(\boldsymbol{r}_+ - \boldsymbol{r}_-)$ where $\boldsymbol{r}_+$ and $\boldsymbol{r}_-$ are the position vectors (ISO 80000-3, item 3-1.11) to carriers of electric charges q and $-q$ (item 6-2), respectively	The electric dipole moment of a substance within a domain is the vector sum of electric dipole moments of all electric dipoles included in the domain. See IEC 60050-121, items 121-11-35 and 121-11-36.
6-7 *(5-13)*	electric polarization *fr* *polarisation* (f) *électrique*	$\boldsymbol{P}$	$\boldsymbol{P} = \mathrm{d}\boldsymbol{p}/\mathrm{d}V$ where $\boldsymbol{p}$ is electric dipole moment (item 6-6) of a substance within a domain with volume V (ISO 80000-3, item 3-4)	See IEC 60050-121, item 121-11-37.
6-8 *(5-15)*	electric current density, areic electric current *fr* *densité* (f) *de courant électrique*	$\boldsymbol{J}$	$\boldsymbol{J} = \rho\boldsymbol{v}$ where ρ is electric charge density (item 6-3) and $\boldsymbol{v}$ is velocity (ISO 80000-3, item 3-8.1)	Electric current I (item 6-1) through a surface S is $I = \int_S \boldsymbol{J} \cdot \boldsymbol{e}_n \, \mathrm{d}A$ where $\boldsymbol{e}_n \, \mathrm{d}A$ is vector surface element. See IEC 60050-121, item 121-11-11.
6-9 (—)	linear electric current density, lineic electric current *fr* *densité* (f) *linéique de courant électrique*	$\boldsymbol{J}_S$	$\boldsymbol{J}_S = \rho_A\boldsymbol{v}$ where ρ_A is surface density of electric charge (item 6-4) and $\boldsymbol{v}$ is velocity (ISO 80000-3, item 3-8.1)	Electric current I (item 6-1) through a curve C on a surface is $I = \int_C \boldsymbol{J}_S \times \boldsymbol{e}_n \cdot \mathrm{d}\boldsymbol{r}$ where $\boldsymbol{e}_n$ is a unit vector perpendicular to the surface and line vector element and $\mathrm{d}\boldsymbol{r}$ is the differential of position vector $\boldsymbol{r}$. See IEC 60050-121, item 121-11-12.
6-10 *(5-5)*	electric field strength *fr* *champ* (m) *électrique*	$\boldsymbol{E}$	$\boldsymbol{E} = \boldsymbol{F}/q$ where $\boldsymbol{F}$ is force (ISO 80000-4, item 4-9.1) and q is electric charge (item 6-2)	See IEC 60050, item 121-11-18. q is the charge of a test particle at rest.

UNITS				ELECTROMAGNETISM
Item No.	**Name**	**International symbol**	**Definition**	**Conversion factors and remarks**
6-5.a	coulomb per metre	C/m		
6-6.a	coulomb metre	C · m		
6-7.a	coulomb per metre squared	C/m^2		
6-8.a	ampere per square metre	A/m^2		
6-9.a	ampere per metre	A/m		
6-10.a	volt per metre	V/m	1 V/m = 1 N/C	For the definition of the volt, see item 6-11.a.