ISO

ISO RECOMMENDATION

R 31

PART V

QUANTITIES AND UNITS
OF ELECTRICITY AND MAGNETISM

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BRIEF HISTORY

The ISO Recommendation R 31, *Part V – Quantities and Units of Electricity and Magnetism,* was drawn up by Technical Committee ISO/TC 12, *Quantities, Units, Symbols, Conversion Factors and Conversion Tables,* the Secretariat of which is held by the Danish Standards Association, Dansk Standardiseringsråd (DS).

Work on this question by the Technical Committee began in 1957. The ISO/TC 12 Secretariat drew up three draft proposals in succession; the last one was adopted, in 1960, as a Draft ISO Recommendation.

It should be noted that the following international organizations have had these draft proposals sent to them and have taken part in the discussions at the meetings of Technical Committee ISO/TC 12:

> International Committee on Weights and Measures,
> International Electrotechnical Commission,
> International Union of Pure and Applied Chemistry,
> International Union of Pure and Applied Physics
>   and its Sub-Committee SUN,
> International Commission on Illumination,
> Comité international de métrologie légale,
> World Meteorological Organization,
> International Commission on Radiological Units and Measurements,
> International Telegraph and Telephone Consultative Committee.

In June 1961, this Draft ISO Recommendation (No. 439) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to some modifications of an editorial nature, by the following Member Bodies:

Australia	Hungary	Poland
Austria	India	Portugal
Belgium	Israel	Romania
Canada	Italy	Sweden
Chile	Japan	Switzerland
Czechoslovakia	Mexico	U. A. R.
Denmark	Netherlands	United Kingdom
France	New Zealand	U. S. A.
Greece	Norway	Yugoslavia

Three Member Bodies apposed the approval of the Draft:

Germany, Ireland, U. S. S. R.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council which decided, in November 1965, to accept it as an ISO RECOMMENDATION.

Introduction

General remarks

This document, containing a table of *Quantities and Units of Electricity and Magnetism,* is part of a more comprehensive publication dealing with quantities and units in various fields of science and technology. Other parts of this more comprehensive publication are at present

ISO Recommendation R 31,

Part I (2nd edition): *The International System of Units and Quantities and Units of Space and Time[1]),*

Part II: *Quantities and Units of Periodic and Related Phenomena,*

Part III: *Quantities and Units of Mechanics,*

Part IV: *Quantities and Units of Heat,*

Part VII: *Quantities and Units of Acoustics,*

Part XI: *Mathematical Signs and Symbols for use in Physical Sciences and Technology.*

General information regarding the arrangement of the tables and the symbols and abbreviations used is to be found in the Introduction to ISO/R 31/Part I, where the full definitions of fundamental units are given as an appendix.

The statements in the definition columns for quantities are given merely for identification; they are not intended to be complete definitions.

Special remarks

This document follows, unless the contrary is indicated, the IEC[2]) recommendations concerning the quantities and units of electricity and magnetism. In particular, the units of the Giorgi or MKSA system recommended by the IEC are given preference by placing them first and by printing the item number in heavy type. These units belong to the International System of Units adopted by the Conférence Générale des Poids et Mesures.

Items relating to units corresponding to those of the "symmetric" CGS unit system are marked with an asterisk (*). Items and remarks relating to non-rationalized quantities are also marked with the same asterisk.

Other items for which no recommendations appear in the relevant IEC publications are marked with a dagger (†). Individual significant deviations from IEC recommendations are also marked with the same dagger.

The numerical value of the velocity of light in vacuo, expressed in centimetres per second, is often needed for the conversion factors. For simplicity, in this document, this number is denoted by ζ.

Explanatory remarks concerning quantities, equations and units in this document

In the field of electricity and magnetism, several systems of equations expressing the relations between physical quantities are used. As these equations have to be used only with corresponding unit systems, it is necessary in this Introduction to refer to the different systems of equations used in this field and their relation to the unit systems.

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[1]) The title of the first edition of this document was: "Fundamental Quantities and Units of the MKSA system and Quantities and Units of Space and Time".

[2]) International Electrotechnical Commission (IEC).

Equations and quantities

For electricity and magnetism, different "systems" of equations have been developed depending on the number and the particular choice of basic quantities on which the system of equations is founded. For the purpose of explaining this document only the following systems have to be mentioned:

I. Systems of equations with four basic quantities

In the equations with four basic quantities, at least one electric quantity is included in the basic set. In such a system the permittivity and the permeability in vacuo appear explicitly as physical quantities in the relevant equations. Two different forms of equations, based on the same set of four basic quantities, are in use:

I. 1   The *rationalized system of equations,* called "rationalized", because in these equations factors 4π or 2π only appear in cases involving spherical or circular symmetry respectively.
This rationalized system of equations is most commonly used in practical calculations in physics and in electrical technology.

I. 2   The *non-rationalized system of equations,* in which the factors 4π and 2π often appear in equations, where they would not be expected.

The equations and quantities given in the tables all belong to these two systems of equations. Where in the document there is a "rationalized" and a corresponding "non-rationalized" quantity, the word "rationalized" is generally omitted from the name of the former. Non-rationalized quantities are denoted in this document by symbols bearing a prime.

The use of rationalized equations is especially recommended.

II. Systems of equations with three basic quantities

Different systems of equations have been developed for electric and magnetic phenomena with only three basic quantities.

II. a   The *electrostatic system of equations,* defining the electric charge on the basis of Coulomb's law for the force between two electric charges, by taking the permittivity in vacuo to be a dimensionless quantity, equal to unity.

II. b   The *electromagnetic system of equations,* defining the electric currents on the basis of the law for the force between two electric currents, by taking the permeability in vacuo to be a dimensionless quantity, equal to unity.

II. c   The *symmetric system of equations,* using the electric quantities from system II. a, and the magnetic quantities from system II. b. As a result of combining the two sets of quantities, the velocity of light in vacuo appears explicitly in some of the equations combining electric with magnetic quantities.

Also for these systems of equations founded on three basic quantities two versions, a rationalized and a non-rationalized version, are possible. However, only the non-rationalized version has been commonly used.

For reasons of brevity, only equations founded on four basic quantities have been included in the tables. Since, however, in atomic and nuclear physics, a system of equations founded on three basic quantities, in particular the "symmetric" system (II. c), is commonly used, some of the essential equations of this latter system are given in the appendix, see page 18.

Units

The quantities occurring in the tables have to be measured in units belonging to a unit system founded on four basic units. The following four basic units of the International System of Units are used as the basic units for electricity and magnetism (MKSA system):

metre, kilogramme, second and ampere.

The quantities occurring in the three systems of equations founded on three basic quantities have to be measured respectively in units of

a. the electrostatic CGS system,
b. the electromagnetic CGS system,
c. the "symmetric" CGS system (or "Gauss system"),

each of which is founded on the three basic units:

centimetre, gramme and second.

Some units of the "symmetric" CGS system have been indicated in the remarks column.

In order to relate the units of these CGS systems to the corresponding units of the MKSA system, the tables contain also units of the following two systems:

A. the system founded on the four basic units:
   centimetre, gramme, second and franklin,
B. the system founded on the four basic units:
   centimetre, gramme, second and biot,

where the franklin and the biot are units of charge and current respectively, as defined in the tables. The relations between the units of the systems A and B and those of the MKSA system can be expressed in the form of equations with conversion factors which are pure numbers. The franklin and the biot correspond respectively to the electrostatic CGS unit of charge and the electromagnetic CGS unit of current. From these correspondences others follow; beneath the names of the units for the systems A and B, there are given in square brackets the names of the corresponding units of the electrostatic or the electromagnetic CGS systems. In the remarks column, these corresponding units are expressed in terms of CGS units of mechanics.

The tables contain in general the units of the system A for quantities related to electrostatics and those of the system B for quantities related to magnetism. This selection corresponds to the "symmetric CGS unit system" (or "Gauss system") which should be used in connection with the "symmetric" system of equations II. c. A particular exception is the occurrence of the unit biot (corresponding to the electromagnetic CGS unit of electric current) item No. 5-1.c; where it is introduced for the purpose of giving its definition.

For the rationalized quantities, only the MKSA units have been given. For the non-rationalized quantities, the units of the systems A or B are given. This does not imply that these latter units can not be used for rationalized quantities.

5. Electricity and Magnetism

Item No.	Quantity	Symbol	Definition[1]	Remarks
5-1.1	electric current	I		$I = \dfrac{\mathrm{d}Q}{\mathrm{d}t}$
5-2.1	electric charge, quantity of electricity	Q		$Q = \int I\,\mathrm{d}t$
5-3.1	volume density of charge, charge density	ϱ	Charge divided by volume.	
5-4.1	surface density of charge	σ	Charge divided by surface area.	
5-5.1	electric field strength	$E, (K)$	Force, exerted by electric field on an electric charge, divided by that charge.	
5-6.1	electric potential	V, φ	For electrostatic fields, a scalar quantity the gradient of which, with reversed sign, is equal to the electric field strength.	
5-6.2	potential difference, tension	$U, (V)$	The potential difference between point 1 and point 2 is the line integral from 1 to 2 of the electric field strength.	
5-6.3	electromotive force	E		

[1] The statements in this column are given merely for identification and they are not intended to be complete definitions.

5. Electricity and Magnetism

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
5-1.a	**ampere**	A	The ampere is the unit of electric current defined under that name by the Conférence Générale des Poids et Mesures.		For details, see ISO Recommandation R 31/Part I.
5-1.b	franklin per second, Fr/s [corresponds to the electrostatic CGS unit of electric current]		See definition 5-2.b.	1 Fr/s $=$ 10 ζ^{-1} A $= 3.33564 \times 10^{-10}$ A $= \zeta^{-1}$ Bi	1 electrostatic CGS unit of electric current $= 1$ cm$^{\frac{3}{2}}\cdot$g$^{\frac{1}{2}}\cdot$s^{-2} $= 1$ erg$^{\frac{1}{2}}\cdot$cm$^{\frac{1}{2}}\cdot$s$^{-1}\triangleq 1$ Fr/s For velocity of light in vacuo c, see 5-40.1 $c = \zeta$ cm/s and $\zeta = 2.99792 \times 10^{10}$ For ζ, see Introduction.
†5-1.c	biot, Bi [corresponds to the electromagnetic CGS unit of electric current]		This unit of electric current is that constant current which, when maintained in two parallel rectilinear conductors of infinite length and of negligible circular cross-section and placed at a distance of 1 centimetre apart in vacuo, would produce between these conductors a force equal to 2 dynes per centimetre length.	1 Bi $=$ 10 A	1 electromagnetic CGS unit of electric current $= 1$ cm$^{\frac{1}{2}}\cdot$g$^{\frac{1}{2}}\cdot$s$^{-1} = 1$ dyn$^{\frac{1}{2}}\triangleq 1$ Bi 1 biot is equal to 1 decaampere.
5-2.a	coulomb	C	1 C $=$ 1 A$\cdot$s		
*5-2.b	franklin, Fr [corresponds to the electrostatic CGS unit of electric charge]		This unit of charge is that charge, which exerts on an equal charge at a distance of 1 centimetre in vacuo a force of 1 dyne.	1 Fr $=$ 10 ζ^{-1} C $= 3.33564 \times 10^{-10}$ C $= \zeta^{-1}$ Bi$\cdot$s	1 electrostatic CGS unit of electric charge $= 1$ cm$^{\frac{3}{2}}\cdot$g$^{\frac{1}{2}}\cdot$s^{-1} $= 1$ erg$^{\frac{1}{2}}\cdot$cm$^{\frac{1}{2}}\triangleq 1$ Fr For ζ, see Introduction.
5-3.a	coulomb per cubic metre	C/m³			
5-4.a	coulomb per square metre	C/m²			
5-5.a	volt per metre	V/m	1 V/m $=$ 1 N/C		
*5-5.b	dyne per franklin, dyn/Fr [corresponds to the electrostatic CGS unit of electric field strength]			1 dyn/Fr $= 10^{-6} \zeta$ V/m $= 2.99792 \times 10^4$ V/m	1 electrostatic CGS unit of electric field strength $= 1$ cm$^{-\frac{1}{2}}\cdot$g$^{\frac{1}{2}}\cdot$s$^{-1}\triangleq 1$ dyn/Fr For ζ, see Introduction.
5-6.a	volt	V	1 V $=$ 1 W/A		1 V $= 1$ m²$\cdot$kg$\cdot$s$^{-3}\cdot$A^{-1} For watt, see 3-23.a, ISO/R 31/Part III.
*5-6.b	erg per franklin, erg/Fr [corresponds to the electrostatic CGS unit of electric potential]			1 erg/Fr $= 10^{-8} \zeta$ V $= 2.99792 \times 10^2$ V	1 electrostatic CGS unit of electric potential $= 1$ cm$^{\frac{1}{2}}\cdot$g$^{\frac{1}{2}}\cdot$s$^{-1}\triangleq 1$ erg/Fr For ζ, see Introduction.

* See Introduction, Special remarks.
† This is not contained in the relevant IEC publications.

Item No.	Quantity	Symbol	Definition [1]	Remarks
5-7.1	displacement, (rationalized displacement)	D	The displacement is a vector quantity, the divergence of which is equal to the charge density.	
*5-8.1	non-rationalized displacement	D'	The non-rationalized displacement is a vector quantity, the divergence of which is equal to 4π times the charge density.	This quantity is sometimes called electric induction. $D' = 4\pi D$
5-9.1	electric flux, flux of displacement, (flux of rationalized displacement)	Ψ	The electric flux across a surface element is the scalar product of the surface element and the displacement.	
*5-10.1	flux of non-rationalized displacement	Ψ'	The flux of non-rationalized displacement across a surface element is the scalar product of the surface element and the non-rationalized displacement.	$\Psi' = 4\pi\,\Psi$
5-11.1	capacitance	C	Charge divided by potential difference.	
5-12.1	permittivity	ε	Displacement divided by electric field strength.	
5-12.2	permittivity of vacuum	ε_0		$\varepsilon_0 = 10^{11}\,\zeta^{-2}\,(4\pi)^{-1}$ F/m $= 8.854\,19 \times 10^{-12}$ F/m
*5-13.1	non-rationalized permittivity	ε'	Non-rationalized displacement divided by electric field strength.	$\varepsilon' = 4\pi\varepsilon$
*5-13.2	non-rationalized permittivity of vacuum	ε_0'		$\varepsilon_0' = 4\pi\varepsilon_0 = 1$ Fr^2/(erg · cm)
5-14.1	relative permittivity	ε_r	$\varepsilon_r = \varepsilon/\varepsilon_0$	This quantity is dimensionless. $\varepsilon_r = \varepsilon'/\varepsilon_0'$ *)
†5-15.1	electric susceptibility	χ_e	$\chi_e = \varepsilon_r - 1$	This quantity is dimensionless.
*5-16.1	non-rationalized electric susceptibility	χ_e'	$\chi_e' = (\varepsilon_r - 1)/4\pi$	This quantity is dimensionless. $\chi_e' = (4\pi)^{-1}\chi_e$

[1]) See footnote on page 6.
* See Introduction, Special remarks.
† This is not contained in the relevant IEC publications.

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
5-7.a	coulomb per square metre	C/m²			
*5-8.a	franklin per square centimetre, Fr/cm² [corresponds to the electrostatic CGS unit of displacement]				1 electrostatic CGS unit of displacement $= 1\ cm^{-\frac{1}{2}} \cdot g^{\frac{1}{2}} \cdot s^{-1} \triangleq 1\ Fr/cm^2$ When the non-rationalized displacement is equal to 1 Fr/cm², the corresponding displacement is equal to: $10^5\ \zeta^{-1}\ (4\pi)^{-1}\ C/m^2$ $= 2.654\,42 \times 10^{-7}\ C/m^2$ For ζ, see Introduction.
5-9.a	coulomb	C			
*5-10.a	franklin, Fr [corresponds to the electrostatic CGS unit of flux of displacement]				1 electrostatic CGS unit of flux of displacement $= 1\ cm^{\frac{3}{2}} \cdot g^{\frac{1}{2}} \cdot s^{-1} \triangleq 1\ Fr$ When the flux of non-rationalized displacement is equal to 1 Fr, the corresponding flux of displacement is equal to: $10\ \zeta^{-1}\ (4\pi)^{-1}\ C$ $= 2.654\,42 \times 10^{-11}\ C$ For ζ, see Introduction.
5-11.a	farad	F	1 F = 1 C/V		
*5-11.b	franklin squared per erg, Fr²/erg [corresponds to the electrostatic CGS unit of capacitance]			$1\ Fr^2/erg = 10^9\ \zeta^{-2}\ F$ $= 1.112\,65 \times 10^{-12}\ F$	1 electrostatic CGS unit of capacitance $= 1\ cm \triangleq 1\ Fr^2/erg$ For ζ, see Introduction.
5-12.a	farad per metre	F/m			
5-13.a	franklin squared per erg centimetre, Fr²/(erg·cm) [corresponds to the electrostatic CGS unit of permittivity]				1 electrostatic CGS unit of permittivity $= 1 \triangleq 1\ Fr^2/(erg \cdot cm)$ When the non-rationalized permittivity is equal to 1 Fr²/(erg·cm), the corresponding permittivity is equal to: $10^{11}\ \zeta^{-2}\ (4\pi)^{-1}\ F/m$ $= 8.854\,19 \times 10^{-12}\ F/m$ For ζ, see Introduction.

* See Introduction, Special remarks.

Item No.	Quantity	Symbol	Definition [1]	Remarks
5-17.1	electric polarization	P	$P = D - \varepsilon_0 E$	$P = (4\pi)^{-1}(D' - \varepsilon_0' E)$ *)
5-18.1	electric dipole moment	$p, (p_e)$	The electric dipole moment is a vector quantity, the vector product of which with the electric field strength is equal to the torque.	
5-19.1	current density	$J, (S)$	A vector quantity the integral of which over a given surface is equal to the current flowing through that surface.	
5-20.1	linear current density	$A, (\alpha)$	Current divided by the breadth of conducting sheet.	
5-21.1	magnetic field strength	H	The magnetic field strength is a vector quantity, the curl (rotation) of which is equal to the current density, including the displacement current.	
* 5-22.1	non-rationalized magnetic field strength	H'	The non-rationalized magnetic field strength is a vector quantity, the curl (rotation) of which is equal to 4π times the current density, including the displacement current.	$H' = 4\pi H$
5-23.1	magnetic potential difference	U_m	The magnetic potential difference between point 1 and point 2 is the line integral from 1 to 2 of the magnetic field strength.	
5-23.2	magnetomotive force	F, F_m	$F = \oint H_s ds$	
5-24.1	magnetic flux density, magnetic induction	B	The magnetic flux density is a vector quantity such that the force exerted on an element of current is equal to the vector product of this element and the magnetic flux density.	
5-25.1	magnetic flux	Φ	The magnetic flux across a surface element is the scalar product of the surface element and the magnetic flux density.	

[1]) See footnote on page 6.
* See Introduction, Special remarks.

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
5-17.a	coulomb per square metre	C/m²			
* **5-17.b**	franklin per square centimetre, Fr/cm² [corresponds to the electrostatic CGS unit of electric polarization]			$1\ \mathrm{Fr/cm^2} = 10^5\ \zeta^{-1}\ \mathrm{C/m^2}$ $= 3.335\,64 \times 10^{-6}\ \mathrm{C/m^2}$	1 electrostatic CGS unit of electric polarization $= 1\ \mathrm{cm^{-\frac{1}{2}}} \cdot \mathrm{g^{\frac{1}{2}}} \cdot \mathrm{s^{-1}} \triangleq 1\ \mathrm{Fr/cm^2}$ For ζ, see Introduction.
5-18.a	coulomb metre	C · m			
* **5-18.b**	franklin centimetre, Fr · cm [corresponds to the electrostatic CGS unit of electric dipole moment]			$1\ \mathrm{Fr \cdot cm} = 10^{-1}\ \zeta^{-1}\ \mathrm{C \cdot m}$ $= 3.335\,64 \times 10^{-12}\ \mathrm{C \cdot m}$	1 electrostatic CGS unit of electric dipole moment $= 1\ \mathrm{cm^{\frac{3}{2}}} \cdot \mathrm{g^{\frac{1}{2}}} \cdot \mathrm{s^{-1}} \triangleq 1\ \mathrm{Fr \cdot cm}$ For ζ, see Introduction.
5-19.a	ampere per square metre	A/m²			
5-20.a	ampere per metre	A/m			
5-21.a	ampere per metre	A/m			
* **5-22.a**	biot per centimetre, Bi/cm [corresponds to the oersted, Oe, the electromagnetic CGS unit of magnetic field strength]				$1\ \mathrm{Oe} = 1\ \mathrm{cm^{-\frac{1}{2}}} \cdot \mathrm{g^{\frac{1}{2}}} \cdot \mathrm{s^{-1}}$ $= 1\ \mathrm{dyn^{\frac{1}{2}}} \cdot \mathrm{cm^{-1}} \triangleq 1\ \mathrm{Bi/cm}$ When the non-rationalized magnetic field strength is equal to 1 Bi/cm, the corresponding magnetic field strength is equal to $10^3\ (4\pi)^{-1}\ \mathrm{A/m} = 79.5775\ \mathrm{A/m}$
5-23.a	ampere	A			Sometimes called "ampere-turn".
5-24.a	tesla	T	$1\ \mathrm{T} = 1\ \mathrm{Wb/m^2} = 1\ \mathrm{V \cdot s/m^2}$		This unit is also called weber per square metre.
* **5-24.b**	dyne per biot centimetre, dyn/(Bi · cm) [corresponds to the gauss, Gs, G, the electromagnetic CGS unit of magnetic flux density]			$1\ \mathrm{dyn/(Bi \cdot cm)} = 10^{-4}\ \mathrm{Wb/m^2}$	$1\ \mathrm{Gs} = 1\ \mathrm{cm^{-\frac{1}{2}}} \cdot \mathrm{g^{\frac{1}{2}}} \cdot \mathrm{s^{-1}}$ $= 1\ \mathrm{dyn^{\frac{1}{2}}} \cdot \mathrm{cm^{-1}} \triangleq 1\ \mathrm{dyn/(Bi \cdot cm)}$ G is used in physics. The name gauss is also used for the unit 10^{-4} tesla.
5-25.a	weber	Wb	$1\ \mathrm{Wb} = 1\ \mathrm{V \cdot s}$		
* **5-25.b**	dyne centimetre per biot, dyn · cm/Bi [corresponds to the maxwell, Mx, the electromagnetic CGS unit of magnetic flux]			$1\ \mathrm{dyn \cdot cm/Bi} = 10^{-8}\ \mathrm{Wb}$	$1\ \mathrm{Mx} = 1\ \mathrm{cm^{\frac{3}{2}}} \cdot \mathrm{g^{\frac{1}{2}}} \cdot \mathrm{s^{-1}}$ $\triangleq 1\ \mathrm{dyn \cdot cm/Bi}$ The name maxwell is also used for the unit 10^{-8} weber.

* See Introduction, Special remarks.

Item No.	Quantity	Symbol	Definition [1]	Remarks
5-26.1	magnetic vector potential	A	The magnetic vector potential is a vector quantity, the curl (rotation) of which is equal to the magnetic flux density.	
5-27.1	self inductance	L	The magnetic flux through a loop, caused by the current in the loop, divided by this current.	
5-27.2	mutual inductance	M, L_{12}	The magnetic flux through a loop, due to the current in another loop, divided by this current.	
5-28.1	coupling coefficient	$k, (\varkappa, \kappa)$	$k = L_{12}/\sqrt{L_1 L_2}$	These quantities are dimensionless.
5-28.2	leakage coefficient	σ	$\sigma = 1 - k^2$	
5-29.1	permeability	μ	Magnetic flux density divided by magnetic field strength.	
5-29.2	permeability of vacuum	μ_0		$\mu_0 = 4\pi \cdot 10^{-7}$ H/m $= 1.256\ 64 \times 10^{-6}$ H/m
*5-30.1	non-rationalized permeability	μ'	Magnetic flux density divided by non-rationalized magnetic field strength.	$\mu' = (4\pi)^{-1}\mu$
*5-30.2	non-rationalized permeability of vacuum	μ_0'		$\mu_0' = (4\pi)^{-1}\mu_0 = 1$ dyn/Bi²
5-31.1	relative permeability	μ_r	$\mu_r = \mu/\mu_0$	This quantity is dimensionless. $\mu_r = \mu'/\mu_0'$ *)
5-32.1	magnetic susceptibility	$\varkappa, \kappa$	$\varkappa = \mu_r - 1$	This quantity is dimensionless.
*5-33.1	non-rationalized magnetic susceptibility	$\varkappa', \kappa'$	$\varkappa' = (\mu_r - 1)/4\pi$	This quantity is dimensionless. $\varkappa' = (4\pi)^{-1}\varkappa$
5-34.1	electromagnetic moment (magnetic moment)	m	The electromagnetic moment is a vector quantity, the vector product of which with the magnetic flux density is equal to the torque.	
5-35.1	magnetization	H_1, M	$H_1 = (B/\mu_0) - H$	$H_1 = (4\pi)^{-1}(B/\mu_0' - H')$ *)
5-36.1	magnetic polarization	B_1, J	$B_1 = B - \mu_0 H$	
*5-37.1	non-rationalized magnetic polarization	J'	$4\pi J' = B - \mu_0' H'$	$J' = (4\pi)^{-1}B_1$

[1]) See footnote on page 6.
* See Introduction, Special remarks.

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
5-26.a	weber per metre	Wb/m			
5-27.a	henry	H	$1\ H = 1\ V \cdot s/A$ $= 1\ Wb/A$		
*5-27.b	erg per biot squared, erg/Bi² [corresponds to the electromagnetic CGS unit of inductance]			$1\ erg/Bi^2 = 10^{-9}\ H$	1 electromagnetic CGS unit of inductance = 1 cm ≙ 1 erg/Bi²
5-29.a	henry per metre	H/m	$1\ H/m = 1\ V \cdot s/(A \cdot m)$ $= 1\ Wb/(A \cdot m)$		
*5-30.a	dyne per biot squared, dyn/Bi² [corresponds to the electromagnetic CGS unit of permeability]				1 electromagnetic CGS unit of permeability = 1 ≙ 1 dyn/Bi² When the non-rationalized permeability is equal to 1 dyn/Bi², the corresponding permeability is equal to: $4\pi \cdot 10^{-7}\ H/m$ $= 1.256\,64 \times 10^{-6}\ H/m$
5-34.a	ampere metre squared	A·m²			
*5-34.b	biot centimetre squared, Bi·cm² [corresponds to the electromagnetic CGS unit of electromagnetic moment]			$1\ Bi \cdot cm^2 = 10^{-3}\ A \cdot m^2$	1 electromagnetic CGS unit of electromagnetic moment $= 1\ cm^{\frac{5}{2}} \cdot g^{\frac{1}{2}} \cdot s^{-1}$ ≙ 1 Bi·cm²
5-35.a	ampere per metre	A/m			
5-36.a	tesla	T	$1\ T = 1\ Wb/m^2$ $= 1\ V \cdot s/m^2$		
*5-37.a	dyne per biot centimetre, dyn/(Bi·cm) [corresponds to the electromagnetic CGS unit of magnetic polarization]				1 electromagnetic CGS unit of magnetic polarization $= 1\ cm^{-\frac{1}{2}} \cdot g^{\frac{1}{2}} \cdot s^{-1}$ ≙ 1 dyn/(Bi·cm) When the non-rationalized magnetic polarization is equal to 1 dyn/(Bi·cm), the corresponding magnetic polarization is equal to: $4\pi \cdot 10^{-4}\ T$ $= 1.256\,64 \times 10^{-3}\ T$

* See Introduction, Special remarks.

Quantities
5-38.1 ... 5-48.1

Item No.	Quantity	Symbol	Definition[1])	Remarks
†5-38.1	electromagnetic energy density	w	Electromagnetic field energy divided by volume.	
5-39.1	Poynting vector	S	Flux density of electromagnetic field energy.	The Poynting vector is equal to the vector product of electric field strength and magnetic field strength.
5-40.1	velocity of propagation of electromagnetic waves in vacuo	c		$c = \dfrac{1}{\sqrt{\varepsilon_0 \mu_0}} = 2.997\ 925 \times 10^8$ m/s ("standard error" $\pm 3 \times 10^2$ m/s) J. W. M. Du Mond and E. R. Cohen, Recommended Values of the Physical Constants-1963, IUPAP Commission on Nuclidic Masses, Doc. MN 632-Sept. 4, 1963. Sometimes the symbol c is used for the phase velocity in a medium, in which case c_0 may be used for the velocity in vacuo.
5-41.1	resistance (to direct current)	R	Electric potential difference divided by current when there is no electromotive force in the conductor.	
5-42.1	conductance (to direct current)	G	$G = 1/R$	
5-43.1	resistivity	ϱ	Electric field strength divided by current density when there is no electromotive force in the conductor.	
5-44.1	conductivity	γ, σ	$\gamma = 1/\varrho$	
5-45.1	reluctance	R, R_m	Magnetic potential difference divided by magnetic flux.	
5-46.1	permeance	$\varLambda, (P)$	$\varLambda = 1/R_\mathrm{m}$	
5-47.1	number of turns in winding	N		These quantities are dimensionless.
5-47.2	number of phases	m		
5-47.3	number of pairs of poles	p		
5-48.1	phase displacement	φ	When $U = U_\mathrm{m} \cos \omega t$ and $I = I_\mathrm{m} \cos (\omega t - \varphi)$ then φ is the phase displacement.	This quantity is dimensionless. $\omega t - \varphi$ is called the phase of I.

[1]) See footnote on page 6.
† This is not contained in the relevant IEC publications.

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
5-38.a	joule per cubic metre	J/m³			
5-39.a	watt per square metre	W/m²			
5-40.a	metre per second	m/s			
*5-40.b	centimetre per second	cm/s			
5-41.a	ohm	Ω	$1\ \Omega = 1\ V/A$		
5-42.a	siemens	S	$1\ S = 1\ A/V$		$1\ S = 1\ \Omega^{-1}$ also called reciprocal ohm or mho.
5-43.a	ohm metre	Ω·m			
5-44.a	siemens per metre	S/m			
5-45.a	reciprocal henry	H⁻¹			
5-46.a	henry	H			

* See Introduction, Special remarks.

Item No.	Quantity	Symbol	Definition[1])	Remarks
5-49.1	impedance, (complex impedance)	Z	The complex representation of potential difference divided by the complex representation of current.	$Z = |Z|\,\mathrm{e}^{\mathrm{j}\varphi} = R + \mathrm{j}X$ $|Z| = \sqrt{R^2 + X^2}$ When $X = \omega L - 1/(\omega C)$, ωL and $1/(\omega C)$ are called inductive reactance and capacitive reactance respectively.
5-49.2	modulus of impedance, (impedance)	$|Z|$		
5-49.3	reactance	X	Imaginary part of impedance.	
5-49.4	resistance	R	Real part of impedance.	Compare 5-41.1.
5-50.1	quality factor	Q	$Q = |X|/R$	This quantity is dimensionless.
5-51.1	admittance, (complex admittance)	Y	$Y = 1/Z$	$Y = |Y|\,\mathrm{e}^{-\mathrm{j}\varphi} = G + \mathrm{j}B = \dfrac{R - \mathrm{j}X}{|Z|^2}$ $|Y| = \sqrt{G^2 + B^2}$
5-51.2	modulus of admittance, (admittance)	$|Y|$		
5-51.3	susceptance	B	Imaginary part of admittance.	
5-51.4	conductance	G	Real part of admittance.	Compare 5-42.1.
5-52.1	active power	P	When $U = U_\mathrm{m} \cos \omega t = \sqrt{2}\,U_\mathrm{eff} \cos \omega t$ and $I = I_\mathrm{m} \cos(\omega t - \varphi) = \sqrt{2}\,I_\mathrm{eff} \cos(\omega t - \varphi)$ then $I_\mathrm{eff}\,U_\mathrm{eff} = S$ $I_\mathrm{eff}\,U_\mathrm{eff} \cos\varphi = P$ $I_\mathrm{eff}\,U_\mathrm{eff} \sin\varphi = Q$	U_eff and I_eff are called the effective values of potential difference and current respectively. The name "power factor" is used for the quantity P/S.
5-53.1	apparent power	$S,\ (P_s)$		
5-54.1	reactive power	$Q,\ (P_q)$		

[1]) See footnote on page 6.