



IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering

STANDARDS

IEEE Standards Coordinating Committee 14

Developed by the
IEEE Standards Coordinating Committee 14 on
Quantities, Units, and Letter Symbols

IEEE Std 280™-2021
(Revision of IEEE Std 280-1982)



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Approved 16 June 2021

IEEE SA Standards Board

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Abstract: Letter symbols to represent various quantities used in electrical science and technology are presented in this standard.

Keywords: IEEE 280™, letter symbols, measurement units, metric system, metrology, SI, symbols

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Introduction

This introduction is not part of IEEE Std 280-2021, IEEE Standard for Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

This standard was originally developed from three separate standards, ASA Z10.5-1949, Letter Symbols for Electrical Quantities; ASA Y10.9-1953, Letter Symbols for Radio; and 57IRE21S1, Letter Symbols and Mathematical Signs. The first edition of this standard was issued as USAS Y10.5-1968 / IEEE Std 280™-1968, Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering. In the development of this historical standard, the International Electrotechnical Commission Publication 27, Letter symbols to be used in electrical technology, was followed closely.

The standard was revised again in 1985. At that time, the style was updated, and the following revisions were made: the text concerning unit symbols was expanded and the text was modified to reflect the SI system of units as described in the then current American National Standard Metric Practice (ANSI/IEEE 268™-1982).

In this revision, the standard has been revised to reflect current practices, references were updated, deprecated symbols were removed, corrections were made, and an informative bibliography was added. In addition, the text was updated to reflect the SI system of units as described in the American National Standard for Metric Practice, IEEE/ASTM SI 10-2016.

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~~An American National Standard~~

IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering

1. Overview

1.1 Scope

This standard covers letter symbols used to represent physical quantities in the field of electrical science and electrical engineering. These symbols are independent of the units ~~(see ANSI/IEEE Std 260-1978 [2]¹)~~ employed or special values assigned. Also included are selected symbols for mathematics and for physical constants.

1.2 Purpose

This standard provides a basic reference for letter symbols, and corresponding units, in the field of electrical science and electrical engineering. It is intended to be used by producers of technical documents and for the interpretation of such documents.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{1,2}

¹ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

² The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). 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/ANSI Std 260.3TM, American National Standard Mathematical Signs and Symbols for Use in Physical Sciences and Technology.^{3,4,5}

IEEE/ASTM SI 10TM, American National Standard for Metric Practice.⁶

~~When the following American National Standards referred to in this standard are superseded by a revision approved by the American National Standards Institute, the latest version shall be used.~~

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⁵ ANSI publications are available from the American National Standards Institute (<https://www.ansi.org/>).

⁶ ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

~~[1]—ANSI Y10.17-1961 (R1973), American National Standard Guide for Selecting Greek Letters Used as Letter Symbols for Engineering Mathematics.~~

~~ANSI/IEEE Std 260-1978,~~ IEEE Std 260.1™, Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units).

IEEE Std 945™, Recommended Practice for Preferred Metric Units for Use in Electrical and Electronics Science and Technology.

~~[3] ANSI/IEEE Std 268-1982, American National Standard Metric Practice.~~

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁷

abbreviation: A letter or a combination of letters that, by convention, represents a word or a name in a particular language.

acronym: A combination of the initial letters of other words that is pronounced as a word.

letter symbol: A letter or combination of letters standing for a physical quantity, a unit of measurement, or a prefix used with units of measurement.

mathematical constant: A number that does not change, whose value is fixed by an unambiguous definition.

NOTE—An example of an unambiguous definition is the ratio of the circumference of a circle to its diameter.⁸

⁷ IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

⁸ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

physical constant: A number that does not change, whose value is based on a physical measurement.

physical quantity: A measurable attribute of phenomena or matter.

NOTE-Examples of physical quantities are length, mass, and time.

3.2 Acronyms and abbreviations

AM Amplitude Modulation

ANSI American National Standards Institute

ASTM American Society for Testing and Materials

BIPM Bureau International des Poids et Mesures (International Bureau of Weights and Measures)

CGPM Conférence Générale des Poids et Mesures (General Conference on Weights and Measures)

CIPM Comité International des Poids et Mesures (International Committee for Weights and Measures)

FM Frequency Modulation

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineers

ISO International Organization for Standardization

NIST National Institute of Standards and Technology

SI Systeme International (d'unites) (International System of Units)

4. General principles of letter symbol standardization

4.1 Letter symbols

Letter symbols² include symbols for physical quantities (*quantity symbols*) and symbols for the units in which these quantities are measured (*unit symbols*). ²Letter symbol as a technical term does not have the same meaning as either *name* or *abbreviation*. An abbreviation is a letter or a combination of letters (Plus sometimes an apostrophe or a full stop), which by convention represents a *word* or a *name* in a particular language; hence, an abbreviation can ~~may~~ be different in a different language. A symbol represents a *quantity* or a *unit* and is, therefore, independent of language.

Example: For electromotive force, the symbol is E , whereas the abbreviation is emf in English, "fern" in French, and EMK in German. The word *ampere* is sometimes abbreviated amp; the symbol for this unit is A.

A quantity symbol is, in general, a single letter (e.g., I ~~(for example, I for electric current)~~ ~~specified as to general form of type,~~ and modified when appropriate by one or more subscripts or superscripts. Sometimes symbols comprising two letters are used, for example Reynolds number Re . In a given work the same letter symbol shall ~~should~~ appear throughout for the same physical quantity, regardless of the units employed or of special values assigned.

²~~Symbols comprising two letters are sometimes used for numerical transport parameters such as Reynolds number Re .~~

A unit symbol⁴ is a letter or group of letters (e.g. ~~for example~~, mm for millimeter), or in a few cases, is a special sign, which is ~~that may be~~ used in place of the name of a unit.⁹ Unit symbols shall not be treated in the same manner as general abbreviations. The SI unit symbols are the same worldwide regardless of the spelling, language, or alphabet. By contrast, unit names can be spelled (and pronounced) differently from one language to the next and can be written in many different language character sets.

4.2 Alphabets and typography

Letter symbols are mainly restricted to the English and Greek alphabets. ⁸Greek letters that are easily confused with English letters shall be ~~are~~ avoided.¹⁰ ~~See ANSI Y 10.17-1961 (1973), [1].~~ ⁵The type families that are used for text in modern book and journal publishing all include italic (sloping) type faces and related roman (upright) type faces. The former shall be ~~are~~ used for quantity symbols, and the latter, for unit symbols. The distinctions are discussed more fully in the following paragraphs. (In the context of this standard, the term 'roman' is used simply to mean upright in contrast with 'italic' ~~sloping~~ and carries no connotation regarding serifs, line widths, or the like.) In situations where roman and italic are ~~not~~ both unavailable ~~available~~, care shall be taken to avoid confusion between quantities and units. For example, an underline is frequently used to indicate italic type, ~~and where an underline can be provided, as in manual typewriting, this practice is often helpful.~~

Unconventional typefaces should ~~generally~~ not be used for letter symbols. Script and Old English faces, for example, are typically not appropriate for unit symbols. Such special faces have seen limited use for quantity symbols, but good modern practice avoids them ~~(see 3.3, last paragraph).~~

⁹~~Formerly it was common to treat~~ Unit symbols have sometimes been treated in the same manner as general abbreviations, but the ~~current~~ recommendations of the International ~~Committee Organization~~ for Weights and Measures Standardization ~~(CIPM ISO)~~, and of many other international and national bodies concerned with standardization, emphasize the symbolic character of these designations and rigidly prescribe the manner in which they shall be treated. This ~~The~~ concept of the unit symbol is therefore adopted in this standard.

¹⁰ See discussion on conventions and Greek characters in ANSI/IEEE Std 260.3™.

Symbols for physical quantities, physical constants, indices, mathematical variables, ~~indices~~, and general functions shall be ~~functions~~ ~~are~~ printed in italic (~~sloping~~) type. ^{11,12} For example,

~~A~~ , A	area
e	charge of an electron
i, j, k, n	indices
x, y, z	Cartesian coordinates
$f(x)$	function of x

Symbols for physical units, mathematical constants, specific mathematical functions, operators, and numbers used as indices shall be ~~are~~ printed in roman type. For example,

cm	centimeter
e	base of natural logarithms
$\sin x$	sine of x
$J_2(z), J_n(z)$	Bessel functions
dx	differential of x

Subscripts and superscripts are governed by the above principles. For example,

X_C, X_L capacitive and inductive reactance (physical quantities)

a_{ij}, a_{45} matrix elements (indices, numbers used as indices)

¹¹ The term physical constant (e.g., Planck constant) is used here to contrast with mathematical constant (e.g., base of the natural logarithms).

¹²⁶ The term general/functions is used here to contrast with specific mathematical functions, for which roman type is to be used.

Additionally, subscripts used to identify the type (such as input, output), or a specific condition (such as at constant pressure) shall be ~~Those that are letter symbols for quantities or for indices are printed in italic type, while all others are~~ printed in roman type.⁷ For example,

I_i, I_o input current, output current

X_{av} average value of x

C_p heat capacity at constant pressure p

~~a_{ij}, a_{45}~~ ~~matrix elements~~

For indicating the vector character of a quantity, boldface italic type shall be ~~is~~ used. For example,

$\mathbf{F}$ force

$\mathbf{H}$ magnetic field strength

Ordinary italic type shall be ~~is~~ used to represent the magnitude of a vector quantity. It is also commonly used for a vector quantity when there is no need to draw attention to the vector character of the quantity.

When tensor quantities of second or higher order are to be represented by a single letter, sans-serif bold italic type shall ~~should~~ be used (for example, $\mathbf{A}, \mathbf{B}$).

Matrices shall be bold italic type and are usually capital letters (for example, $\mathbf{A}, \mathbf{B}$). Elements of matrices are usually lower case.

The above conventions on italicization are consistent with [BII] and [B22].¹³

¹³ ⁴The numbers in brackets correspond to those of the bibliography ~~references~~ in Annex A ~~Section 2~~.

4.3 Remarks concerning quantity symbols

Quantity symbols shall ~~may~~ be used in mathematical expressions in a ~~any~~ way that is consistent with good mathematical usage. The product of two quantities a , b , is indicated by writing ab . The quotient is ~~may be~~ indicated by writing $\frac{a}{b}$, a/b , or ab^{-1} .

When ~~If~~ more than one solidus (/) is used in any algebraic term, parentheses shall be inserted to remove any ambiguity. For example, ~~Thus one may~~ write $(a/b)/c$, or $a/(b/c)$, but not $a/b/c$.

Subscripts and superscripts are widely used with quantity symbols. Several subscripts or superscripts, sometimes separated by commas, may be attached to a single letter. But, so far as logical clarity permits, subscripts and superscripts shall ~~should~~ not be attached to other subscripts and superscripts. A symbol that has been modified by a superscript shall ~~should~~ be enclosed in parentheses before an exponent is attached.

Conflicts that occur because different quantities are assigned identical symbols shall ~~in the same or different standard symbol lists should~~ be resolved in one of the following ways by use of one of the following:

- ~~1) By use of a reserve symbol (alternative symbol) if one is listed~~
- ~~2) By use of a subscript or superscript selected by the author for one or more of the conflicting requirements~~
- ~~3) By use of uppercase letters as variants for lowercase letters and vice versa, but only if no ambiguity results.~~

4.4 Remarks concerning unit symbols

Unit symbols, not unit names, shall be used in complicated expressions. Roman type ~~shall be~~, ~~in general lowercase, is~~ used for unit symbols, even when the surrounding text is in italic font. In general, use lowercase ~~except~~ for unit symbols. ~~a very few that use special signs (such as ° for degree).~~ If, ~~however,~~ the symbol is for a unit whose name is derived from a proper name (e.g., James Watt), uppercase roman type ~~shall be is used~~ for the first letter (W, for the example given).¹⁴ ~~As a further exception to the general rule,~~ The symbol L ~~shall be is~~ used for liter to avoid confusion between the lowercase letter l and the numeral 1. Some additional exceptions arise in the special cases where symbols are joined, as in eV, the symbol for electronvolt, and in mmHg, the symbol for conventional millimeter of mercury, ~~a unit of pressure.~~ The distinction between upper and lowercase letters ~~shall should~~ be followed, even if the symbol appears in applications where the other lettering is in uppercase style. The form of unit symbols is the same for singular and plural. Unit symbols shall ~~, and they are~~ not be followed by a period except at the end of a sentence. Positive and negative exponents may be used with unit symbols.

~~In the complete expression for a quantity,~~ A space ~~is used should be allowed~~ between the numerical value and the unit symbol, except:

- Between the unit symbols for degree, minute, and second of plane angle
- When the quantity is used in an adjectival sense

For example, write 35 mm ~~ram~~, not 35mm, and 2' .371 ~~m~~, not 2' .371m. When the quantity is used in an adjectival sense, a hyphen ~~shall be is often~~ used instead of a space between the number and the unit name or between the number and the symbol (except when the first character of the symbol is not a letter, as in dc ~~°C~~).

¹⁴ ~~7~~ Prefixes are considered separately (see 4.5).

Examples:

Adjectival sense	Non-adjectival sense
3-meter pole...	The length is 3 meters.
35-mm film...	The width is 35 mm.
100 °C hot plate...	The temperature is 100 °C.

(New)

~~A 3-meter pole — The length is 3 meters.~~

~~A 35-mm film — The width is 35 mm.~~

Greater care is required to form products and quotients of unit symbols, as many unit symbols consist of more than one letter.

~~EXCEPTION: No space is left between the numerical value and the symbols for degree, minute, and second of plane angle.~~

When a compound unit is formed by multiplication of two or more other units, its symbol should consist ~~consists~~ of the symbols for the separate units joined by a raised dot (preferred) or separated by a thin, non-breaking space (for example, N·m or N m for newton meter). If no confusion would result, the dot may be omitted in the case of familiar compounds or where symbols are separated by an exponent. For example, such as ~~such as~~ watthour (symbol Wh) and voltampere (symbol VA), or N·m²kg². ~~if no confusion would result.~~⁸ Hyphens shall ~~should~~ not be used in symbols for compound units. ~~Positive and negative exponents may be used with the symbols for units.~~

When a compound unit is formed by division of one unit by another, its symbol shall be ~~is~~ constructed in one of the following forms:

$$\text{m/s or m}\cdot\text{s}^{-1} \text{ or m s}^{-1} \text{ or } \frac{\text{m}}{\text{s}}$$

(New)

⁸It may also be omitted where symbols are separated by an exponent as in N·m²kg⁻²

(Deleted)

NOTE— $m \cdot s^{-1}$ or $m \, S^{-1}$ may be used for meter per second but ms^{-1} symbolizes $1/ms$ or $10^3 \, S^{-1}$ as described in 4.5. The raised dot or space is therefore extremely important.

In simple cases ~~a use of the~~ solidus (oblique stroke or slash, /) should be used to represent a quotient. ~~slash) is preferred, but~~ In no case should more than one solidus, or a solidus followed by a product, be used in the same expression unless parentheses are inserted to avoid ambiguity. In complicated cases negative powers should be used.⁹For example, write:

$(J/mol) / K$ or $J / (mol \cdot K)$ or $(J / mol) K^{-1}$

but *not* $J/mol/K$ or $J/mol \cdot K$.

Letter symbols and mathematical notation shall ~~should~~ not be mixed with unit names in the same expression. For example, write joule ~~joules~~ per kilogram or J/kg . Do not write joule ~~joules~~/kilogram or joule ~~joules~~/kg, or $J/kilogram$.

Reference IEEE Std 260.1™ for letter symbols for units of measurement and IEEE Std 945™ for preferred metric units.

4.5 The International System of Units (SI)

Some units in this standard ~~some units~~ are identified as SI units. These units belong to the International System of Units (Système International d'Unités), which is the name given in 1960 by the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) (CGPM Measures) to the coherent system of units based on the ~~following~~ base ~~units and~~ quantities and units of Table 1.

⁹~~The notation for products and quotients of unit symbols is intentionally made more explicit than given in 3.3 for quantity symbols because some unit symbols consist of more than one letter.~~

SI may also be omitted where symbols are separated by an exponent as in $\text{N}\cdot\text{m}^2\text{kg}^{-2}\text{s}^{-9}$; the notation for products and quotients of unit symbols is intentionally made more explicit than that given in 3.3 for quantity symbols because some unit symbols consist of more than one letter.

SI includes as subsystems the MKS system of units, which covers mechanics, and the MKSA system, which covers mechanics and electricity.

Table 1 -51 base quantities and units

Quantity	Unit
Length	meter
Mass	kilogram
Time	second
Electric current	ampere
Thermodynamic temperature	kelvin
Amount of substance	mole
Luminous intensity	candela

The spellings *meter* and *liter* are recommended. This is in accordance with guidance given by the Department of Commerce, which is given the responsibility of interpreting SI for the United States under the Metric Conversion Act of 1975. The variant spellings *metre* and *litre* are also used, especially in British English.

The spellings meter, liter, and deka are recommended.¹⁵

The ~~following~~ prefixes in Table 2 shall be ~~are~~ used to indicate decimal multiples or submultiples of SI units.^{16, 40}

¹⁵ These spellings are in agreement with NIST Special Publication 330, 2019 Edition [8 24].

^{16 40} The use of SI prefixes with U.S. customary units is not recommended, except in the case of the micro inch and kilopound-force.

Table 2 -51 unit prefixes and symbols

Multiple	SI prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

[\(New\)](#)

Multiple	SI Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

(Deleted)

Compound prefixes, formed by the juxtaposition of two or more SI prefixes, shall ~~are~~ not ~~to~~ be used.

For example, use

1 nm, *not* 1 m μ m

1 pF, *not* 1 $\mu\mu$ F

For historical reasons, although the SI unit of mass is the kilogram (kg), the SI prefixes are attached to the gram (g). Thus, use milligram (mg), not microkilogram (μ kg).

If values are required outside the range covered by the prefixes, they shall ~~should~~ be expressed using powers of ten applied to the non-prefixed ~~base~~ unit, e.g., 10^{-34} J.

An exponent attached to a symbol containing a prefix indicates that the multiple or submultiple of the unit (the unit with its prefix) is raised to the power expressed by the exponent. For example:

$$1 \text{ cm}^3 = (10^{-2} \text{ m})^3 = 10^{-6} \text{ m}^3$$

$$1 \text{ ns}^{-1} = (10^{-9} \text{ s})^{-1} = 10^9 \text{ s}^{-1}$$

(New)

$$1 \text{ ns}^{-1} = (10^{-9} \text{ s})^{-1} = 10^9 \text{ s}^{-9}$$

(Deleted)

$$1 \text{ mm}^2/\text{s} = (10^{-3} \text{ m})^2/\text{s} = 10^{-6} \text{ m}^2/\text{s}$$

For further information concerning metric practice and the SI, refer to ~~ANSI/IEEE/ASTM SI10-Std 268-1982 [3]~~.

4.6 Usage

Attachment of letters to a unit symbol as a means of giving information about the quantity under consideration is incorrect. Thus, MWe for "megawatts electrical (power)," Vac for "volts ac," and kJt for "kilojoules thermal (energy)" shall not be used. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig," so often used to distinguish between absolute and gage pressure. If the context leaves any doubt as to which is meant, the word pressure shall be qualified appropriately. For example:

- "...at a gage pressure of 13 kPa"
- "... at an absolute pressure of 13 kPa"

When space limitations make it necessary to juxtapose information about the quantity being measured with the unit name or unit symbol, such information shall be separated from the unit symbol by a space, by a comma followed with a space, or by the equivalent. Thus, the following examples are appropriate for use on nameplates, gage scale plates, table headings, graph labels, etc.:

- rating-1 15 V ac

- kPa, gage

- kPa (abs.)

On the other hand, letters may be attached to a unit symbol where needed to properly identify the unit involved. In such symbols as in Hg, mmHg, and ftH₂O, the suffixes are needed to identify the units, which are units of pressure, not of length. Similarly, it is proper to write Btu_{IT}, Cal_{th}, gal_{us}, etc. to distinguish from the related but different units Btu₆₀, cal₁₅, gal_{imp}, etc. However, such subscripts are neither needed nor permitted with SI units.

5. Special principles for quantity symbols in electrical science and electrical engineering

5.1 Phasor quantities

Phasor quantities, represented by complex numbers or complex time-varying functions, are extensively used in certain branches of electrical engineering. The following notation and typography shall ~~are to~~ be used:

Table 3 -Phasor quantities notations and typography

Notation		Remarks
Complex quantity	Z	$Z = Z e^{j\phi}$ $Z = \text{Re } Z + j \text{Im } Z$
Real part	$\text{Re } Z, Z'$	—
Imaginary part	$\text{Im } Z, Z''$	—
Conjugate complex quantity	Z^*	$Z^* = \text{Re } Z - j \text{Im } Z$
Modulus of Z	$ Z $	—
Phase of Z , Argument of Z	$\arg Z$	$\arg Z = \phi$

(New)

Notation *		Remarks
Complex quantity	Z	$Z = Z e^{j\phi}$ $Z = \text{Re } Z + j \text{Im } Z$
Real part	$\text{Re } Z, Z'$	
Imaginary part	$\text{Im } Z, Z''$	
Conjugate complex quantity	Z^*	$Z^* = \text{Re } Z - j \text{Im } Z$
Modulus of Z	$ Z $	
Phase of Z , Argument of Z	$\arg Z$	$\arg Z = \phi$

(Deleted)

*The following alternative notation has been used in electrical power engineering: Complex quantity, $\boxed{\dot{Z}}$; Conjugate complex quantity, $\boxed{\dot{Z}^*}$ Modulus of complex quantity, Z . Further use of this notation for this purpose is not recommended.