International Vocabulary of Metrology

Fourth edition – Second Committee Draft (VIM4 2CD)

31 July 2023

The contents of this document shall not be quoted in any publication

Please note that this CD still does not include the French text of the entries.

Changes with respect to the first Committee Draft are tracked.

Foreword

Since its foundation, in 1997, the Joint Committee for Guides in Metrology (JCGM), has the purpose to develop and promote the use of the International vocabulary of metrology (the VIM) and the Guide to the expression of uncertainty in measurement (the GUM).
Eight international organizations currently form the JCGM:
- the two inter-governmental organizations concerned with metrology: the Bureau International des Poids et Mesures (BIPM) and the Organisation Internationale de Métrologie Légale (OIML);
- the two principal international standardization organizations: the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC);
- three international science unions: the International Union of Pure and Applied Chemistry (IUPAC), the International Union of Pure and Applied Physics (IUPAP), and the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC);
- one international accreditation organization: the International Laboratory Accreditation Cooperation (ILAC).

The JCGM has two Working Groups, devoted to the GUM (JCGM-WG1:GUM), and the VIM (JCGM-WG2:VIM) respectively.

In 2021, a first draft of this fourth edition of the VIM was submitted for comments and proposals to the eight organizations represented in the JCGM, which in most cases consulted their members or affiliates, including numerous National Metrology Institutes. Comments were studied and discussed, taken into account when appropriate, and replied to by JCGM-WG2. A second draft was submitted in 2023 to the eight organizations for a further review.

(*to be completed in due time, with information about final stages of the reviewing process and publication*)

In the fifteen years from the publication of the previous, third edition of the VIM, metrology proved to be a lively, evolving body of knowledge, with a strategic societal role to guarantee the public trust of information acquired about empirical properties. These changes are reflected in the thorough revision of this Vocabulary, and in particular in its broadened scope, which now encompasses also the examination of nominal properties, under the acknowledgment that what actually characterizes metrology is not the focus on quantitative entities, but the transparency of its processes and of the reliability of their results.

Introduction

The International Vocabulary of Metrology (VIM) is a guidance document, developed by the eight Member Organizations of the Joint Committee for Guides in Metrology (JCGM), that aims at disseminating scientific and technological knowledge about metrology by harmonizing worldwide the related fundamental terminology. While developed for being as understandable as possible to the wide readership of researchers and practitioners, its institutional task is to constitute a recommendation that JCGM member organizations are encouraged to implement, each according to its own purposes and in reference to its own scope.

The third edition of the VIM (denoted herein as the “VIM3”) was published by the JCGM in 2008, and republished with minor corrections in 2012. After publication, the JCGM Working Group responsible for VIM maintenance and revision (JCGM/WG2) began considering feedback it had received. In the meantime, and most significantly, several JCGM Member Organizations pointed out the increasing importance of a metrologically-aware treatment of nominal properties, and therefore the need for more entries in the VIM about nominal properties and the process of their examination. This led WG2 to the reconsideration of some key concepts of the VIM, starting from the ones related to the very distinction between quantitative and non-quantitative properties.

This fourth edition of the VIM (VIM4) has been designed to address these issues, with the awareness that metrology is an active body of knowledge, that is called to maintain its key role in an ever-changing world. For measurement to remain a reliable source of public trust, its basic concept system – what the VIM aims at providing – must be open to consistently encompass innovation, while guaranteeing faithfulness to the long societal and scientific tradition of measurement.

Any new edition of the VIM has been an opportunity for providing an interpretation of how the body of knowledge about metrology is structured, and the VIM4 follows this path by providing a revised organization of its chapters, including a new chapter about nominal properties and their examination, in compliance with a decision taken by the JCGM Member Organizations.

* Chapter 1, “Quantities and units” introduces the key entities of metrology: quantities, units, values, and scales.

* Chapter 2, “Measurement” focuses on measurement as both an experimental and mathematical process, by also including the entries related to measurement models.

* Chapter 3, “Measurement quality”, is about what characterizes the quality of measurement processes and procedures, measurement instruments and systems, and of course measurement results, thus first of all measurement uncertainty but also measurement error, accuracy, and so on.

* Chapter 4, “Measuring devices and their properties” is about measuring instruments and systems, their components and their properties.

* Chapter 5, “Measurement standards (etalons) and metrological traceability” expands the context by dealing with metrological systems, including measurement standards and calibration: what is required for guaranteeing the metrological traceability of measurement results.

* Chapter 6, “Nominal properties and examinations”, is about nominal properties and their examination.

While the VIM3 included an entry for ‘nominal property’ (i.e., non-quantitative, only classificatory

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properties), a number of related additional entries have been introduced into the VIM4, mainly taken from the *Vocabulary on nominal property, examination, and related concepts for clinical laboratory sciences* (IFCC-IUPAC Recommendations 2017; G.Nordin et al, Pure Appl. Chem. 90, 5, 2018), and adapted for making them consistent with the VIM. This required revising the entries that the VIM3 had introduced about ordinal properties, for which an order but not a unit is defined. This arose once more the controversial issue whether order is sufficient for making a property quantitative, and therefore whether the term "ordinal quantities" should be used for designating such properties. After a careful analysis, it was decided to minimize the changes on this matter with respect to the VIM3, and therefore to maintain the assumptions that ordinal properties are quantities and measurement applies also to them.

A consequence of the more extensive treatment of nominal properties (and, to a lesser extent, of ordinal quantities) in the VIM4 is that the definitions of 'measurement' and 'metrology' needed a careful reconsideration. In particular, the question arose of whether the definitions of either or both should be expanded beyond quantities to include nominal property examination. An inquiry among JCGM Member Organizations was conducted, yielding sometimes strong opinions on both sides of the issue. It was therefore decided that for now the time is not right to make such a change about 'measurement', that thus remains related to quantitative properties. Vice versa, the observation that today most, if not all, National Metrology Institutes deal also with nominal properties and their examinations was considered a sufficient justification to expand the scope of 'metrology', which then in the VIM4 encompasses them. Furthermore, notes have been added to some relevant entries to indicate that the subject is currently debated and future versions of the VIM could take its outcomes into account on this matter.

It is assumed here that metrology develops from the acknowledgement that there exist properties of given objects, where a property is either quantitative, like mass, or non-quantitative, like shape. Of course, properties can be either empirical or informational/mathematical (an example of the latter being the number of divisors of an integer number), and this Vocabulary is only concerned with empirical properties. For the sake of brevity, the term "object" is used here to refer to anything that has properties, thus including bodies, phenomena, substances, and processes (other terms sometimes used with the same meaning are, for example, "item" and "unit under test"). Any two properties of given objects are in principle either comparable (like the radius and the length of a given cylindrical rod) or not (like the radius and the mass of a given cylindrical rod). Objects, properties, and their comparability are so fundamental that they are assumed here without definition.

The systematic revision of the entries related to properties, thus including those about units, scales, and values, has led to focusing on the ambiguity of the term "quantity" (and the same applies to "ordinal quantity" and "nominal property"), used to refer to both quantities in the general sense, such as length and mass, and individual quantities, such as given lengths and given masses. In a vocabulary of fundamental metrology the difference is significant. For example, comparisons in terms of equivalence and order apply to individual, not general, quantities, and values are attributed to individual, not general, quantities. Vice versa, the distinction between base and derived quantities in a system of quantities refers to general, and not individual, quantities. However, the context is usually sufficient to remove the ambiguity, and therefore for linguistic simplicity the one term "quantity" is maintained in this Vocabulary, where the definition of 'quantity' has been phrased to encompass both general and individual quantities (and, again, the same applies to "ordinal quantity" and "nominal property"). Moreover, in daily-life English language there is another ambiguity about the meaning of

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the term “quantity”, as is clear by considering for example (i) “mass is a physical quantity” and (ii) “the object was produced in large quantity”. While both are correct sentences, the term “quantity” is used in them in incompatible ways: the adjective “large” is acceptable in (ii) but not in (i), as “mass is a large quantity” is nonsense; substituting “quantity” with “quantitative property” is acceptable in (i) but not in (ii), as “the object was produced in large quantitative property” is nonsense. While such uses are so common that there is no reason to claim that one of them is more correct, or even the correct one, in this Vocabulary “quantity” is used only with the first meaning. Furthermore, in some contexts “quantity” and “magnitude” are sometimes considered synonyms, or at least related, as in the previous edition of the VIM where ‘quantity’ was defined as a property that has a magnitude. However, the term “magnitude” was acknowledged to be ambiguous, and not easy to translate into other languages. Hence, it is not used in this Vocabulary, in which the specific concepts ‘ratio quantity’, ‘interval quantity’, ‘ordinal quantity’, and ‘nominal property’ are operationally defined according to the conditions of their comparability. The development of this new edition of the VIM was also an opportunity to improve the treatment of values of quantities, as appearing in basic relations like (m_A = 0.1234 kg), now more explicitly interpreted as an actual equation stating that the individual quantity identified as the mass m of a given object A and the individual quantity identified as 0.1234 times the kilogram, thus as a value of mass, are the same mass. The discovery that the same individual quantity, in the example a given mass, is identified in such different ways, i.e., as the property of a given object and as a multiple or submultiple of a given individual quantity chosen as the unit, is the fundamental information produced by a measurement, whose trustworthiness is stated in terms of measurement uncertainty. As a consequence, the definition of the sometimes controversial concept ‘true value of a quantity’ was revised, by considering that a true value of a quantity of a given object is simply a value that makes the equation relating the quantity and the value true.

Another key change made in the VIM4 relates to the cluster of entries related to the characterization of the quality of measurement and its results: measurement uncertainty, measurement error, measurement accuracy, measurement trueness, and so on. The VIM3 explicitly acknowledged the existence of different interpretations about this fundamental subject – summarily presented as an opposition between an Error Approach (sometimes called Traditional Approach or True Value Approach) and an Uncertainty Approach – which led to difficulties to provide definitions that could be widely acceptable. An encompassing position has been chosen in the VIM4, by adopting operational definitions whenever possible, phrased in terms of reference values, of which true values are specific cases when it applies, where the definitions are complemented with notes describing when and under which conditions the reference values are or can be in fact true values, and when they are not. This approach is considered to provide for maximum flexibility for the differing perspectives on the necessity and usefulness of ‘true value’.

With the introduction of the revised International System of Units (SI) in 2019, it is worth mentioning that in the VIM4 the relevant entries have been revised for guaranteeing their consistency with the new approach, in which units are individual quantities defined in reference to (“defining”) constant quantities. The VIM4 refers to the SI Brochure in particular about the delicate, and still open to debate, subject of how to characterize and term the quantities that are counted or are defined as ratios of ratio quantities, like refractive index and mass fraction. They are called here “quantities with unit one”, while explicitly acknowledging that changes in the term or the definition are possible in the future.

Deleted: While for linguistic simplicity just the term “quantity” is maintained in many occurrences in this vocabulary, two entries have been introduced, for ‘general quantity’, and ‘individual quantity’, and notes have been added to indicate whether ‘general quantity’ or ‘individual quantity’ is intended if there is any chance for ambiguity. This led us to provide an operational definition of ‘general quantity’ – “property whose instances can be compared by ratio or only by order” – that made it possible to avoid reference to magnitudes (in recognition of the sometimes incompatible ways in which this concept is understood, and also because the term “magnitude” is not cleanly translatable into some languages).…

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For the sake of transparency and to support users in the transition from the VIM3 to the VIM4, all changes that were considered significant are presented and justified in an Annex of this Vocabulary.

Finally, in the development of this new edition of the VIM the entire text of the VIM3 was revised with the aim of 1) improving readability of the definitions, the Notes, and the Examples, 2) adding some further clarifications through new Notes and Examples, and 3) reducing the explicit emphasis on terminology, perceived by some users as a source of complexity. Furthermore, the VIM4 incorporates the annotations to the VIM3 that were developed by WG2 to provide interim clarifications and simplified language, including the use of admitted shorter terms if this makes definitions and notes more understandable, with the assumption that more explicit, full terms should be used when the context does not make the intended meaning clear. With this proviso, the VIM4 maintains compliance with basic terminological rules, in particular the condition that the definitions must be non-circular with each other, to guarantee that the substitution principle can always be applied.

NOTE: In the context of the current endeavour of providing increasingly sophisticated online access to measurement-related data and information, it is anticipated that the content of the VIM4 will be made accessible via internet in both human-readable and machine-readable formats.

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Conventions

Terminology rules

The definitions and terms given in this fourth edition, as well as their formats, comply as far as possible with the rules of terminology, as outlined in ISO 704, ISO 1087 and ISO 10241. In particular, the substitution principle applies: that is, it is possible in any definition to replace a term for a concept defined elsewhere in the VIM by the definition corresponding to that term, without introducing contradiction or circularity.

Entries – each with a preferred term and possibly one or more admitted terms, a definition, and possibly notes and examples – are listed in six chapters and in conceptual order, to the extent practical, in each chapter.

In some definitions, the use of non-defined concepts (also called “primitives”) is unavoidable. In this Vocabulary such non-defined concepts include: object, system, component, property, reference, experiment, material, device, and signal.

Entries appearing in earlier editions have a double reference number, as appropriate; the fourth edition reference number is printed in bold face, and the references from earlier editions are given in parentheses and in light font.

Synonyms

Multiple terms for the same concept are permitted. If more than one term is given, the first term is the preferred one, and it is used in context whenever it may help avoiding ambiguities. Permitted shorter terms are sometimes used for the sake of simplicity.

Bold face

In any entry, terms for concepts defined elsewhere in the VIM are printed in bold face the first time they appear.

Quotation marks

In the English text of this document, single quotation marks (‘...’) surround the term representing a concept unless it is in bold. Double quotation marks (“...”) are used when only the term is considered, or for a quotation. In the French text, quotation marks («...») are used for quotations, or to highlight a word or a group of words.

Decimal marker

The decimal marker in the English text is the point on the line, and the comma on the line is the decimal market in the French text.

1 Quantities and units

1.1 [VIM3: 1.1; VIM2: 1.1; VIM1: 1.01]

quantity

property for which comparability by ratio, or by difference, or by order applies

NOTE 1 The same term "quantity" is commonly used to refer to both quantities in the general sense, such as length and mass, and individual quantities, such as any given length and any given mass, where a given length could be identified as the property of a given object or as a **value** of length. This duplicity has been acknowledged for a long time [29], and the context is usually sufficient to understand whether the term "quantity" refers to either a general or an individual quantity: for the sake of simplicity this linguistic custom is maintained in this Vocabulary. The following Table exemplifies the distinction between general quantities and individual quantities identified as empirical properties of given objects, including the case in which a general quantity admits some more specific general quantities, such as radius and wavelength with respect to length, so that for example radii are lengths but not all lengths are radii (as usual, the term "radius" is used here to refer both to a geometric segment and to its length).

General quantity		Individual quantity
length, l	radius, r	radius of cylindrical rod A, r_A or r(A)
	wavelength, λ	wavelength of the unperturbed ground state hyperfine transition frequency of the caesium 133 atom, λ_{Cs}
energy, E	kinetic energy, T	kinetic energy of particle i in a given system, T_i
	heat, Q	heat of vaporization of sample i of water, Q_i
electric charge, Q		electric charge of the proton, e
electric resistance, R		electric resistance of resistor i, R_i
amount-of-substance concentration, c		amount-of-substance concentration of ethanol in wine sample i, $c_i(C_2H_5OH)$
number concentration, C		number concentration of erythrocytes in blood sample B_i, C(Erys; B_i)
Rockwell C hardness, HRC		Rockwell C hardness of steel sample i, HRC_i

NOTE 2 Any individual quantity is an instance of a general quantity – for example the radius of cylindrical rod A is an instance of the general quantity length – and individual quantities are instances of the same general quantity if they are comparable with each other. **Measurement units**, **measurands**, **values of quantities**, and **measured values** are all examples of individual quantities.

NOTE 3 Different types of comparisons are possible among comparable properties, and types of properties are specified accordingly, in particular:

– properties that can be compared by ratio (such that for example one length may be twice another length), are **ratio quantities**;

– properties that can be compared by difference, but not by ratio (such that for example the difference of two Celsius temperatures may be twice the difference of two other Celsius temperatures), are **interval quantities**;

– properties that can be compared by order, but not by difference (such that for example one Mohs hardness may be greater than another Mohs hardness), are **ordinal quantities** (where in the relevant literature ordinal properties are sometimes considered to be non-quantitative);

– properties that can be compared by equivalence, but not by order (such that for example one shape may be equivalent to another shape), are non-quantitative, being **nominal properties**.

Differently from nominal properties and ordinal quantities, both ratio and interval quantities can be characterized as having a measurement unit.

The list above is not complete, as other types are known. In particular, cyclic / modular quantities like angle amplitudes, for which comparability by ratio modulo 2π applies, would need a more developed treatment.

NOTE 4 As defined here, quantities are scalar. Multi-dimensional entities such as complex quantities, vectors, and

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Deleted: **individual quantities**, such as any given length and any given mass. Acknowledging the importance of this distinction, separate definitions are given in this Vocabulary for quantities in the general sense and individual quantities, but the short term "quantity" is used whenever the linguistic context is sufficient to identify the intended meaning.¶
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tensors are considered quantities in a broader sense if their components are (scalar) quantities.

NOTE 5 Quantities can be classified as, for example, physical quantities, chemical quantities, and biological quantities, or as **base quantities** and **derived quantities** in a given **system of quantities**.

NOTE 6 Symbols for quantities are given in the ISO 80000 and IEC 80000 series of International Standards *Quantities and units* [23]. The symbols for quantities are written in italics, irrespective of the type used in the rest of the text. A given symbol can indicate different quantities.

NOTE 7 The preferred IUPAC and IFCC format to refer to quantities in laboratory medicine is "System–Component; kind of quantity" (see [35]).

EXAMPLE The substance concentration of glucose in blood plasma in a given person at a given time could be described as Plasma(Blood)–Glucose; amount-of-substance concentration = 5.1 mmol/L.

1.2 [new]
quantities of the same kind

quantities that are comparable with each other

NOTE 1 Quantities of the same kind are individual quantities that are instances of the same general quantity. Quantities that are identified as properties of given objects are comparable by empirical means; quantities that are identified as **values** of properties are comparable by mathematical means.

EXAMPLE The radius of a given circle and the wavelength of the sodium D radiation are quantities of the same kind: being properties of given objects, they can be compared by empirical means. 0.1234 m and 589 nm are also quantities of the same kind: being values of quantities, they can be compared by mathematical means.

NOTE 2 The expression "of the same kind" is sometimes also used for general quantities, though the condition of comparability in the definition does not apply to general quantities. Two general quantities are said to be of the same kind if their instances are comparable.

EXAMPLE Radius and wavelength are, in this sense, general quantities of the same kind, because radii and wavelengths are comparable with each other.

NOTE 3 Quantities of the same kind have the same **dimension** in a given **system of quantities**. However, quantities of the same dimension are not necessarily of the same kind.

EXAMPLES Moment of force and energy are not regarded as being of the same kind, although they have the same dimension. Similarly for heat capacity and entropy, as well as for number of entities, relative permeability, and mass fraction.

NOTE 4 Similar expressions, such as "quantities of different kinds" and "quantities of a given kind", are also used.

1.3 [new]
ratio quantity

quantity for which comparability by ratio applies

NOTE 1 The quantity mentioned in the definition is a general quantity. Any individual quantity that is an instance of that general quantity inherits this feature, and is therefore a ratio quantity in turn.

EXAMPLE Length, mass, etc. are ratio quantities, and therefore any given length, any given mass, etc. is also a ratio quantity.

NOTE 2 A ratio quantity has instances that are ordered, a distance between pairs of them is defined, and has an intrinsic zero. Hence, ratios of instances of ratio quantities have empirical meaning, so that for example one length may be twice another length.

NOTE 3 **Values** can be attributed to the instances of a ratio quantity when a **unit** for that quantity has been defined.

NOTE 4 All **base quantities** of the **International System of Quantities** are ratio quantities.

1.4 [new]
interval quantity

quantity for which comparability by difference but not by ratio applies

NOTE 1 The quantity mentioned in the definition is a general quantity. Any individual quantity that is an instance of that general quantity inherits this feature, and is therefore an interval quantity in turn.

EXAMPLE Position in space and instant of time are interval quantities, and therefore any given position in space and any given instant of time is also an interval quantity.

NOTE 2 An interval quantity has instances that are ordered and a distance between pairs of them is defined, but it does not have an intrinsic zero. Hence, only ratios of differences of instances of interval quantities, but not ratios of instances

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of interval quantities, have empirical meaning, so that for example the difference between two positions in space may be twice the difference of two other positions in space.

NOTE 3 **Values** can be attributed to the instances of an interval quantity when both a zero and a **unit** for that quantity have been defined.

1.5 [VIM3: 1.3; VIM2: 1.2]
system of quantities

set of **quantities** together with a set of non-contradictory equations relating those quantities

NOTE The quantities mentioned in the definition are general **ratio** or **interval quantities**. Hence, **ordinal quantities**, such as Mohs hardness, are not part of a system of quantities.

1.6 [VIM3: 1.4; VIM2: 1.3; VIM1: 1.02]
base quantity

quantity that in a given **system of quantities** is not defined in terms of the others

NOTE 1 The quantity mentioned in the definition is a general **ratio quantity**.

NOTE 2 For a given system of quantities, the set of base quantities is conventionally chosen, but the number of base quantities is not arbitrary.

EXAMPLE The base quantities in the **International System of Quantities** are listed in entry 1.8.

NOTE 3 Base quantities are mutually independent in a system of quantities since a base quantity cannot be defined as a product of powers of the other base quantities.

NOTE 4 The quantity *number of entities* can be regarded as a base quantity in any system of quantities.

1.7 [VIM3: 1.5; VIM2: 1.4; VIM1: 1.03]
derived quantity

quantity that in a given **system of quantities** is defined in terms of the **base quantities** of that system

NOTE 1 The quantity mentioned in the definition is a general **ratio** or **interval quantity**.

EXAMPLE In a system of quantities having length and mass as base quantities, mass density is a derived quantity defined as the quotient of mass and volume, where volume is in turn a derived quantity, defined as proportional to length to the third power.

NOTE 2 It is intended that a general quantity is not defined in terms of itself, and therefore that in a given system of quantities the set of base quantities and the set of derived quantities are disjoint.

1.8 [VIM3: 1.6]
International System of Quantities
ISQ

system of quantities based on the seven **base quantities**: time, length, mass, electric current, thermodynamic temperature, amount of substance, and luminous intensity

NOTE 1 The ISQ is published in the ISO 80000 and IEC 80000 series of International Standards *Quantities and units* [23].

NOTE 2 The **base units** of the **SI** are chosen in accordance with the base quantities of the ISQ.

NOTE 3 The term "time" is sometimes used for referring to the general quantity *instant of time* (for example 7:00 UTC), that is an **interval quantity**, and sometimes to the general quantity *duration*, i.e., range of time interval, that is a **ratio quantity**.

1.9 [VIM3: 1.7; VIM2: 1.5; VIM1: 1.04]
quantity dimension
dimension of a quantity
dimension

relation of a **quantity** to the **base quantities** of a **system of quantities** as a product of the base

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quantities each raised to a power, omitting any proportionality factor

NOTE 1 The quantity mentioned in the definition is a general **ratio** or **interval quantity**, where any individual quantity that is an instance of that general quantity has then the same dimension.

NOTE 2 The conventional symbolic representation of the dimension of a base quantity is a single upper-case letter in roman (upright) sans-serif type. The conventional symbolic representation of the dimension of a **derived quantity** is the product of the base quantities each raised to a power according to the definition of the derived quantity. The dimension of a quantity *Q* is denoted by dim *Q*.

EXAMPLE 1 In the **ISQ**, dim *F* = T^{-2} L M is the dimension of force.

EXAMPLE 2 In the ISQ, dim *ρ* = L^{-3} M is the dimension of both mass concentration and mass density (volumic mass).

EXAMPLE 3 For small swings, the period *T* of a pendulum of length *l* at a place with the local acceleration of gravity *g* is approximately

$$T = 2\pi\sqrt{\frac{l}{g}}$$

or

$$T = C(g)\sqrt{l}$$

where

$$C(g) = \frac{2\pi}{\sqrt{g}}$$

Hence dim *C*(*g*) = T L$^{-1/2}$.

NOTE 3 In deriving the dimension of a quantity, no account is taken of whether the quantity is scalar, vector, or tensor, provided that for multi-dimensional entities their components are **quantities of the same kind**.

NOTE 4 In a given system of quantities,

→ quantities of the same kind have the same dimension,

→ quantities of different dimensions are always of different kinds, and

→ quantities having the same dimension are not necessarily of the same kind (for example, angular velocity and frequency have same dimension, T^{-1}, though they are not quantities of the same kind).

NOTE 5 As defined in the *SI Brochure* [1], the symbols for the dimensions of the base quantities in the ISQ are:

Base quantity	Symbol for dimension
time	T
length	L
mass	M
electric current	I
thermodynamic temperature	Θ
amount of substance	N
luminous intensity	J

Thus, the dimension of a quantity *Q* is denoted by dim *Q* = T$^{\alpha}$L$^{\beta}$M$^{\gamma}$I$^{\delta}$Θ$^{\varepsilon}$N$^{\zeta}$J$^{\eta}$ where the exponents, named "dimensional exponents", are positive, or negative numbers, or zero.

1.10 [VIM3: 1.8; VIM2: 1.6; VIM1: 1.05]
quantity with unit one

dimensionless quantity

quantity for which all the exponents of the factors in its **dimension** are zero

NOTE 1 The quantity mentioned in the definition is a general **ratio quantity**. Any individual quantity that is an instance of that general quantity inherits this feature, and is therefore a quantity with unit one in turn.

NOTE 2 The term "quantity with unit one" is used in *SI Brochure* [1] to refer to quantities whose **values** are pure numbers. The term "dimensionless quantity" is still commonly used and is kept here for historical reasons. However, all quantities have a dimension. The term "quantity of dimension one" used in the previous edition of the VIM reflects the convention in which the symbolic representation of the dimension for such quantities was the symbol "1". The term "quantity of dimension number" is also sometimes used. This multiplicity highlights that the subject is still not widely

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agreed: hence, changes in the term or the definition are possible in the future.

NOTE 3 The values of quantities with unit one are numbers, their **unit** being the number 1, though the unit 1 or unit name “one” are not explicitly shown.

NOTE 4 Some quantities with unit one are defined as the ratios of two **quantities of the same kind**.

EXAMPLES Refractive index, relative permeability, mass fraction, friction factor.

NOTE 5 In reporting the values of quantities defined as the ratios of two quantities of the same kind, the relevant units should be specified when there is possibility of ambiguity.

EXAMPLES mg/kg (for mass fraction) or μmol/mol (for amount-of-substance fraction).

NOTE 6 *Number of X, where X is a given* entity that can be counted, is a quantity with unit one.

EXAMPLES Number of turns in a coil, number of molecules in a sample, degeneracy of the energy levels of a quantum system.

1.11 [new]

reference quantity

quantity identified and adopted by convention for empirically comparing it with other **quantities of the same kind**

NOTE 1 The quantity mentioned in the definition is an individual quantity.

NOTE 2 A reference quantity is usually chosen so that its **value**, possibly with a **measurement uncertainty**, is assumed to be known, as it is in the case of the quantities whose definition is realized by **measurement standards**. An exception is when a reference quantity is used to define a **measurement unit** or a **measurement scale**, as in this case the value is defined with the identification of the quantity. In either case, the value is a **reference value**.

NOTE 3 The empirical comparison of a reference quantity with some other quantities of the same kind could also be mediated by means of intermediate comparisons, as in the case of the **traceability chains**.

1.12 [VIM3: 1.9; VIM2: 1.7; VIM1: 1.06]

measurement unit

unit of measurement

unit

reference quantity with which any other **quantity of the same kind** can be compared by ratio, resulting in a number

NOTE 1 A unit can be identified as:

– the property of a given object (e.g., the kilogram as it was defined in the **SI** until 2019, as the mass of the international prototype of the kilogram);

– the property of a given class of objects (e.g., the candela as it was defined in the SI until 2019, as the luminous intensity of a radiation source in a stated conditions) or a function of such a property (e.g., the kelvin as it was defined until 2019, as a given fraction the thermodynamic temperature of a given physical state);

– a function of one or more given constant quantities (e.g., the metre as it is currently defined in the SI, as the length proportional, with a stated factor, to the product of the speed of light in vacuum and the inverse of a given frequency of the caesium 133 atom under given conditions).

NOTE 2 **Interval quantities** do not have an intrinsic zero. Nonetheless, a measurement unit for them can be defined as a difference between two chosen quantities, so that ratios of differences result in a number.

NOTE 3 **Ordinal quantities** have no units because they cannot be compared by ratio.

NOTE 4 Units are designated by conventionally assigned names and symbols.

NOTE 5 Units of quantities of the same **dimension** can be designated by the same name and symbol even when the quantities are not of the same kind. For example, “joule per kelvin” and J/K are respectively the name and symbol of both a unit of heat capacity and a unit of entropy, which are usually not considered to be quantities of the same kind. However, in some cases special unit names are restricted to be used with quantities of a specific kind only. For example, the unit second to the power minus one (1/s) is called “hertz” (Hz) when used for frequencies and “becquerel” (Bq) when used for activities of radionuclides.

NOTE 6 Units of **quantities with unit one** are numbers. In some cases these units are expressed by quotients such as millimole per mole equal to 10^{-3} and microgram per kilogram equal to 10^{-9}. Units expressed by quotients are useful to aid understanding and avoid confusion when **measured values** are reported.

NOTE 7 For a given quantity, the short term “unit” is often combined with the name of the quantity, such as “mass unit”

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or “unit of mass”.

1.13 [VIM3: 1.10; VIM2: 1.13; VIM1: 1.11]
base unit

measurement unit that is adopted by convention for a **base quantity**

NOTE 1 In each coherent **system of units**, there is only one base unit for each base quantity.

EXAMPLE In the **SI**, the metre is the base unit of length. In the centimetre, gram, second (CGS) system, the centimetre is the base unit of length.

NOTE 2 A base unit can also serve for a **derived quantity** of the same **dimension**.

EXAMPLE Rainfall, when defined as areic volume (volume per area), has the metre as a **coherent derived unit** in the SI.

NOTE 3 For *number of entities*, the number one, symbol “1”, can be regarded as a base unit in any **system of units**.

1.14 [VIM3: 1.11; VIM2: 1.14; VIM1: 1.12]
derived unit

measurement unit for a **derived quantity**

EXAMPLES The metre per second, symbol m/s, and the centimetre per second, symbol cm/s, are derived units of speed in the **SI**. The kilometre per hour, symbol km/h, is a unit of speed outside the SI but accepted for use with the SI. The knot, equal to one nautical mile per hour, is a unit of speed outside the SI.

1.15 [VIM3: 1.12; VIM2: 1.10; VIM1: 1.13]
coherent derived unit

coherent unit

derived unit that, for a given **system of quantities** and for a chosen set of **base units**, is a product of base units each raised to a power, omitting any proportionality factor

NOTE 1 A power of a base unit is the base unit raised to an exponent.

NOTE 2 The coherence of a derived unit can be determined only with respect to a particular system of quantities and a given set of base units.

EXAMPLES Given that velocity is defined by the **quantity equation** $v = dx/dt$, the metre per second is the coherent derived unit of velocity in a system of units, like the **SI**, where the metre and second are base units. Given that amount-of-substance concentration is defined by the quantity equation $c = n/V$, the mole per cubic metre is the coherent derived unit of amount-of-substance concentration in a system of units, like the SI, where the metre and mole are base units. The kilometre per hour and the knot, given as examples of derived units in entry 1.14, are instead not coherent derived units in such a system of quantities for such a set of base units.

NOTE 3 A derived unit can be coherent with respect to one system of quantities but not to another.

EXAMPLE The centimetre per second is the coherent derived unit of speed in the centimetre, gram, second (CGS) **system of units** but is not a coherent derived unit in the SI.

NOTE 4 The coherent derived unit for every derived **quantity with unit one** in a given system of units is the number one, symbol “1”.

1.16 [VIM3: 1.13; VIM2: 1.9; VIM1: 1.08]
system of units

set of **base units** and **derived units**, together with their multiples and submultiples, defined in accordance with given rules, for a given **system of quantities**

1.17 [VIM3: 1.14; VIM2: 1.11; VIM1: 1.09]
coherent system of units

system of units in which the **measurement unit** for each **derived quantity** is a **coherent derived unit**

NOTE 1 A system of units can be coherent only with respect to a system of quantities and the adopted **base units**.

NOTE 2 For a coherent system of units, **numerical value equations** have the same form, including numerical factors,

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as the corresponding **quantity equations**.

1.18 [VIM3: 1.15; VIM2: 1.15; VIM1: 1.14]
off-system measurement unit

off-system unit

measurement unit that does not belong to a given **system of units**

EXAMPLE 1 The electronvolt (about 1.602 18 · 10^{-19} J) is an off-system unit of energy with respect to the **SI**.

EXAMPLE 2 Day, hour, and minute are off-system units of time with respect to the SI.

1.19 [VIM3: 1.16; VIM2: 1.12; VIM1: 1.10]
International System of Units

SI

system of units, based on a set of defining constants, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)

NOTE 1 At the 26th CGPM (2018) the SI was revised. Effective from 20 May 2019, the SI is the system of units in which seven physical, either fundamental or technical, constants have stated fixed values. These seven defining constants are the hyperfine transition frequency of caesium 133, the speed of light in vacuum, the Planck constant, the elementary charge, the Boltzmann constant, the Avogadro constant, and the luminous efficacy, as defined in the *SI Brochure* [1]. From such constants and their values, and in accordance with the **ISQ**, the definitions of the base units of the SI are deduced, as documented in the *SI Brochure*. The names of the seven base quantities of the ISQ and the names and the symbols of the corresponding base units of the SI are listed in the following Table.

Base quantity	Base unit	
Name	Name	Symbol
time	second	s
length	metre	m
mass	kilogram	kg
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

NOTE 2 The **base units** and the **coherent derived units** of the SI form a coherent set, called the “set of coherent SI units”.

NOTE 3 For a full description and explanation of the SI, see the *SI Brochure* [1].

NOTE 4 In **quantity calculus**, the quantity *number of entities* can be regarded as a **base quantity**, with the base unit one, symbol “1”.

NOTE 5 The rules for the use of the SI **units** include the prefixes for **multiples of units** and **submultiples of units** listed in the following Table, together with their names and their symbols.

Factor	Prefix	
	Name	Symbol
10^{30}	quetta	Q
10^{27}	ronna	R
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P

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10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	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
10^{-27}	ronto	r
10^{-30}	quecto	q

Source: *SI Brochure* [1]

1.20 [VIM3: 1.17; VIM2: 1.16; VIM1: 1.15]
multiple of a unit

measurement unit obtained by multiplying a given measurement unit by an integer greater than one

EXAMPLE 1 The kilometre is a decimal multiple of the metre.

EXAMPLE 2 The hour is a non-decimal multiple of the second.

NOTE 1 **SI** prefixes for decimal multiples of SI **base units** and SI **derived units** are given in Note 5 of entry 1.19. These prefixes are sometimes used also with off-system units, as in the case of the kiloelectronvolt (keV).

NOTE 2 SI prefixes refer strictly to powers of 10, and should not be used for powers of 2. For example, 1 kilobit should not be used to represent 1 024 bits (2^{10} bits), which is 1 kibibit.

Prefixes for binary multiples are:

Factor	Prefix	
	Name	Symbol
$(2^{10})^8$	yobi	Yi
$(2^{10})^7$	zebi	Zi
$(2^{10})^6$	exbi	Ei
$(2^{10})^5$	pebi	Pi
$(2^{10})^4$	tebi	Ti
$(2^{10})^3$	gibi	Gi
$(2^{10})^2$	mebi	Mi
$(2^{10})^1$	kibi	Ki

Source: IEC 80000-13 [8].

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1.21 [VIM3: 1.18; VIM2: 1.17; VIM1: 1.16]
submultiple of a unit

measurement unit obtained by dividing a given measurement unit by an integer greater than one

EXAMPLE 1 The millimetre is a decimal submultiple of the metre.

EXAMPLE 2 For a plane angle, the minute is a non-decimal submultiple of the degree.

NOTE **SI** prefixes for decimal submultiples of SI **base units** and SI **derived units** are given in Note 5 of entry 1.19. These prefixes are sometimes used also with off-system units, as in the case of the millirem (mrem).

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1.22 [VIM3: 1.24]
conversion factor between units

ratio of two **measurement units** for **quantities of the same kind**

EXAMPLE km/m = 1 000 and thus 1 km = 1 000 m, where 1 000 is the conversion factor.

NOTE The units may belong to different **systems of units**.

EXAMPLE 1 h/s = 3 600 and thus 1 h = 3 600 s, where 3 600 is the conversion factor.

EXAMPLE 2 (km/h)/(m/s) = (1/3.6) and thus 1 km/h = (1/3.6) m/s, where 1/3.6 is the conversion factor.

1.23 [VIM3: 1.27; VIM2: 1.22; VIM1: 1.21]
measurement scale

function from a set of **reference quantities of the same kind** to a set of identifiers, where the function preserves the information of comparison about such **quantities**

NOTE 1 A measurement scale for an **ordinal quantity** is an **ordinal scale**. In constructing a measurement scale for an ordinal quantity all reference quantities must be explicitly listed.

EXAMPLE Mohs scale of mineral hardness was constructed by choosing an ordered set of non-equivalent hardnesses (of talc, gypsum, calcite, etc) and an ordered set of identifiers (1, 2, 3, etc), and relating each hardness to an identifier so that greater hardnesses are associated to greater identifiers. Hence, in the Mohs scale any sample as hard as talc has a hardness 1, and so on.

NOTE 2 A measurement scale for an **interval quantity** can be constructed by choosing two non-equivalent individual quantities instances of that general quantity and a distinct number as the identifier of each of them, and associating a number to any other individual quantity instance of that general quantity so that equal differences of quantities correspond to equal differences of the associated numbers. Hence, in constructing a measurement scale for an interval quantity only two reference quantities have to be explicitly chosen, while all other reference quantities can be derived by the algebraic structure of the interval quantity.

EXAMPLE Celsius scale of temperature was constructed by choosing the freezing point of water and the boiling point of water at 1 atm pressure, associating 0 and 100 as their respective identifiers, and associating numbers to other temperatures accordingly, so that 50 was associated to the temperature exactly in between the freezing point of water and the boiling point of water, and so on.

NOTE 3 A measurement scale for a **ratio quantity** can be constructed by choosing one individual quantity instance of that general quantity as the **unit** and the number 1 as its identifier, and associating a number to any individual quantity instance of that general quantity so that equal ratios of quantities correspond to equal ratios of the associated numbers. Hence, in constructing a measurement scale for a ratio quantity only one reference quantity has to be explicitly chosen, while all other reference quantities can be derived by the algebraic structure of the ratio quantity, in particular as **multiples** and **submultiples of the unit**.

EXAMPLE A scale of length is constructed by taking the metre as the unit, where the number k is the identifier associated to a length of k metres.

NOTE 4 Each identifier in a measurement scale corresponds to a **value** of the relevant general quantity on the given scale. In particular, the number 1 in any scale for a ratio quantity corresponds to the value of the unit of that quantity, for example to the value 1 m of individual quantity chosen as the metre in the case of length. Since ordinal quantities do not have a unit, even when the identifier 1 is used in an ordinal scale it only refers to an ordinal position. For example, in the case of Mohs scale of mineral hardness the identifier 1 corresponds to the value 1 on the Mohs scale, which is the hardness of talc.

NOTE 5 A **scale of a displaying measuring instrument** is usually obtained from a measurement scale by marking some identifiers on the instrument together with the name of the scale.

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1.24 [VIM3: 1.19; VIM2: 1.18; VIM1: 1.17]
value of a quantity

quantity value
value

individual **quantity** identified either as the product of a number and a **measurement unit** or on an **ordinal scale**

EXAMPLE 1 112 m^{-1} as a curvature of arcs.

EXAMPLE 2 −5 °C as a Celsius temperature.

EXAMPLE 3 1.32 as a refractive index of samples.

EXAMPLE 4 43.5 HRC as a Rockwell C hardness.

EXAMPLE 5 1.76 μmol/kg as a molality.

EXAMPLE 6 5.0 IU/L as a concentration of a substance. IU is a non-SI unit for the amount of a specific substance (although no unique chemical entity is specified) as defined in an **international measurement standard** by WHO, for **measurement procedures** for which the material is **commutable**.

NOTE 1 The same value can identify quantities of different objects, and the same individual quantity can be identified by more than one value. Further, a value may not identify a quantity of any given object.

EXAMPLE 1 5.34 m or 534 cm as the same length identified by two different values.

EXAMPLE 2 0.152 kg or 152 g as the same mass identified by two different values.

EXAMPLE 3 3 μg/kg or 3 · 10^{-9} as the same mass fraction identified by two different values.

NOTE 2 A value identified on an ordinal scale is a **value of an ordinal quantity**.

NOTE 3 Values of quantities appear in relations such as

quantity identified as the property of a given object = *value of a quantity*

for example

l_A = 5.34 m

Such an equation can be interpreted as stating that the individual quantity identified as the length l of a given rod A and the individual quantity identified as 5.34 times the metre are the same length. If the equation is true, the value appearing on its right-hand side is a **true value**.

NOTE 4 In some mathematical theories of measurement, values of quantities are more generically understood as symbols associated with quantities of objects for representation purposes. According to this understanding, the relation in Note 3 is not interpreted as an equation, but as a representation, and the value 5.34 m is interpreted as a symbol representing the length l of rod A.

NOTE 5 The number mentioned in the definition can be complex.

EXAMPLE (7 + 3*j*) Ω as an electric impedance at a given frequency, where $j = \sqrt{-1}$.

NOTE 6 In the case of vector or tensor quantities, each component has a value.

EXAMPLE Force acting on a given particle, for example in Cartesian components (F_x; F_y; F_z) = (−31.5; 43.2; 17.0) N.

NOTE 7 The term "value" is often used with the specification of the name of a quantity, as in the case of "value of length". When there is no possible ambiguity, the unqualified term "value" can be used.

1.25 [VIM3: 1.20; VIM2: 1.21; VIM1: 1.20]
numerical value of a quantity

numerical quantity value
numerical value

ratio of a **quantity** and a **unit**, where the quantity and the unit are **quantities of the same kind**

NOTE 1 The numerical value {*Q*} of a quantity *Q* is frequently denoted {*Q*} = *Q*/[*Q*], where [*Q*] denotes the unit. Hence, for any given **quantity**, its numerical value depends on the unit.

EXAMPLE If the concerned quantity is identified as the property of a given object, like the length of a given rod, the information on its numerical value is acquired by means of an empirical process, in particular **measurement**. If instead the concerned quantity is identified as the **value of a quantity**, its numerical value is mathematically known. For example, for a value of 5.700 kg, the numerical value is (5.700 kg)/kg = 5.700. The same information can be expressed as 5 700 g in which case the numerical value is (5 700 g)/g = 5 700.

NOTE 2 For **quantities with unit one**, there is no difference between the value and the numerical value of the quantity,

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when the **coherent unit** one is used. For quantities defined as the ratio of two quantities of the same kind, the ratio of two units is sometimes used to indicate the kind of the two quantities and to provide a multiplicative factor for the numerical value.

EXAMPLE 1 For an efficiency ratio of output power to input power equal to 0.7, the numerical value is 0.7, but it is 70 when the value is expressed as 70 %.

EXAMPLE 2 In an amount-of-substance fraction equal to 3 mmol/mol, the numerical value is 3 and the unit is mmol/mol. The unit mmol/mol is numerically equal to 0.001.

NOTE 3 **Ordinal quantities** have no numerical values. The numeral in an expression of the **value of an ordinal quantity** is not a numerical value of a quantity, but an identifier for the ordinal position of the quantity on the **ordinal scale**.

1.26 [VIM3: 2.11; VIM2: 1.19; VIM1: 1.18]
true value of a quantity

true quantity value

true value

value of a quantity of a given object such that the equation relating the **quantity** and the value is true

NOTE 1 The quantity mentioned in the definition is an individual quantity that is identified as the property of a given object.

NOTE 2 Values of quantities appear in relations such as

quantity identified as the property of a given object = value of a quantity

for example

$l_A = 5.34$ m

Such an equation can be interpreted as stating that the individual quantity identified as the length *l* of a given rod A and the individual quantity identified as 5.34 times the metre are the same length. If the equation is true, the value appearing on its right-hand side is a true value.

NOTE 3 True values are, in principle and in practice, unknowable, except in the case of the constant quantities used to define **units** through the conventional choice of a numerical value of each of such constants (see Note 1 of entry 1.12), as in the **SI** [1]. The true value, in the defined unit, of these defining constants is then unique and known by definition.

NOTE 4 An individual quantity can have a unique true value or a set of true values, depending on (i) the actual physical state of the object, (ii) the way the quantity is defined, and (iii) the chosen set of possible values, where the physical state of the object only partially constrains the way the quantity can be defined. For example, for the same object a quantity could be defined as (a) the length of the object, or (b) the average distance between opposite points of the object in specified environmental conditions, or (c) the distance between two specified opposite points of the object in specified environmental conditions. In the case of ratio or interval quantities, a set of possible values is established by choosing the unit and the number of significant digits.

EXAMPLE The physical structure of a rod is such that below the scale of 1 mm its surfaces are irregular. Let a quantity be defined as the length of the rod, with no further specifications, and its possible values be chosen in micrometres. If *x* is supposed to be a true value, then any other value *x′* such that $|x – x′| < 0.5$ mm can be supposed to be true in turn.

NOTE 5 Some approaches dispense altogether with true values and rely on **metrological compatibility** and **metrological traceability of measurement results** for assessing their validity.

1.27 [VIM3: 2.12]
conventional value of a quantity

conventional quantity value

conventional value

value attributed by agreement to a **quantity** of a given object, for a given purpose

EXAMPLE 1 Standard acceleration of free fall (formerly called “standard acceleration due to gravity”), $g_n = 9.806\,65$ m s^{-2}.

EXAMPLE 2 Conventional value of a given mass standard, $m = 100.003\,47$ g.

NOTE 1 The agreement, as well as the given purpose, mentioned in the definition may be at a local, regional or global level.

NOTE 2 The term “conventional true quantity value” is sometimes used for referring to conventional values, but its use

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is discouraged, given the substantial difference between truth and conventionality.

NOTE 3 Sometimes a conventional value is an estimate of a **true value**.

NOTE 4 A conventional value can have an associated **measurement uncertainty**.

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1.28 [VIM3: 5.18]
reference value of a quantity

reference quantity value

reference value

value used as a basis for comparison with values of **quantities of the same kind**

NOTE 1 Examples of reference values are **true values** of a **measurand**, in which case they are unknown, and **conventional values**, in which case they are known.

NOTE 2 A reference value can have an associated **measurement uncertainty**.

EXAMPLES A reference value can be, for example, a value associated with a **measurement standard**, such as a **certified value** provided with a **certified reference material** or a **conventional value** provided by a **material measure**, or a value provided by a **reference measurement procedure**.

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a) a material, for example a **certified reference material**,b) a device, for example a stabilized laser,c) a **reference procedure**,d) a **measurement standard**.

1.29 [VIM3: 1.21]
quantity calculus

system of mathematical rules and operations applied to **quantities**

NOTE 1 The quantities mentioned in the definition are ratio or interval **quantities**.

NOTE 2 **Quantity equations** in quantity calculus are independent of the choice of **units**, whereas **numerical value equations** are not.

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1.30 [VIM3: 1.22]
quantity equation

mathematical relation among **quantities** in a given **system of quantities**, independent of **measurement units**

NOTE 1 The quantities mentioned in the definition are ratio or interval quantities.

NOTE 2 The quantities on the left-hand side and the right-hand side of a quantity equation must have the same dimension. Checking this is sometimes called the “dimensional analysis” of the equation.

EXAMPLE 1 $Q_1 = \zeta Q_2 Q_3$ where Q_1, Q_2 and Q_3 denote different quantities, and where ζ is a numerical factor.

EXAMPLE 2 $T = (½) mv^2$ where T is the kinetic energy and v the speed of a particle of mass m.

EXAMPLE 3 $n = It/F$ where n is the amount of substance of a univalent component, I is the electric current and t the duration of the electrolysis, and where F is the Faraday constant.

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1.31 [VIM3: 1.23]
unit equation

mathematical relation among **measurement units**

EXAMPLE 1 Given the **quantity equation** $Q_1 = \zeta Q_2 Q_3$, where Q_1, Q_2 and Q_3 denote different **quantities**, $[Q_1] = [Q_2]\,[Q_3]$ where $[Q_1]$, $[Q_2]$, and $[Q_3]$ denote the units of Q_1, Q_2, and Q_3, respectively, and ζ is a numerical factor, which equals 1 in a **coherent system of units**.

EXAMPLE 2 J := kg m^2/s^2, where J, kg, m, and s are the symbols for the joule, kilogram, metre, and second, respectively (the symbol := denotes “is by definition equal to” as given in the ISO 80000 and IEC 80000 series of International Standards *Quantities and units* [23]).

EXAMPLE 3 km/h = (1/3.6) m/s.

Deleted: For the **quantities** in Example 1 of entry 1.26,

1.32 [VIM3: 1.25]
numerical value equation

numerical quantity value equation

mathematical relation among **numerical values**, based on a given **quantity equation** and the related **measurement units**

EXAMPLE 1 Given the quantity equation $Q_1 = \zeta\, Q_2\, Q_3$, where Q_1, Q_2 and Q_3 denote different **quantities**, $\{Q_1\} = \zeta \{Q_2\} \{Q_3\}$ where $\{Q_1\}$, $\{Q_2\}$, and $\{Q_3\}$ denote the numerical values of Q_1, Q_2, and Q_3, respectively.

EXAMPLE 2 In the quantity equation for kinetic energy of a particle, $T = (½)\, mv^2$, if $m = 2$ kg and $v = 3$ m/s, then $\{T\} = (½) \cdot 2 \cdot 3^2$ is a numerical value equation giving the numerical value 9 of T in joules.

1.33 [VIM3: 1.26]

ordinal quantity

quantity for which comparability by order and equivalence only applies

NOTE 1 The quantity mentioned in the definition is first a general quantity, where any individual quantity that is an instance of that general quantity is then an ordinal quantity.

EXAMPLE 1 Mohs hardness.

EXAMPLE 2 Flammability, i.e., the capability of materials to burn.

EXAMPLE 3 Beaufort wind force.

EXAMPLE 4 Subjective level of abdominal pain on a scale from zero to five.

NOTE 2 Order is a relation that is reflexive (for any quantity Q_i, $Q_i \le Q_i$), transitive (for any three comparable quantities Q_i, Q_j, and Q_k, if $Q_i \le Q_j$ and $Q_j \le Q_k$ then $Q_i \le Q_k$), and antisymmetric (for any two comparable quantities Q_i and Q_j, if $Q_i \le Q_j$ and $Q_j \le Q_i$ then $Q_i = Q_k$). Usually also strong connection (for any two comparable quantities Q_i and Q_j, either $Q_i \le Q_j$ or $Q_j \le Q_i$) is required.

NOTE 3 Ordinal quantities are sometimes defined by the procedure according to which they are measured.

NOTE 4 Ordinal quantities have neither **units** nor **dimensions**, and therefore can enter into empirical relations only. Differences and ratios of ordinal quantities have no empirical meaning.

NOTE 5 Ordinal quantities are arranged according to **ordinal scales**.

1.34 [VIM3: 1.28; VIM2: 1.22; VIM1: 1.21]

ordinal scale

measurement scale that preserves the information of comparison by order and equivalence only

NOTE 1 An ordinal scale establishes an association from an ordered set of **reference quantities**, each of them being an instance of the same general **ordinal quantity**, to an ordered set of identifiers.

EXAMPLE 1 Mohs scale of mineral hardness, where the hardness of talc is associated with the ordinal identifier 1, the hardness of gypsum is associated with the ordinal identifier 2, and so on.

EXAMPLE 2 Beaufort wind force scale.

NOTE 2 An ordinal scale may be established by **measurements** according to a **measurement procedure**.

1.35 [new]

value of an ordinal quantity

value

individual **quantity** identified on an **ordinal scale**

NOTE **Ordinal quantities** have no **numerical values**. The numeral in an expression of the value on some ordinal scales is not a numerical value of a quantity, but an identifier for the ordinal position of the individual quantity on the scale. For example, in the Mohs scale of mineral hardness the identifier 1 corresponds to the value 1 on the Mohs scale, which is the hardness of talc.

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ordinal quantity in the general sense
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2 Measurement

2.1 [VIM3: 2.1; VIM2: 2.1; VIM1: 2.01]
measurement

process of experimentally obtaining one or more **values** that can reasonably be attributed to a **quantity** together with any other available relevant information

NOTE 1 The quantity mentioned in the definition is an individual quantity that is identified as the property of a given object.

NOTE 2 The relevant information mentioned in the definition can be about the values obtained by the measurement, such that some may be more representative of the **measurand** than others.

NOTE 3 Measurement is sometimes considered to apply to **nominal properties**, but not in this Vocabulary, where the process of obtaining values of nominal properties is called "**examination**".

NOTE 4 In chemistry, measurement is sometimes referred to as "quantitative analysis", and examination is referred to as "qualitative analysis".

NOTE 5 Measurement is an experimental process in the sense that it requires an empirical component and a computational (informational) component or counting of entities at some step of the process and the use of models and calculations that are based on conceptual considerations.

NOTE 6 The conditions of reasonable attribution mentioned in the definition take into account a description of the quantity commensurate with the intended use of a **measurement result**, a **measurement procedure**, and a calibrated **measuring system** operating according to the specified measurement procedure, including the measurement conditions. Moreover, a **maximum permissible error** and/or a **target uncertainty** can be specified.

2.2 [VIM3: 2.2; VIM2: 2.2; VIM1: 2.02]
metrology

science of **measurement** and **examination**, and their applications

NOTE 1 Metrology includes all theoretical and practical aspects of measurement and examination, whatever the **measurement uncertainty** or **examination reliability**, and field of application may be.

NOTE 2 In the previous editions of this Vocabulary 'metrology' was defined as referring to measurement only. Meanings of terms sometimes evolve as terms are used, and this is the case for "metrology", that is commonly used today (such as in "National Metrology Institute") irrespective of the type of the properties under consideration, thus also including **nominal properties**. This is also a justification for the broadened scope of this Vocabulary, that, differently from the past, includes nominal properties and their examination.

2.3 [VIM3: 2.3; VIM2: 2.6; VIM1: 2.09]
measurand

quantity intended to be measured

NOTE 1 The quantity mentioned in the definition is an individual quantity that is identified as the property of a given object.

NOTE 2 The specification of a measurand typically requires knowledge of the general **quantity**, description of the state of the object carrying the quantity, including any quantity having a relevant effect on the quantity intended to be measured, and, if required, the chemical or biological entities involved.

NOTE 3 In some cases the measurand is specified by a documented and accepted **measurement procedure** or **method**. In laboratory medicine this is referred to as a "procedure defined measurand". ISO/TC 334 refers to this as an "operationally defined measurand" (see [20], definition 3.7). In these cases only results obtained by the same procedure can be compared.

> EXAMPLE The activity of the enzyme alanine transaminase (ALAT) in a given blood plasma, as specified by the IFCC Committee on Reference Systems for Enzymes, is:
> Plasma—Alanine transaminase; catalytic concentration (IFCC 2002) is equal to 1,2 µkat/L [9].

NOTE 4 In the past the term "measurand" was used to refer to both the quantity intended to be measured and the quantity being measured, i.e., the quantity with which the **measuring system** interacts. Given that, despite the best efforts of the measurer, the quantity intended to be measured might not be the same as the quantity being measured, it is important to acknowledge this difference and then this ambiguity was removed by calling "measurand" only the

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Deleted: In laboratory medicine the IUPAC-IFCC format for a procedure defined measurand is "System—Component; kind-of-quantity(procedure)".
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former.

NOTE 5 The **measurement**, along with the measuring system and the conditions under which the **measurement** is carried out, might change the object such that the quantity which interacts with the measuring system may differ from the measurand as defined. In this case, adequate **correction** to the **measured value** may be necessary depending on the **target uncertainty**.

EXAMPLE 1 The potential difference between the terminals of a battery may decrease when using a voltmeter with a significant internal conductance to perform the measurement. Given the knowledge of the internal resistances of the battery and the voltmeter, the open-circuit potential difference can be calculated from such resistances by applying suitable theoretical considerations.

EXAMPLE 2 If the measurand is the length of a steel rod in equilibrium with the reference temperature of 20 °C, but the actual ambient temperature is 23 °C, then a correction is necessary.

NOTE 6 The term "analyte", or the name of a substance or compound, should not be confused with the term "measurand", because analytes are not quantities.

EXAMPLE *Amount of substance of glucose in plasma* is a measurand, while *glucose* is the analyte.

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2.4 [VIM3: 2.4; VIM2: 2.3; VIM1: 2.05]
measurement principle

principle of measurement

phenomenon serving as a basis of a **measurement**

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EXAMPLE 1 Thermoelectric effect applied to the measurement of temperature.

EXAMPLE 2 Energy absorption applied to the measurement of amount-of-substance concentration.

EXAMPLE 3 Lowering of the concentration of glucose in blood in a fasting rabbit applied to the measurement of insulin concentration in a preparation.

2.5 [VIM3: 2.5; VIM2: 2.4; VIM1: 2.06]
measurement method

method of measurement

description of the general organization of operations used in a **measurement**

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NOTE 1 Measurement methods may be qualified in various ways such as:

- substitution measurement method,
- differential measurement method, and
- null measurement method;

or

- direct measurement method, and
- indirect measurement method.

See [5].

NOTE 2 The use of the terms "measurement method" and "measurement procedure" differs, for historical reasons, in different areas of **metrology**. The terms are sometimes used interchangeably. In general, however, a measurement method specifies a broader category of operations than does a **measurement procedure**, which requires a detailed set of instructions.

2.6 [new]
primary measurement method

primary method of measurement

primary method

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measurement method used to obtain a **measurement result** for a **quantity** without reference to a **measurement standard** for a **quantity of the same kind**

EXAMPLE A primary measurement method for measuring the hydrostatic pressure of a constrained fluid (gas or liquid) is to use a **measurement system** (known as a "piston gauge" or "pressure balance"), consisting of a piston of known cross-sectional diameter, fitted into a cylinder of only slightly larger diameter, loaded on the top with mass pieces of known mass, with the constrained fluid exerting force on the bottom of the piston such that the piston is in equilibrium and thus not moving up or down. The hydrostatic pressure at the bottom of the piston can be calculated using previously measured **values** of diameter and mass, which does not require a separate measurement standard of pressure.

NOTE According to the SI Brochure [1], primary methods are the highest-level experimental methods used for the realization of definition of **units** using the equations of physics and chemistry. The essential characteristic of a primary method is that it allows a quantity to be measured in a particular unit by using only **measurements** of quantities that do not involve that unit.

2.7 [VIM3: 2.6; VIM2: 2.5; VIM1: 2.07]
measurement procedure

detailed description of a **measurement** according to a given **measurement method**, based on a **measurement model**

NOTE 1 A measurement procedure should be sufficiently documented to enable an operator to perform a measurement.

NOTE 2 A measurement procedure can include a statement concerning a **target uncertainty**.

NOTE 3 A measurement procedure is sometimes called a “standard operating procedure”, abbreviated as SOP.

NOTE 4 The use of the terms “measurement method” and “measurement procedure” differs, for historical reasons, in different areas of **metrology**. The terms are sometimes used interchangeably. In general, however, a measurement method specifies a broader category of operations than does a measurement procedure, which requires a detailed set of instructions.

2.8 [VIM3: 2.7]
reference measurement procedure
reference procedure

measurement procedure, recognized by an authoritative source, and used in the process of providing **measurement results** for a **quantity** for assessing **trueness** of **values** obtained from other measurement procedures for **quantities of the same kind**

NOTE 1 Reference measurement procedures are often used in **calibration**, sometimes referred to as “calibration procedures”, and in attributing values to properties of **reference materials**.

NOTE 2 Reference measurement procedures are established by a recognized authoritative source to 1) deliver, in comparison with other procedures determining the same measurand, the most reliable measurement result, or 2) become the reference in a developing field of measurement, or 3) provide an operationally defined measurand (see Note 3 to entry 2.3).

2.9 [VIM3: 2.8]
primary reference measurement procedure
primary reference procedure

reference measurement procedure used to obtain a **measurement result** for a **quantity** without relation to a **measurement standard** for a **quantity of the same kind**

EXAMPLE The volume of water delivered by a 50 ml pipette at 20 °C is measured by weighing the water delivered by the pipette into a beaker, taking the mass of beaker plus water minus the mass of the initially empty beaker, and correcting the mass difference for the actual water temperature using the volumic mass (mass density).

2.10 [VIM3: 2.9; VIM2: 3.1; VIM1: 3.01]
measurement result
result of measurement

set of **values** being attributed to a **measurand** together with any other available relevant information

NOTE 1 In a measurement result some values may be more representative of the measurand than others: in such cases, the measurement result can be reported as a probability distribution. Other options are possible, and widely used depending on the expected used of the measurement result, in particular as an interval of values, whose half width is an **expanded uncertainty**, or as a single **measured value** and a **measurement uncertainty**. When the measurement uncertainty is negligible in comparison with **target uncertainty**, and in many daily situations, measurement results are reported as a single measured value. In this case, only significant digits should be reported.

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Deleted: NOTE 1 A measurement result generally contains relevant information about the set of values, such that some may be more representative of the measurand than others. This may be reported as a probability distribution. ...

thus conveying the information about measurement uncertainty in terms of the last significant digit reported.

NOTE 2 In the past, a measurement result was sometimes reported as a single measured value attributed to a measurand and explained to mean an **indication**, or an uncorrected result, or a corrected result, according to the context.

NOTE 3 This definition differs from the definition in the GUM ("value attributed to a measurand, obtained by measurement") in recognition of the fact that "In general, the result of a measurement is only an approximation or estimate of the value of the measurand and thus is complete only when accompanied by a statement of the uncertainty of that estimate." ([30], entry 3.1.2).

2.11 [VIM3: 2.10]
measured value of a quantity

measured quantity value

measured value

value of a quantity representing a **measurement result**

NOTE 1 When a measurement result is represented by a **measured value**, the information should usually be complemented with a **measurement uncertainty**.

NOTE 2 For a **measurement** involving replicate **indications**, each indication can be used to provide a corresponding measured value. This set of measured values can be used to calculate a resulting measured value, such as an average or median, usually with a decreased associated measurement uncertainty.

NOTE 3 In cases where the range of the interval of the true values believed to represent the measurand is not small compared with the measurement uncertainty, a measured value is often an estimate of the average or median of the set of true values.

NOTE 4 In the GUM, the terms "result of measurement" and "estimate of the value of the measurand" or just "estimate of the measurand" are used to refer to measured values [30].

NOTE 5 "Measured value" should not be used to refer to indications and "indication" should not be used to refer to measured values.

2.12 [VIM3: 2.48]
measurement model

model of measurement

mathematical relation among all **quantities** known to be involved in a **measurement**

NOTE 1 A general form of a measurement model is the equation $h(Y, X_1, \ldots, X_n) = 0$, where Y, the **output quantity**, is the **measurand**, the **value** of which is to be inferred from information about the **input quantities** $X_1, \ldots, X_n$.

NOTE 2 In more complex cases where there are two or more output quantities, the measurement model consists of more than one equation.

EXAMPLES See JCGM 102 [32], 6.2.2, for several examples where there are two or more output quantities.

NOTE 3 JCGM 106 [33] treats models used in **metrology** in a more general sense, and discusses different types of measurement models used in metrology, such as theoretical, empirical, statistical, hybrid, etc.

2.13 [VIM3: 2.49]
measurement function

function of **quantities**, the **value** of which, when calculated using known values for the **input quantities**, is a **measured value** of the **output quantity**

NOTE 1 If a **measurement model** $h(Y, X_1, \ldots, X_n) = 0$ can explicitly be written as $Y = f(X_1, \ldots, X_n)$, where Y is the output quantity in the measurement model, the function f is the measurement function. More generally, f may symbolize an algorithm, yielding for input values $x_1, \ldots, x_n$ a corresponding unique output value $y = f(x_1, \ldots, x_n)$.

NOTE 2 A measurement function is also used to calculate the **measurement uncertainty** associated with the measured value of Y.

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2.14 [VIM3: 2.50]
input quantity in a measurement model

input quantity

quantity, the known **value** of which is required for calculating a **measured value** of a **measurand**

EXAMPLE When the length of a steel rod at a specified temperature is the measurand, the actual temperature, the length at that actual temperature, and the linear thermal expansion coefficient of the rod are input quantities.

NOTE **Indications**, **corrections**, and **influence quantities** can be input quantities.

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2.15 [VIM3: 2.51]
output quantity in a measurement model

output quantity

quantity, the **measured value** of which is calculated using the known **values** of **input quantities in a measurement model**

2.16 [VIM3: 2.52; VIM2: 2.7; VIM1: 2.10]
influence quantity

quantity that does not affect the quantity being measured but that affects the **measurement result**

NOTE 1 The quantity mentioned in the definition is an individual quantity that is identified as the property of a given object.

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EXAMPLE 1 Frequency of the alternating current in the measurement with an ammeter of the amplitude of that current.

EXAMPLE 2 Amount-of-substance concentration of bilirubin in a direct measurement of haemoglobin amount-of-substance concentration in human blood plasma.

EXAMPLE 3 Temperature of a micrometer screw gauge used for measuring the length of a rod, but not the temperature of the rod itself which can enter into the definition of the **measurand**.

EXAMPLE 4 Background pressure in the ion source of a mass spectrometer during a measurement of amount-of-substance fraction.

NOTE 2 In the GUM [30] the term “influence quantity” is used for referring not only to the quantities affecting the **measuring system**, as in the definition above, but also to those quantities that affect the quantities actually measured.

Deleted: NOTE 2 An indirect measurement involves a combination of direct measurements. The measurement result, each of which may be affected by influence quantities.

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2.17 [VIM3: 2.53; VIM2: 3.15, 3.16; VIM1: 3.14, 3.15]
correction

quantity, in a **measurement model**, compensating for an estimated **systematic error**

NOTE 1 The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.

NOTE 2 Corrections can be used for both **input quantities** and **output quantities in a measurement model**. If any of the related systematic errors are negligible with respect to the **target uncertainty**, the corresponding correction is usually avoided, especially if it is unpractical or uneconomical.

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3 Measurement quality

3.1 [VIM3: 2.26; VIM2: 3.9; VIM1: 3.09]
measurement uncertainty

uncertainty of measurement
uncertainty

parameter characterizing the dispersion of the **values** being attributed to a **measurand**, based on the information used

NOTE 1 Measurement uncertainty is generally part of a **measurement result**.

NOTE 2 Measurement uncertainty can be interpreted as doubt about a **true value** of the measurand that remains after making a **measurement**.

NOTE 3 The parameter characterizing dispersion can be, for example, a **standard uncertainty** (or a specified multiple of it), or the half-width of an interval, having a stated **coverage probability**.

NOTE 4 Measurement uncertainty includes components arising from several sources, as listed in the GUM [30], including both **random** and **systematic errors**, caused by **measurement precision** and **measurement trueness** accordingly.

NOTE 5 Components of measurement uncertainty arising from systematic errors include components associated with **corrections**. Sometimes estimated systematic errors are not corrected for but, instead, associated measurement uncertainty components are incorporated.

NOTE 6 In general, it is understood that the measurement uncertainty is associated with a stated value attributed to the measurand. The choice of a different value results in a modification of the associated uncertainty.

NOTE 7 Guidance about the evaluation and expression of measurement uncertainty is provided by the GUM [30].

3.2 [VIM3: 2.27]
definitional uncertainty

lower bound of **measurement uncertainty** resulting from the finite amount of detail in the definition of a **measurand**

EXAMPLE The measured thickness of a sheet of material at a given temperature may vary at different points on the sheet because of manufacturing unevenness. If not otherwise specified, this variation contributes to definitional uncertainty of the measured thickness of a given sheet of material at a given temperature.

NOTE 1 Definitional uncertainty sets the practical minimum measurement uncertainty achievable in any **measurement** of a given measurand. A measurand should be defined in such a way that the related definitional uncertainty is negligible compared to the **combined uncertainty** or the **target uncertainty**.

NOTE 2 Definitional uncertainty can be considered as an estimate of the range of the interval of true values of a defined measurand.

NOTE 3 Any change in the descriptive detail in the definition of a measurand usually leads to another definitional uncertainty.

NOTE 4 In the GUM [30], entry D.3.4, and in IEC 60359 [7], definitional uncertainty is termed “intrinsic uncertainty”.

3.3 [VIM3: 2.34]
target uncertainty

upper limit of **measurement uncertainty** decided on the basis of the intended use of **measurement results**

3.4 [VIM3: 4.24]
instrumental measurement uncertainty

instrumental uncertainty

component of **measurement uncertainty** caused by a **measuring instrument** or **measuring system** in use

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NOTE 1 Instrumental uncertainty is evaluated using information obtained in **calibration** of a measuring instrument or measuring system, except for a **primary measurement standard** for which other means are used.

NOTE 2 Instrumental uncertainty is used in a **Type B evaluation of measurement uncertainty**.

NOTE 3 Information relevant to instrumental uncertainty is usually given in the instrument specifications or in the calibration certificates.

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3.5 [VIM3: 2.28]
Type A evaluation of measurement uncertainty

Type A evaluation

evaluation of a component of **measurement uncertainty** by a statistical analysis of **measured values** obtained under defined **measurement** conditions

NOTE 1 For various types of measurement conditions, see **repeatability condition of measurement**, **intermediate precision condition of measurement**, and **reproducibility condition of measurement**.

NOTE 2 For uncertainty evaluation see the GUM [30], ISO 5725 [13], ISO 13528 [14], ISO/TS 21748 [21], and ISO 21749 [22].

Deleted: NOTE 2 For information about statistical analysis, see for example the GUM.

3.6 [VIM3: 2.29]
Type B evaluation of measurement uncertainty

Type B evaluation

evaluation of a component of **measurement uncertainty** by means other than a **Type A evaluation**

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EXAMPLES Evaluation based on information

- associated with authoritative published **reference values**,
- associated with the value of a specified property of a **certified reference material**, as provided by reference material certificate
- obtained from a **calibration** certificate,
- about drift,
- obtained from the **accuracy class** of a verified **measuring instrument**,
- obtained from limits inferred through personal experience and expertise.

NOTE See also the GUM [30], entry 2.3.3.

3.7 [VIM3: 2.30]
standard measurement uncertainty

standard uncertainty of measurement

standard uncertainty

measurement uncertainty expressed as a standard deviation

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3.8 [VIM3: 2.31]
combined standard measurement uncertainty

combined standard uncertainty

standard uncertainty that is obtained using the standard uncertainties associated with the **input quantities in a measurement model**

NOTE In case of correlations of the random variables modelling input quantities in a measurement model, covariances must also be taken into account when calculating the combined standard uncertainty (see also the GUM [30], entry 2.3.4).

3.9 [VIM3: 2.32]
relative standard measurement uncertainty

relative standard uncertainty

standard uncertainty divided by the absolute value of a **measured value**

3.10 [VIM3: 2.33]
uncertainty budget

statement of a **measurement uncertainty**, of the components of that measurement uncertainty, and of their calculation and combination

NOTE An uncertainty budget specifies the **measurement model**, estimates and measurement uncertainties associated with the **quantities** in the measurement model, covariances, type of applied probability distributions, degrees of freedom, type of evaluation of measurement uncertainty, and any **coverage factor** if **expanded uncertainty** is considered, where relevant.

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3.11 [VIM3: 2.35]
expanded measurement uncertainty

expanded uncertainty

product of a **standard measurement uncertainty** and a factor greater than one

NOTE 1 The factor mentioned in the definition is a **coverage factor** and depends upon the type of probability distribution attributed to the **quantity** in a **measurement model** and the selected **coverage probability**. Expanded uncertainties are meaningful only for symmetric distributions.

NOTE 2 Expanded measurement uncertainty is termed "overall uncertainty" in paragraph 5 of Recommendation INC-1 (1980) (see the GUM [30]).

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3.12 [VIM3: 2.36]
coverage interval

interval containing the **value** of a **measurand** with a stated probability, based on the information used

NOTE 1 A coverage interval does not need to be centred on the chosen **measured value** (see JCGM 101 [31]).

NOTE 2 A coverage interval should not be termed "confidence interval" to avoid confusion with the statistical concept (see the GUM [30], entry 6.2.2).

NOTE 3 A coverage interval can be derived from an **expanded uncertainty** for symmetrical distributions (see the GUM [30], entry 2.3.5). Generally, there is more than one coverage interval.

NOTE 4 The value of a measurand mentioned in the definition is sometimes considered to be a **true value**, where the adjective "true" is considered to be redundant in the GUM [30].

NOTE 5 The definition has been adapted from JCGM 101 [31], entry 3.12.

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3.13 [VIM3: 2.37]
coverage probability

probability that the **value** of a **measurand** is contained within a specified **coverage interval**

NOTE 1 Coverage probability is also termed "level of confidence" in the GUM [30].

NOTE 2 The value of a measurand mentioned in the definition is sometimes considered to be a **true value**, where the adjective "true" is considered to be redundant in the GUM [30].

NOTE 3 The definition has been adapted from JCGM 101 [31], entry 3.13.

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3.14 [VIM3: 2.38]

coverage factor

number greater than one by which a **standard uncertainty** is multiplied to obtain an **expanded uncertainty**

NOTE 1 Coverage factors are meaningful for computing expanded uncertainties only for symmetric distributions.

NOTE 2 A coverage factor is usually symbolized *k* (see also the GUM [30], entry 2.3.6).

3.15 [VIM3: 2.13; VIM2: 3.5; VIM1: 3.05]

measurement accuracy

accuracy

closeness of agreement between a **measured value** and a **reference value** of a **measurand**

NOTE 1 Accuracy is customarily thought of as pertaining to

1) a **measurement procedure**: in this case closeness of agreement is often reported quantitatively in terms of **bias** and standard deviation, which are evaluated through **validation** or **verification**, where known reference values are provided by **measurement standards**, **certified reference materials** or **reference measurement procedures**. Algorithms for evaluation are given in ISO 5725 [13]);

2) a **measuring instrument** or a **measuring system**: in this case closeness of agreement is often reported quantitatively in terms of an **accuracy class** or **maximum permissible error**, which are evaluated through verification or calibration, where known reference values are provided by measurement standards, certified reference materials or reference measurement procedures;

3) a **measurement** whose outcome is a single measured value or a set of measured values: in either of these cases the reference value is a **true value**, which is not known, and is estimated using all available information including information about the accuracy of the measurement procedure and of the measuring instrument used in the measurement. Sometimes measurement accuracy is reported quantitatively in terms of **measurement uncertainty**.

NOTE 2 Accuracy can be interpreted as the combination of **measurement trueness** and **measurement precision**. However, the term "measurement accuracy" should not be used to refer to measurement trueness and the term "measurement precision" should not be used to refer to measurement accuracy.

NOTE 3 A measurement is said to be more accurate when it offers a smaller **measurement error**.

3.16 [VIM3: 2.14]

measurement trueness

trueness

closeness of agreement between the average of **measured values** obtained by replicate **measurements** and a **reference value** under specified conditions

NOTE 1 Measurement trueness is sometimes interpreted as closeness of a **systematic measurement error** to zero. In this case closeness is often reported in terms of a bias.

NOTE 2 Measurement trueness is customarily thought of as pertaining to either 1) a **measurement procedure**, 2) a **measuring instrument** or a **measuring system**, or 3) a single measured value or a set of measured values.

NOTE 3 In practice, the number of averaged measured values must be large enough to make random variability of the average of measured values obtained under specified conditions negligible. Measurement trueness may be reported in terms of parameters listed in ISO 5725 [13].

3.17 [VIM3: 2.15]

measurement precision

precision

closeness of agreement among **indications** or **measured values** obtained by replicate **measurements** on the same or similar objects under specified conditions

NOTE 1 Measurement precision is sometimes interpreted as closeness of a **random measurement error** to zero. In this case, closeness is often reported quantitatively in terms of standard deviation, variance, coefficient of variation or

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precision limits under the specified conditions of measurement.

NOTE 2 Measurement precision is customarily thought of as pertaining to either 1) a **measurement procedure**, 2) a **measuring instrument** or a **measuring system**, or 3) a set of indications or measured values.

NOTE 3 The specified conditions mentioned in the definition can be, for example, **repeatability conditions of measurement**, **intermediate precision conditions of measurement**, or **reproducibility conditions of measurement**. The specified conditions typically relate to, but are not necessarily limited to, **measurement method**, measurement procedure, measuring system, measuring system operator, operating conditions, period of time and measurement location. The specification of the conditions should include what the changes are, to the extent practical.

NOTE 4 Measurement precision may be evaluated by replicate measurements on similar objects, provided that variability among the objects is negligible.

3.18 [VIM3: 2.16; VIM2: 3.10; VIM1: 3.10]

measurement error

error of measurement

error

measured value minus a **reference value**

NOTE 1 Measurement error is customarily thought of as pertaining to either 1) a **measurement procedure**, 2) a **measuring instrument** or a **measuring system**, or 3) a single measured value or a set of measured values.

NOTE 2 The term “measurement error” can be used either a) when a reference value is known, for example, in **calibration** where a reference value is obtained using a **measurement standard** and the **systematic measurement error** pertained to a measuring instrument is often evaluated together with an associated **uncertainty**, or b) when a reference value is a **true value**, which is not known.

NOTE 3 Measurement error is traditionally interpreted as having systematic components and random components, though the distinction between **systematic error** and **random error** may depend on the context. Sometimes systematic error and random error are combined additively.

NOTE 4 Measurement error should not be confused with production error or mistake.

3.19 [VIM3: 2.17; VIM2: 3.14; VIM1: 3.13]

systematic measurement error

systematic error of measurement

systematic error

component of **measurement error** that in replicate **measurements** remains constant or varies in a predictable manner

NOTE 1 A **reference value** for a systematic error is a **true value**, or a **measured value** of a **quantity** provided by a **measurement standard** of stated **measurement uncertainty**, or a **conventional value**.

NOTE 2 A **correction** can be applied to compensate for an estimated systematic error, provided that the uncertainty of the correction is known or negligible.

3.20 [VIM3: 2.18]

measurement bias

bias

estimate of a **systematic error**

NOTE 1 Measurement bias differs from bias in mathematical statistics. Measurement bias should be accompanied with a stated **uncertainty** which can be negligible for some purposes.

NOTE 2 Sometimes measurement bias is incorporated in a **measurement model** as a **correction** for an estimated systematic error.

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3.21 [VIM3: 2.19; VIM2: 3.13; VIM1: 3.12]
random measurement error

random error of measurement
random error

component of **measurement error** that in replicate **measurements** varies in an unpredictable manner

NOTE Random errors of a set of replicate measurements form a distribution that can be summarized by its average, which is generally assumed to be zero, and its standard deviation.

3.22 [VIM3: 2.20; VIM2: 3.6 Notes 1 and 2]
repeatability conditions of measurement

repeatability conditions

specified conditions of **measurement** where **indications** or **measured values** are obtained by replicate measurements with the same **measurement procedure** on the same or similar objects in the same laboratory by the same operator using the same **measuring system** within a short period of time

NOTE The short period of time mentioned in the definition is intended to be as short as necessary in order to avoid the occurrence of changes in the specified conditions (see ISO 5725-1 [13], section 4.4).

3.23 [VIM3: 2.21; VIM2: 3.6; VIM1: 3.06]
measurement repeatability

repeatability

measurement precision under **repeatability conditions**

NOTE Repeatability may be evaluated by replicate measurements on similar objects, provided variability among the objects is negligible.

3.24 [VIM3: 2.22]
intermediate precision conditions of measurement

intermediate precision conditions

specified conditions of **measurement**, where **measured values** are obtained by replicate measurements with the same **measurement method**, on the same or similar objects over an extended period of time in the same laboratory

EXAMPLE 1 Intermediate precision conditions applied to **measurement results** obtained on internal measurement quality control materials in a laboratory over a stated period of time to monitor the quality of the measurements.

EXAMPLE 2 Repeated PCR or ELISA measurements of the same object carried out under intermediate precision conditions if multiple 96-well-plates are used.

NOTE 1 The extended period of time mentioned in the definition is intended to be long enough to allow for changes in the specified conditions.

NOTE 2 The specification of an intermediate precision condition should include what the changes in conditions are, to the extent practical.

3.25 [VIM3: 2.23]
intermediate measurement precision

intermediate precision

measurement precision under **intermediate precision conditions**

NOTE 1 Intermediate precision may be evaluated by replicate measurements on similar objects, provided variability among the objects is negligible.

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NOTE 2 Relevant statistical terms are given in ISO 5725-3 [13].

3.26 [VIM3: 2.24; VIM2: 3.7 Note 2]
reproducibility conditions of measurement

reproducibility conditions

specified conditions of **measurement**, where **measured values** are obtained by replicate measurements on the same or similar objects in different laboratories by different operators using different **measuring systems**

EXAMPLE Reproducibility conditions applied to collaborative study of the **measurement procedure**, organized by several laboratories. In this case the same measurement procedure is used by all laboratories.

NOTE 1 In some cases the different laboratories may use different **measurement methods**.

NOTE 2 The specification of reproducibility conditions should include all changes in conditions of measurement in different laboratories, that are significant for explanation of the observed spread of measured values.

3.27 [VIM3: 2.25; VIM2: 3.7; VIM1: 3.07]
measurement reproducibility

reproducibility

measurement precision under **reproducibility conditions**

NOTE 1 Reproducibility may be evaluated by replicate **measurements** on similar objects, provided variability among the objects is negligible.

NOTE 2 Relevant statistical terms are given in ISO 5725-1 and ISO 5725-2 [13].

3.28 [VIM3: 4.26; VIM2: 5.21; VIM1: 5.23]
maximum permissible measurement error

maximum permissible error

limit of error

MPE

extreme **measurement error**, with respect to a known **reference value**, permitted by specifications or regulations for a given **measurement**, **measuring instrument**, or **measuring system** working at the **rated operating conditions**

NOTE 1 Usually, the terms "maximum permissible errors" or "limits of error" are used where there are two different extreme values.

NOTE 2 The term "tolerance" should not be used for referring to maximum permissible errors.

NOTE 3 An MPE may be expressed as a single value, or a set of values or a function, to cover different operating conditions within the rated operating conditions.

3.29 [VIM3: 4.27; VIM2: 5.22; VIM1: 5.25]
datum measurement error

datum error

measurement error of a **measuring instrument** or **measuring system** at a specified **measured value**

NOTE If a specified measured value is zero the terms "zero error" or "error at zero" are used. Zero error should not be confused with absence of measurement error.

3.30 [VIM3: 4.29]
null measurement uncertainty

measurement uncertainty at zero

measurement uncertainty associated with a null or near zero **measured value**

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NOTE 1 Null measurement uncertainty relates to a **measurand** where one does not know whether the measurand is too small to be detected or the **indication** of the **measuring instrument** is due only to noise.

NOTE 2 Null measurement uncertainty also applies when a difference is obtained between **measurement** of a sample and a blank.

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4 Measuring devices and their properties

4.1 [VIM3: 3.1; VIM2: 4.1; VIM1: 4.01]
measuring instrument

device used for making **measurements**, alone or in conjunction with one or more supplementary devices

NOTE 1 A measuring instrument that can be used alone for making measurements in some contexts is regarded as a **measuring system**. Hence, throughout this Vocabulary the term "measuring system" is used to refer also to measuring instruments for the sake of simplicity.

NOTE 2 A measuring instrument is either an **indicating measuring instrument** or a **material measure**.

4.2 [VIM3: 3.2; VIM2: 4.5; VIM1: 4.05]
measuring system

set of **measuring instruments**, and often **measurement standards** and other components, assembled and adapted to give information used to generate **measured values** within specified intervals for **quantities** of specified kinds

NOTE 1 The quantities mentioned in the definition are individual quantities that are identified as the properties of given objects.

NOTE 2 The components mentioned in the definition may be devices, reagents, and supplies.

NOTE 3 A measuring system is sometimes referred to as "measuring equipment" or "device", for example in ISO/IEC 10012 [24] and ISO 17025 [18].

NOTE 4 Although the terms "measuring system" and "measurement system" are frequently used synonymously, the latter is instead sometimes used to refer to a measuring system plus all other entities involved in a measurement, including the object under measurement and the person(s) performing the measurement.

NOTE 5 A measuring system can be used as a **measurement standard.**

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4.3 [VIM3: 3.3; VIM2: 4.6; VIM1: 4.06]
indicating measuring instrument

measuring instrument providing an output signal carrying information about the **value** of the **quantity** being measured

EXAMPLES Voltmeter, micrometer, thermometer, electronic balance.

NOTE 1 The quantity being measured that is mentioned in the definition might not be the same as the **measurand**, for example when the measuring instrument does not properly interact with the object under measurement.

NOTE 2 An indicating measuring instrument may provide a record of its **indication**.

NOTE 3 An output signal may be presented in visual or acoustic form. It may also be transmitted to one or more other devices.

4.4 [VIM3: 3.4; VIM2: 4.6; VIM1: 4.06]
displaying measuring instrument

indicating measuring instrument where the output signal is presented in visual form

4.5 [VIM3: 3.5; VIM2: 4.17; VIM1: 4.19]
scale of a displaying measuring instrument

component of a **displaying measuring instrument**, consisting of an ordered set of marks together with any associated **values**

4.6 [VIM3: 3.6; VIM2: 4.2; VIM1: 4.02]
material measure

measuring instrument embodying or supplying, in a permanent manner during its use, **quantities** of one or more given kinds, each with an assigned **value**

EXAMPLES Standard weight, volume measure, standard electric resistor, line scale (ruler), gauge block, standard signal generator, **certified reference material**, each embodying or supplying one or several quantities, each with an assigned value.

NOTE 1 The **indication** of a material measure is its assigned value.

NOTE 2 A material measure can be used as a **measurement standard**.

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4.7 [VIM3: 3.7; VIM2: 4.3; VIM1: 4.03]
measuring transducer

component of a **measuring system** that provides an output signal having a specified relation to the input signal

EXAMPLES Thermocouple, strain gauge, pH electrode, bimetallic strip.

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4.8 [VIM3: 3.8; VIM2: 4.14; VIM1: 4.15]
sensor

component of a **measuring system** that is directly affected by the **quantity** being measured

EXAMPLES Sensing coil of a platinum resistance thermometer, rotor of a turbine flow meter, float of a level-measuring instrument, photocell of a spectrometer, thermotropic liquid crystal which changes colour as a function of temperature.

NOTE In some fields, the term “detector” is used for referring to sensors, but not in this Vocabulary.

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4.9 [VIM3: 3.9; VIM2: 4.15; VIM1: 4.16]
detector

device that indicates the presence of an object carrying a property of interest

EXAMPLES Geiger-Müller counter, Scintillation counter, Infrared detector, Halogen leak detector

NOTE In some fields, the term “detector” is used for referring to sensors, but not in this Vocabulary.

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4.10 [VIM3: 3.10; VIM2: 4.4; VIM1: 4.04]
measuring chain

series of components of a **measuring system** constituting a path of the signal from a **sensor** to an output element

EXAMPLE Electro-acoustic measuring chain comprising a microphone, attenuator, filter, amplifier, and voltmeter.

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4.11 [VIM3: 3.11; VIM2: 4.30; VIM1: 4.33]
adjustment

adjustment of a measuring system

set of operations carried out on a **measuring system** so that it provides prescribed **indications** corresponding to given **values** of a **quantity** being measured

NOTE 1 Types of adjustment of a measuring system include **zero adjustment**, offset adjustment, and span adjustment (sometimes called “gain adjustment”).

NOTE 2 Adjustment of a measuring system should not be confused with **calibration**, which is sometimes a prerequisite for adjustment.

NOTE 3 After an adjustment of a measuring system, the measuring system must usually be recalibrated.

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4.12 [VIM3: 3.12]
zero adjustment
zero adjustment of a measuring system

adjustment of a **measuring system** so that it provides a null **indication** corresponding to a zero **value** of a **quantity** being measured

4.13 [VIM3: 4.1; VIM2: 3.2; VIM1: 3.02]
indication
instrumental indication

reading

value of a quantity provided by an **indicating measuring instrument**

NOTE 1 An indication and a corresponding **value** of the **quantity** being measured are not necessarily values of quantities of the same kind. For example, for a thermocouple, the indication is the value of the voltage obtained when a temperature is applied to the thermocouple.

NOTE 2 The second step of **calibration** of a **measuring instrument** or a **measuring system** involves establishing the relation between indications and **measured values**. Indications are independent of whether the instrument has been calibrated.

4.14 [VIM3: 4.2]
blank indication
background indication

indication obtained when the **quantity** of interest is not contributing to the indication

NOTE A blank indication can arise in part from response to a quantity of the same kind as the measurand.

EXAMPLE In determination of the concentration of iron in drinking water, a trace concentration of iron in the analytical reagents used can contribute to the blank indication even when there is no iron in a water sample being used to obtain the blank indication. In this case, blank indication will often be used to correct the instrument indication.

4.15 [VIM3: 4.3; VIM2: 4.19; VIM1: 4.21]
indication interval

interval of **values** bounded by extreme possible **indications**

NOTE 1 An indication interval is usually stated in terms of its smallest and greatest values, for example "99 V to 201 V".

NOTE 2 In some fields, the term referring to an indication interval is "range of indications", but not in this Vocabulary.

4.16 [VIM3: 4.4; VIM2: 5.1; VIM1: 5.01]
nominal indication interval
nominal interval

indication interval, bounded by rounded or approximate extreme **indications**, obtainable with a particular setting of the controls of a **measuring system** and used to designate that setting

NOTE 1 A nominal indication interval is usually stated as its smallest and greatest values, for example "100 V to 200 V".

NOTE 2 In some fields, the term "nominal range" is used to refer to nominal intervals, but not in this Vocabulary.

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4.17 [VIM3: 4.6; VIM2: 5.3; VIM1: 5.03]

nominal value

nominal value of a quantity

nominal value of a quantity of a measuring system

rounded or approximate **value** of a **quantity** of a **measuring system** or measurement standard that provides guidance for its appropriate use

EXAMPLE 1 100 Ω as the nominal value of electric resistance as a characterizing quantity of a standard resistor.

EXAMPLE 2 1 000 ml as the nominal value of volume as a characterizing quantity of a single-mark volumetric flask.

EXAMPLE 3 0.1 mol/l as the nominal value of amount-of-substance concentration as a characterizing quantity of a solution of hydrogen chloride, HCl.

NOTE The terms “nominal value” and “nominal value of a quantity” should not be used to refer to **nominal property values**.

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4.18 [VIM3: 4.7; VIM2: 5.4; VIM1: 5.04]

measuring interval

working interval

interval of **values** of **quantities** that can be measured by a given **measuring system** with specified **uncertainty**

NOTE 1 In some fields, the terms “measuring range” or “measurement range” are used for referring to measuring intervals.

NOTE 2 The lower limit of a measuring interval should not be confused with **detection limit**.

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4.19 [new]

operating condition

state and configuration of a **measuring system**, including its environment, when it is in operation

NOTE The state of a measuring system can include whether and how it is powered / energized, the state of internal components / circuitry / interconnections when energized (for example, what is constant and what varies with time), and what are the **values** of the environmental **quantities** that are known to influence the **indication** in a significant, predictable but otherwise undesirable way.

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4.20 [VIM3: 4.9; VIM2: 5.5; VIM1: 5.05]

rated operating condition

operating condition that must be achieved in order that a **measuring system** perform as designed

NOTE Rated operating conditions generally specify intervals of **values** for a **quantity** being measured and for any **influence quantity**, as typically provided by the manufacturer of the measuring system.

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4.21 [VIM3: 4.10; VIM2: 5.6; VIM1: 5.06]

limiting operating condition

extreme **operating condition** that a **measuring system** is required to withstand without damage, and without degradation of performance, when it is subsequently operated under its **rated operating conditions**

NOTE 1 Limiting conditions for storage, transport or operation can differ.

NOTE 2 Limiting conditions can include limiting **values** of a **quantity** being measured and of any **influence quantity**.

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4.22 [VIM3: 4.11; VIM2: 5.7; VIM1: 5.07]

reference operating condition

reference condition

operating condition prescribed for evaluating the performance of a **measuring system** or for comparison of **measurement results**

NOTE 1 Reference operating conditions specify intervals of **values** of the **measurand** and of the **influence quantities**.

NOTE 2 In IEC 60050-300 [5], definition 311-06-02, the term “reference condition” refers to an operating condition under which the specified **instrumental uncertainty** is the smallest possible.

4.23 [VIM3: 4.12; VIM2: 5.10; VIM1: 5.10]

sensitivity

sensitivity of a measuring system

quotient of the change in an **indication** of a **measuring system** and the corresponding change in a given **value** of the **quantity** being measured

NOTE 1 Sensitivity of a measuring system can depend on (i) the quantity being measured, (ii) the **influence quantities**, and (iii) aging of the system. Sensitivity is evaluated under the condition that the influence quantities do not change.

NOTE 2 The change considered in the value of the quantity being measured must be large compared with the **resolution** of the measuring system.

4.24 [VIM3: 4.13]

selectivity

selectivity of a measuring system

property of a **measuring system**, used with a specified **measurement procedure**, whereby it provides **indications** that are independent of **quantities** other than the quantity being measured but that are **of the same kind** as the **measurand**

EXAMPLE 1 Capability of a quadrupole mass spectrometer to provide indications of the presence of background gases in an ultrahigh vacuum chamber by the ion current generated, without disturbance by other specified sources of electric current.

EXAMPLE 2 Capability of a measuring system to provide indications about the power of a signal component at a given frequency without being disturbed by signal components or other signals at other frequencies.

EXAMPLE 3 Capability of a receiver to discriminate between indications about a wanted signal and unwanted signals, often having frequencies slightly different from the frequency of the wanted signal.

EXAMPLE 4 Capability of a measuring system for ionizing radiation to provide indications about a given radiation to be measured in the presence of concomitant radiation.

EXAMPLE 5 Capability of a measuring system to provide indications about the amount-of-substance concentration of creatinine in blood plasma without being influenced by the glucose, urate, ketone, and protein concentrations.

EXAMPLE 6 Capability of a mass spectrometer to provide indications about the amount-of-substance abundance of the 28Si isotope and of the 30Si isotope in silicon from a geological deposit without influence between the two, or from the 29Si isotope.

4.25 [VIM3: 4.14]

resolution

resolution of a measuring system

smallest change in the **quantity** being measured that causes a detectable change in the corresponding **indication**

NOTE 1 Resolution can be different depending on the **value** of the quantity being measured. It may also depend on noise (internal or external) or friction.

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NOTE 2 The resolution of a **measuring system** is not the same thing as the resolution of a **displaying measuring instrument**. The difference is that the resolution of a displaying measuring system is determined from detectable changes in indications, whereas the resolution of a measuring system is determined from detectable changes in **measured values** when using the measuring system, which are in turn based on knowing the relation of the measured value to the indication as obtained through **calibration** of the measuring system.

NOTE 3 Resolution is not necessarily the same as **discrimination threshold**.

4.26 [VIM3: 4.16; VIM2: 5.11; VIM1: 5.12]
discrimination threshold

largest change in the **quantity** being measured that causes no detectable change in the corresponding **indication**

NOTE 1 Discrimination threshold may depend, for example, on noise (internal or external) or friction. It can also depend on the **value** of the quantity being measured and how the change is applied.

NOTE 2 Discrimination threshold is not necessarily the same as **resolution**.

4.27 [VIM3: 4.17; VIM2: 5.13; VIM1: 5.14]
dead band

maximum interval through which the **quantity** being measured can be changed in both directions without producing a detectable change in the corresponding **indication**

NOTE 1 Dead band can depend on the rate of change of the quantity being measured.

NOTE 2 A dead band may be exploited, or purposely introduced, to prevent the occurrence of changes in the indication unrelated to the **value** of the quantity being measured, such as those caused by noise.

4.28 [VIM3: 4.18; VIM2: 4.15 Note 1]
detection limit

limit of detection

value of the **measurand**, obtained by a given **measurement procedure**, for which the probability of falsely claiming the absence of a component in a material is β, given a probability α of falsely claiming its presence

NOTE 1 The abbreviation LOD is sometimes used for referring to detection limit.

NOTE 2 Detection limit is usually considered to be a performance characteristic of a particular measurement procedure.

NOTE 3 The term “sensitivity” is discouraged for referring to detection limits.

4.29 [VIM3: 4.19; VIM2: 5.14; VIM1: 5.16]
stability

stability of a measuring system

property of a **measuring system**, whereby its metrological performance remains constant over time

NOTE Stability may be quantified in several ways.

EXAMPLE 1 In terms of the duration of a time interval over which the metrological performance changes by a stated amount.

EXAMPLE 2 In terms of the change of the metrological performance over a stated time interval.

4.30 [VIM3: 4.20; VIM2: 5.25; VIM1: 5.28]
instrumental bias

average of replicate **indications** minus a **reference value**

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4.31 [VIM3: 4.21; VIM2: 5.16; VIM1: 5.18]
instrumental drift

gradual change over time in **indication** of a **measuring system** due to its limited **stability**

NOTE Instrumental drift is related neither to a change in a quantity being measured nor to a change of any recognized **influence quantity**.

4.32 [VIM3: 4.23; VIM2: 5.17; VIM1: 5.19]
step response time

duration between the instant when an input signal to a **measuring system** is subjected to an abrupt change between two specified constant values and the instant when a corresponding **indication** settles within specified limits around its final steady value

4.33 [VIM3: 4.25; VIM2: 5.19; VIM1: 5.22]
accuracy class

class of **measuring instruments** or **measuring systems** that meet stated metrological requirements that are intended to keep **measurement errors** and **instrumental measurement uncertainties** within specified limits under specified **operating conditions**

NOTE 1 An accuracy class is usually denoted by a number or symbol adopted by convention.

NOTE 2 Accuracy class may apply to **material measures**.

NOTE 3 Accuracy class is not on its own a technically valid indicator as to the fitness for purpose of a measuring instrument or a measuring system, unless prescribed by a validated method.

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variation due to an influence quantity

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5 Measurement standards (etalons) and metrological traceability

5.1 [VIM3: 5.1; VIM2: 6.1; VIM1: 6.01]

measurement standard

etalon

realization of the definition of a **quantity** with stated **value** and associated **measurement uncertainty**, used as a reference

NOTE 1 A measuring instrument, thus possibly a **material measure**, or a **measuring system**, or a **certified reference material** can be used as a measurement standard under specified conditions.

EXAMPLE 1 Laser interferometer (measuring system) used to realize the definition of the metre (utilizing the defining constant of the speed of light) with standard uncertainty of 0.1 μm.

EXAMPLE 2 Pressure balance (measuring system) used to generate and measure absolute-mode atmospheric pressure with a standard uncertainty of 0.2 Pa.

EXAMPLE 3 1 kg mass standard (material measure) with **standard uncertainty** of 3 μg.

EXAMPLE 4 Standard buffer solution (certified reference material) with a pH of 7.072 with standard uncertainty of 0.006.

EXAMPLE 5 Set of reference materials of cortisol in human serum with different concentrations, each accompanied with a certified value with measurement uncertainty.

NOTE 2 In science and technology, the noun "standard" is used with at least two different meanings: as a specification, technical recommendation, or similar normative document (in French "norme") and as a measurement standard (in French "étalon"). This Vocabulary is concerned solely with the second meaning.

NOTE 3 Measurement standards are used to conserve, reproduce, or disseminate the specified individual quantity, and to calibrate measuring systems.

NOTE 4 A measurement standard is frequently used as a reference in establishing **measured values** and associated measurement uncertainties for other **quantities of the same kind**, thereby establishing **metrological traceability** through **calibration** of other measurement standards, **measuring instruments**, or **measuring systems**.

NOTE 5 The standard uncertainty associated with a measurement standard is always a component of the **combined standard uncertainty** (see the GUM [30], entry 2.3.4) in a **measurement result** obtained using the measurement standard. Frequently, this component is small compared with other components of the combined standard uncertainty.

NOTE 6 The relevant quantity of a measurement standard might change over time.

NOTE 7 A measurement standard may realize the definition of more than one quantity of the same kind or of different kinds. For example, a working standard for electric power measuring instruments may provide both alternating current (AC) voltage and AC current sinusoidal waveforms with preset phase angles.

NOTE 8 The term "embodiment" is sometimes used to refer to the realization of a definition of a quantity, as mentioned in the definition.

NOTE 9 The term "measurement standard" is sometimes used for referring to other metrological tools, for example software measurement standards (see ISO 5436-2 [12]).

NOTE 10 Sometimes, the phrase "realization of the definition of a quantity", as in the definition, is shortened as "realization of a quantity". This Vocabulary is concerned with empirical quantities, that are "real" as such: what can be "made real", and therefore realized, are instead definitions that allow us to identify quantities, as properties of given objects, as in the case of measurement standards.

5.2 [VIM3: 5.2; VIM2: 6.2; VIM1: 6.06]

international measurement standard

measurement standard recognized by signatories to an international agreement and intended to serve worldwide as the basis for assigning **values** to other measurement standards for the general quantity concerned

EXAMPLE 1 Prior to the introduction of the revision of the **SI** in 2019, the International Prototype of the Kilogram, maintained by the International Bureau of Weights and Measures (BIPM).

EXAMPLE 2 Chorionic gonadotropin, World Health Organization (WHO) 5th international standard 2013, 07/364, 179 International Units per ampoule.

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EXAMPLE 3 VSMOW2 (Vienna Standard Mean Ocean Water) distributed by the International Atomic Energy Agency (IAEA) for **measurements** of differential stable isotope amount-of-substance ratio.

5.3 [VIM3: 5.3; VIM2: 6.3; VIM1: 6.07]
national measurement standard

national standard

measurement standard recognized by national authority to serve in a state or economy as the basis for assigning **values** to other measurement standards for the general **quantity** concerned

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5.4 [VIM3: 5.4; VIM2: 6.4; VIM1: 6.04]
primary measurement standard

primary standard

measurement standard established using a **primary method**, or a **primary reference procedure**, or created as an artefact, chosen by convention

EXAMPLE 1 Primary standard of amount-of-substance concentration prepared by dissolving a known amount of substance of a chemical component to a known volume of solution.

EXAMPLE 2 Primary standard for pressure based on separate **measurements** of force and area e.g. a pressure balance.

EXAMPLE 3 Prior to the introduction of the revision of the SI in 2019, the International Prototype of the Kilogram, as an artefact, chosen by convention and maintained by the International Bureau of Weights and Measures (BIPM).

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5.5 [VIM3: 5.5; VIM2: 6.5; VIM1: 6.05]
secondary measurement standard

secondary standard

measurement standard established through **calibration** with respect to a **primary standard**

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NOTE Calibration may be obtained directly by comparison between a primary standard and a secondary standard, or involve an intermediate **measuring system** calibrated by the primary standard and assigning a **measurement result** to the secondary standard.

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5.6 [VIM3: 5.6; VIM2: 6.6; VIM1: 6.08]
reference measurement standard

reference standard

measurement standard designated for the **calibration** of other measurement standards for **quantities** of a given kind in a given organization or at a given location

5.7 [VIM3: 5.7; VIM2: 6.7; VIM1: 6.09]
working measurement standard

working standard

calibrator

measurement standard that is used routinely to calibrate or verify **measuring systems**

Deleted: **measuring instruments** or

NOTE 1 A working standard is usually calibrated with respect to a **reference standard**.

NOTE 2 When a working standard is used for **verification**, it is sometimes called “check standard” or “control standard”.

NOTE 3 The term “calibrator” is often used in the context of **calibration** in manufacturing, chemistry, and laboratory medicine.

5.8 [VIM3: 5.8; VIM2: 6.9; VIM1: 6.11]
travelling measurement standard
travelling standard

measurement standard designed for transport between different locations

EXAMPLE Portable battery-operated caesium-133 frequency measurement standard.

NOTE The standard is sometimes of special, robust construction.

5.9 [VIM3: 5.9; VIM2: 6.8; VIM1: 6.10]
transfer measurement device
transfer device

device used as an intermediary to compare **measurement standards**

NOTE Measurement standards are sometimes used as transfer devices.

5.10 [VIM3: 5.10]
intrinsic measurement standard
intrinsic standard

measurement standard based on an inherent and reproducible property of a phenomenon or substance

EXAMPLE 1 Triple-point-of-water cell as an intrinsic standard of thermodynamic temperature.

EXAMPLE 2 Intrinsic standard of electric potential difference based on the Josephson effect.

EXAMPLE 3 Intrinsic standard of electric resistance based on the quantum Hall effect.

EXAMPLE 4 Sample of pure copper as an intrinsic standard of electric conductivity.

NOTE 1 The **value** of the relevant property of an intrinsic standard is assigned by consensus and does not need to be established by relating it to another standard of the same type. Its **measurement uncertainty** is determined by considering two components: the first associated with its value assigned by consensus and the second associated with its construction, implementation, and maintenance.

NOTE 2 An intrinsic standard usually consists of a system produced according to the requirements of a consensus procedure and subject to periodic **verification**. The consensus procedure may contain provisions for the application of **corrections** necessitated by the implementation.

NOTE 3 Intrinsic standards that are based on quantum phenomena usually have superior **stability** compared to those based on material properties.

NOTE 4 The adjective "intrinsic" does not mean that such a measurement standard may be implemented and used without special care or that such a standard is immune to internal and external influences.

5.11 [VIM3: 5.13; VIM2: 6.13; VIM1: 6.15]
reference material
RM

material, sufficiently homogeneous and stable with respect to one or more specified properties, which has been established to be fit for its intended use in **measurement** or in **examination**

NOTE 1 For a reference material to be used as a **measurement standard** for **calibration** purposes it needs to be a **certified reference material**.

NOTE 2 Reference materials can be used for **measurement precision** evaluation and for quality control.

EXAMPLE Human serum without an assigned quantity value for the amount-of-substance concentration of the inherent cholesterol, used for quality control.

NOTE 3 Properties of reference materials can be **quantities** or **nominal properties**.

NOTE 4 A reference material is sometimes incorporated into a device.

EXAMPLE Spheres of uniform size mounted on a microscope slide.

NOTE 5 Some reference materials have assigned values in a **unit** not defined in the **SI**. Such materials include vaccines to which International Units (IU) have been assigned by the World Health Organization.

NOTE 6 ISO Guide 30 has an analogous definition ([11], definition 2.1.1) but uses the term "measurement process" to

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refer to both measurement and examination.

5.12 [VIM3: 5.14; VIM2: 6.14; VIM1: 6.16]
certified reference material

CRM

reference material (RM), characterized by a metrologically valid procedure for one or more specified properties, accompanied by an RM certificate that provides the values of the specified properties, associated **measurement uncertainties** or **examination reliability**, and statements of **metrological traceability** or **examination traceability**

NOTE 1 Metrologically valid approaches for the characterization of RMs are given in ISO 17034 [20].

NOTE 2 Certified reference materials are often intended for **calibration** or for assessing **measurement trueness**.

EXAMPLE Human serum with assigned certified value for the substance concentration of total cholesterol with associated **uncertainty** and a statement of metrological traceability in an accompanying certificate, used for calibration of in-vitro diagnostic assays.

NOTE 3 ISO Guide 30 has an analogous definition ([11], definition 2.1.2), but uses the term "metrological traceability" as being related to both **measurement** and **examination**.

5.13 [new]
certified value of a CRM

value, assigned to a property of a **certified reference material** (CRM) that is accompanied by a **measurement uncertainty** or **examination reliability** and a statement of **metrological traceability** or **examination traceability** identified as such in the RM certificate

NOTE 1 For a **reference material** to be used as a **measurement standard** for **calibration** purposes it needs to be a certified reference material.

NOTE 2 The value mentioned in the definition is either a value of a **quantity** or a value of a **nominal property**.

NOTE 3 ISO Guide 30 has an analogous definition ([11], definition 2.2.3), for 'certified value', but uses the term "metrological traceability" as being related to both **measurement** and **examination**.

5.14 [VIM3: 5.15]
commutability of a reference material

property of a **reference material**, demonstrated by the closeness of agreement between the relation among the **measurement results** for a stated **quantity** in this material, obtained according to **measurement procedures** for which the material is intended for use, and the relation obtained among the measurement results for other specified materials

NOTE 1 The reference material in question is usually a **calibrator** and the other specified materials are usually routine samples.

NOTE 2 ISO 15193 [16] recommends that if an internationally recognized reference measurement procedure for the measurand exists, it should be included in commutability investigation.

NOTE 3 In clinical chemistry, manufacturers' working calibrator(s) and end-user calibrator(s) are not typically required to be commutable, but their capacity for transferring **trueness** from a commutable reference material used as a higher order calibrator to the **values** assigned to clinical samples using an end-user measurement procedure must be assured.

5.15 [VIM3: 5.16]
reference data

data related to a property of an object, or to a system of components of known composition or structure, obtained from an identified source, critically evaluated, and verified for accuracy

EXAMPLE Reference data for solubility of chemical compounds as published by IUPAC [28].

NOTE "Data" is a plural form, "datum" is the singular. "Data" is commonly used in the singular sense, instead of "datum".

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5.16 [VIM3: 5.17]
standard reference data

reference data issued by a recognized authority

EXAMPLE 1 **Values** of the fundamental physical constants, as regularly evaluated and recommended by CODATA of the International Science Council (ISC) [2].

EXAMPLE 2 Relative atomic mass values, also called atomic weight values, of the elements, as evaluated every two years by IUPAC [27].

5.17 [VIM3: 2.39; VIM2: 6.11; VIM1: 6.13]
calibration

process carried out on a **measuring instrument** or a **measuring system** that, under specified conditions

1. establishes a relation between the **values** with **measurement uncertainties** provided by **measurement standards** and corresponding **indications** with associated measurement uncertainties and
2. uses this information to establish a relation for obtaining a **measurement result** from an indication

NOTE 1 The objective of calibration is to provide **metrological traceability** of measurement results obtained when using a calibrated measuring instrument or measuring system.

NOTE 2 The relation for obtaining a measurement result from an indication may be expressed by a statement, **calibration function**, **calibration diagram**, calibration curve, or calibration table, accompanied by a statement of measurement uncertainty if not already provided. In some cases, it may consist of an additive or multiplicative **correction** of the indication with associated measurement uncertainty.

NOTE 3 Calibration should not be confused with **adjustment of a measuring system**, often mistakenly called "self-calibration", nor with **verification** of calibration. Calibration is sometimes a prerequisite for, or sometimes used for, verification, which provides confirmation that specified requirements (often **maximum permissible errors**) are met. Calibration is sometimes also a prerequisite for **adjustment**, which is the set of operations carried out on a measuring system such that the system provides prescribed indications corresponding to given values of **quantities** being measured, typically obtained from measurement standards.

NOTE 4 A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the value and measurement uncertainty attributed to one of the measurement standards.

NOTE 5 Sometimes the first step alone of the operation mentioned in the definition is intended as being calibration. The second step is in fact required to establish **instrumental uncertainty** for the measurement results obtained when using the calibrated measuring system. The two steps together aim to demonstrate the metrological traceability of measurement results obtained by a calibrated measuring system. In the past the second step was usually considered to occur after the calibration.

5.18 [VIM3: 4.31]
calibration function

calibration curve

functional relation between **indications** and corresponding **measured values**

NOTE The functional relation mentioned in the definition is defined, in an inverse fashion, from the first step of calibration, where indications are related to values of quantities of **measurement standards**. Sometimes the function is defined by curve-fitting discrete pairs of indications and values of quantities of measurement standards.

5.19 [VIM3: 4.30]
calibration diagram

graphical expression of the relation between **indication** and corresponding **measurement result**

NOTE 1 A calibration diagram is the strip of the plane defined by the axis of the indications and the axis of **measured**

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values, that represents the relation between an indication and a set of measured values. A one-to-many relation is given, and the width of the strip for a given indication provides the **instrumental uncertainty** within specified **operating conditions**.

NOTE 2 Alternative expressions of the relation mentioned in the definition include a **calibration function** and associated **measurement uncertainty**, a calibration table, or a set of calibration functions.

5.20 [VIM3: 2.40]
calibration hierarchy

sequence of **calibrations** from a reference to the final **measuring system**, where the outcome of each calibration depends on the outcome of the previous calibration

NOTE 1 **Measurement uncertainty** necessarily increases along the sequence of calibrations.

NOTE 2 The elements of a calibration hierarchy are one or more **measurement standards** and measuring systems operated according to **measurement procedures**.

NOTE 3 The reference mentioned in this definition is sometimes thought of in different ways. Probably most commonly, the reference is considered to be the definition of a **unit**, through its practical realization (for example, a realization of the definition of a unit of the **SI**; “traceable to the SI”). However, sometimes the reference is thought of as the realization itself, that is, a **quantity**. The reference could also be any measurement standard for a **quantity of the same kind** (for example, a length standard used in a machine shop for measuring lengths) or primary reference measurement procedure. In the case of **ordinal quantities**, the reference is typically a **measurement procedure** (for example, a procedure for using a hardness measurement machine to obtain values of Rockwell C hardness). The quantity that is the reference or is carried by the reference must have a **reference value** and a measurement uncertainty.

5.21 [VIM3: 2.41; VIM2: 6.10; VIM1: 6.12]
metrological traceability

property of a **measurement result** whereby the result can be related to a reference through a documented unbroken chain of **calibrations**, each contributing to the **measurement uncertainty**

NOTE 1 The reference mentioned in this definition is sometimes thought of in different ways. Probably most commonly, the reference is considered to be the definition of a **unit**, through its practical realization (for example, a realization of the definition of a unit of the **SI**; “traceable to the SI”). However, sometimes the reference is thought of as the realization itself, that is, a **quantity**. The reference could also be any **measurement standard** for a **quantity of the same kind** (for example, a length standard used in a machine shop for measuring lengths) or primary reference measurement procedure. In the case of **ordinal quantities**, the reference is typically a **measurement procedure** (for example, a procedure for using a hardness measurement machine to obtain values of Rockwell C hardness). The quantity that is the reference or is carried by the reference must have a reference value and a measurement uncertainty.

NOTE 2 Metrological traceability requires an established **calibration hierarchy**.

NOTE 3 The documentation of the chain of calibrations will normally specify the time at which the reference was used in establishing the calibration hierarchy, i.e., when the first calibration in the calibration hierarchy was performed, along with any other relevant metrological information about the reference.

NOTE 4 For **measurements** with more than one **input quantity in the measurement model**, each of the input **values** and their uncertainties should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input value, and in particular in evaluating its uncertainty, should be commensurate with its relative contribution to the measurement result.

NOTE 5 Metrological traceability of a measurement result does not ensure that the measurement uncertainty is adequate for a given purpose or that no mistakes have been made.

NOTE 6 The abbreviated term “traceability” is sometimes used for metrological traceability as well as other entities, such as sample traceability, document traceability, instrument traceability, or material traceability, where the history (“trace”) of an item/object is meant. Therefore, the full term “metrological traceability” is preferred if there is any risk of confusion.

5.22 [VIM3: 2.42; VIM2: 6.10 Note 2]
metrological traceability chain

traceability chain

sequence of **measurement standards** and **calibrations** that is used to relate a **measurement**

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result to a reference

NOTE 1 A metrological traceability chain is defined through a **calibration hierarchy**.

NOTE 2 A metrological traceability chain is used to establish **metrological traceability** of a measurement result.

5.23 [VIM3: 2.43]
metrological traceability to a measurement unit

metrological traceability to a unit

metrological traceability where the reference is the definition of a **measurement unit** through its practical realization

NOTE The term "traceability to the SI" is used for referring to metrological traceability to a unit of the **International System of Units**.

5.24 [VIM3: 2.44]
verification

provision of objective evidence that a given item fulfils specified requirements

EXAMPLE 1 Confirmation that a given **reference material** as claimed is homogeneous for the **value** and **measurement procedure** concerned, down to a measurement portion having a stated mass, where "measurement portion" is intended to refer to amount of material, of proper size, for measurement of any quantity of interest, removed from the reference material.

EXAMPLE 2 Confirmation that performance properties or legal requirements of a **measuring system** are achieved.

EXAMPLE 3 Confirmation that a **target measurement uncertainty** can be met.

NOTE 1 When applicable, **measurement uncertainty** should be taken into consideration in a verification.

NOTE 2 The item mentioned in the definition may be, for example, a process, measurement procedure, material, compound, or measuring system.

NOTE 3 The specified requirements mentioned in the definition may be, for example, that a manufacturer's specifications are met.

NOTE 4 Verification in legal metrology, as defined in International Vocabulary of Legal Metrology (VIML) [37], and in conformity assessment in general, pertains to the examination and marking and/or issuing of a verification certificate for a measuring system.

NOTE 5 Verification of a measuring system should not be confused with its **calibration**. Not every verification is a **calibration**.

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NOTE 6 In chemistry, verification of the identity of the entity involved, or of activity, requires a description of the structure or properties of that entity or activity.

NOTE 7 Verification is also defined in other standards such as ISO 17000 **[Error! Reference source not found.]** and ISO 17029 [19] which cover a broader scope of applications.

5.25 [VIM3: 2.45]
validation

verification, where the specified requirements are adequate for an intended use

NOTE 1 According to ISO/IEC 17025 [18], validation of a method may include a **verification** that measurement range, **accuracy**, the **measurement uncertainty** of the **results**, **limit of detection**, limit of quantification, linearity, **repeatability** or **reproducibility**, robustness against external influences or cross-sensitivity against interference from the matrix of the sample robustness, selectivity and specificity of a measurement method fulfil specified requirements.

Deleted: EXAMPLE A **measurement procedure**, ordinarily used for the **measurement** of mass concentration of nitrogen in water, may be validated also for measurement of mass concentration of nitrogen in human serum.

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NOTE 2 Validation is also defined in other standards such as ISO 17000 **[Error! Reference source not found.]** and ISO 17029 [19] which cover a broader scope of applications.

5.26 [VIM3: 2.46]
metrological comparability of measurement results

metrological comparability

comparability of measurement results

property of **measurement results**, for **quantities of a same kind**, where the results are

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metrologically traceable to the same reference

EXAMPLE Measurement results, for the distances between the Earth and the Moon, and between Paris and London, are metrologically comparable when they are both metrologically traceable to the same **unit**, for example the metre.

NOTE Metrological comparability of measurement results does not necessitate that the **measured values** compared be of the same order of magnitude. The same applies to the associated **measurement uncertainties**.

5.27 [VIM3: 2.47] metrological compatibility of measurement results

metrological compatibility

compatibility of measurement results

property of a set of **measurement results** for a specified **measurand**, such that the absolute value of the difference of any pair of **measured values** from two different measurement results is smaller than some chosen multiple of the **standard uncertainty** of that difference

NOTE 1 Metrological compatibility of measurement results replaces what was traditionally termed "staying within the error", as it represents the criterion for deciding whether two measurement results refer to the same measurand or not. If in a set of **measurements** of a measurand, thought to be constant, a measurement result is not compatible with the others, either the measurement was not correct (for example, its **measurement uncertainty** was assessed as being too small) or the measured **quantity** changed between measurements.

NOTE 2 Participation in interlaboratory comparison, for example by proficiency testing, can have the objective of demonstrating the metrological compatibility of measurement results.

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Deleted: NOTE 2 The measurement uncertainty associated with the difference between any pair of measured values should account for the possible correlation between random variables modeling the measurand. If such random variables are completely uncorrelated, the standard uncertainty of their difference is equal to the root mean square sum of their standard uncertainties, while it is lower for positive covariance or higher for negative covariance. ...

6 Nominal properties and examinations

6.1 [VIM3: 1.30]
nominal property

qualitative property

property for which comparability only by equivalence applies

NOTE 1 Nominal properties can be general nominal properties or individual nominal properties, as exemplified in the following table.

General nominal property	Individual nominal property
shape	shape of a given piece of metal
type of chemical element	type of a chemical element in a given sample
type of amino acid	type of amino acid in a specific position of a given protein
taxon	taxon of fish in a given sample
sequence variation	variation of DNA sequence in the gene of a given person in relation to a reference sequence
ABO blood group	ABO blood group of a given person

NOTE 2 Equivalence is a relation ≈ that is reflexive (for any property P_i, $P_i \approx P_i$), symmetric (for any two comparable properties P_i and P_j, if $P_i \approx P_j$ then $P_j \approx P_i$), and transitive (for any three comparable quantities P_i, P_j, and P_k, if $P_i \approx P_j$ and $P_j \approx P_k$ then $P_i \approx P_k$).

NOTE 3 Any individual nominal property is an instance of a general nominal property, so that for example sodium is a type of chemical element. Individual nominal properties that are instances of the same general nominal property are comparable, and are said to be **nominal properties of the same kind**.

NOTE 4 Nominal properties are distinguished from **quantities**, which are properties that can be compared in terms of being greater or lesser.

NOTE 5 In some contexts, but not in this Vocabulary, the term “qualitative property” is used to refer to ordinal quantities.

6.2 [new]
nominal properties of the same kind

nominal properties that are comparable with each other

EXAMPLE 1 Cube, prism, and pyramid are examples of nominal properties of the same kind, *shape*, that can be compared by equivalence with each other.

EXAMPLE 2 Iron, carbon, and magnesium are examples of nominal properties of the same kind, *type of elements of nature*, that can be compared by equivalence with each other.

EXAMPLE 3 Methionine, cysteine, and cysteine are examples of nominal properties of the same kind, *type of amino acids*, that can be compared by equivalence with each other.

6.3 [new]
reference nominal property

nominal property identified and adopted by convention for empirically comparing it with other **nominal properties of the same kind**

EXAMPLE The specific oligosaccharides which distinguish a nominal property in the ABO blood group system, with the value A.

6.4 [new]
nominal scale

function from a set of **reference nominal properties of the same kind** to a set of identifiers, where the function preserves the information of comparison about such **nominal properties**

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Deleted: 4 …n some contexts, but not in this Vocabulary, the term “qualitative property” is used to refer to nominal properties are also called “qualitative properties…rdinal quantities”

Deleted: NOTE 5 Light of a given wavelength is perceived as a colour, so that such a colour can be considered as a quantity, at least an **ordinal quantity** because the ratio of two colours has no physical meaning. Other colours are nominal properties, because they cannot be obtained by the perception of a monochromatic light and cannot be totally ordered.

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EXAMPLE 1 {A, B, AB, O} is a set of identifiers for the blood groups in the ABO system.

EXAMPLE 2 {GG, GA, AA} is the set of possible nucleotide sequence variations corresponding to either homozygous, heterozygous, or no substitution respectively of G for A at position c.*97 in the mRNA (NM_000506.5) of the F2 gene that codes for human prothrombin.

6.5 [new]
value of a nominal property

value

individual **nominal property** identified in a set of **reference nominal properties of the same kind**

EXAMPLE 1 For shape, cube is a value in the set {cube, prism, pyramid, other shape}.

EXAMPLE 2 For taxon of bone fishes, the species *Pollachius virens* is a value in the set of the fish species according to an established taxonomy system.

EXAMPLE 3 NM_000506.5(F2):c.[*97=];[*97G>A] is the value of the sequence variation corresponding to a heterozygous substitution of G for A at position c.*97 in the mRNA (NM_000506.5) of human prothrombin encoded by the F2 gene.

EXAMPLE 4 For colour, as found in anthropological surveys to be in wide use across cultures, white is a value in the set {white, black, red, green, yellow, blue, brown, grey, orange, purple, and pink} (IEC 60050-845 [6]).

EXAMPLE 5 For blood group in the ABO system, A is a value in the set {A, B, AB, O}.

NOTE 1 Values of nominal properties are not names or terms. In Example 1, where X = {cube, prism, pyramid, other shape} is the set of possible values, a value of shape (in X) is cube, which is an identifier of a geometrical entity, not the term "cube" as such. Indeed, the same value may be designated by the term "cube" in English and in French, and other terms in other languages.

NOTE 2 The term "value" in the phrase "value of a nominal property" is intended in analogy with its use in "value of a quantity". In this sense, the fact that the shape of a given object is cube, and that the considered set of possible values of shape is X = {cube, prism, pyramid, other shape}, can be written "shape(object) = sphere in X" in analogy with the fact that the length of that object is 1.23 m can be written "length(object) = 1.23 m". Hence, values are not necessarily quantitative.

NOTE 3 The set of possible values of a nominal property may be revised, for example with the introduction of new elements, as a result of an **examination**.

6.6 [new]
reference value of a nominal property

value of a nominal property used as a basis for comparison with values of **nominal properties of the same kind**

NOTE 1 A reference value of a nominal property can be a true value of a nominal property of an examinand, in which case it is unknown, or a conventional value of a nominal property, in which case it is known.

NOTE 2 The term "reference value of a nominal property" and the definition has been adapted, from [36] entry 3.3.

6.7 [new]
examination of a nominal property

examination

classification

qualitative analysis

process of experimentally obtaining one or more **values** that can reasonably be attributed to a **nominal property** together with any other available relevant information

EXAMPLE 1 Examination of the taxon of a fish as determined by a sample of its mitochondrial DNA.

EXAMPLE 2 Examination of a sequence variation at position NM_000506.5(F2):c.*97G>A of the human prothrombin gene (F2) as determined from a sample of nuclear DNA.

EXAMPLE 3 Examination of erythrocyte antigens A and B by observation and interpretation of agglutination reactions of erythrocytes towards antibodies to A and B antigen respectively.

EXAMPLE 4 Examination of morphologic appearance of thin slices of tissue collected in a biopsy of the tumour.

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EXAMPLE 5 Examination of the iris colour of the eyes of a person.

NOTE 1 The nominal property mentioned in the definition is an individual nominal property that is identified as the property of a given object.

NOTE 2 The relevant information mentioned in the definition may be about the **reliability** of the values obtained by the examination, such that some may be more representative of the **examinand** than others.

NOTE 3 In some cases an examination is performed through intermediate stages, which are **measurements** and whose results are used to obtain the examination result.

NOTE 4 Examination is an experimental process in the sense that it requires an empirical component and a computational (informational) component and the use of models and calculations that are based on conceptual considerations.

NOTE 5 Some other terms for referring to examinations are “evaluation”, “characterization”, “inspection”, “determination”, “identification”, “testing”, and “qualitative testing”.

NOTE 6 In ISO 15189 [15] the term “examination” is also used for referring to measurement, while the term in this vocabulary refers only to nominal properties.

NOTE 7 Recognizing that the definition of value of a nominal property has been modified, the term “examination” has been taken, and the definition has been adapted, from [36] entry 2.6.

6.8 [new]
examinand

nominal property intended to be examined

NOTE 1 The nominal property mentioned in the definition is an individual nominal property.

EXAMPLE 1 The taxon of a given bone fish.
EXAMPLE 2 The erythrocyte surface antigen within the ABO system for blood from a given person.

NOTE 2 The examinand may be different from the nominal property which interacts with the examining system due to changes of the object bearing the property during the **examination**.

EXAMPLE A drug is detected in a processed sample of blood. Under the condition of physiological pH in blood the substance appears in its salt form. Due to a different pH in the sample material the drug actually being detected is in its acid form.

NOTE 3 The term “examinand” and the definition have been taken from [36] entry 2.7.

6.9 [new]
examination principle

phenomenon serving as a basis of an **examination**

EXAMPLE 1 DNA sequencing to determine the nucleic acid sequence.

EXAMPLE 2 Agglutination reaction of red blood cells for the detection of antigens on cell surfaces by the use of antibodies of known specificity.

EXAMPLE 3 Recognition of the morphological pattern of tissue observed using light microscopy.

EXAMPLE 4 Mass spectrometry or chromatography used to identify chemical species.

NOTE 1 The phenomenon mentioned in the definition can be of a physical, chemical, or biological nature.

NOTE 2 The term “examination principle” has been taken, and the definition has been adapted, from [36] entry 2.10.

6.10 [new]
examination method

description of the general organization of operations used in an **examination**

EXAMPLE 1 DNA is extracted from a fish sample and parts of the mitochondrial cytochrome b (cyt b) gene amplified by PCR. The amplified DNA is sequenced, compared to a DNA sequence, and the fish taxon is assigned.

EXAMPLE 2 Nuclear DNA is extracted from a blood sample, the genetic region encompassing NM_000506.5(F2):c.*97G>A is amplified using PCR. The genotype result is compared to three reference samples, representative of the three possible genotypes at the position - wildtype, heterozygous or homozygous mutant.

EXAMPLE 3 A suspension of erythrocytes is mixed with solutions containing antibodies to A-antigen and B-antigen respectively. The agglutination, or absence of agglutination, of cells is recorded and interpreted.

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EXAMPLE 4 Observation of morphology by light microscopy of thin slices of tissue mounted on glass plates, stained by a combination of hematoxylin and eosin stain and comparison for equivalence with reference images and reference descriptions with specified criteria.

NOTE 1 Referring to an examination method is insufficient to carry out an examination with prescribed **examination reliability**, but aids in formulating one or more **examination procedures**.

NOTE 2 The term "examination method" has been taken, and the definition has been adapted, from [36] entry 2.11.

6.11 [new]
examination procedure

detailed description of an **examination** according to one or more **examination principles** and to a given **examination method** and a decision rule necessary to obtain an **examination result**

NOTE 1 An examination procedure specifies the **nominal property** involved, any sampling procedure, equipment, **reference materials** needed, and the set of possible **values of a nominal property** used. The examination procedure also specifies how many **examined values** are necessary to obtain an examination result and how to evaluate the **examination reliability**.

NOTE 2 An examination procedure is intended to provide operational details and should be sufficient for a trained operator to perform an examination satisfactorily.

NOTE 3 An examination procedure can include **measurement procedures** or prescribe using **measurement results**.

NOTE 4 The term "examination procedure" has been taken, and the definition have been adapted, from [36] entry 2.12.

6.12 [new]
reference examination procedure

examination procedure, recognized by an authoritative source, and used in the process of providing **examination results** for assessing **examination reliability** of **values** obtained from other examination procedures for **properties of the same kind**

NOTE 1 Reference examination procedures are often used in **examination calibration** and in attributing values to properties of **reference materials**.

NOTE 2 The term "reference examination procedure" and the definition have been adapted from [36] entry 4.4.

6.13 [new]
examination result

result of examination

set of **values** being attributed to an **examinand** together with any other available relevant information

EXAMPLE Set of characters in a given alphabet, each of them with a probability of recognition, reporting the result produced by an **examining system** aimed at recognizing a given character written on a given page.

NOTE 1 An examination result sometimes contains relevant information about the set of values of the **nominal property**, such that some may be more representative of the examinand than others. This may be reported by a probability distribution over the set of values, from which **examination reliability**, and therefore the risk of misclassification, can be evaluated.

NOTE 2 In some cases an examination result is a single **examined value**, together with some information about its examination reliability, as a risk of misclassification. Sometimes no explicit information about examination reliability is provided, when the risk of misclassification is negligible for the intended use.

EXAMPLE 1 The fish in a given sample is of the species *Pollachius virens*, with a given risk of misclassification.
EXAMPLE 2 The prothrombin gene in the DNA of a given person has the sequence variation NM_000506.5(F2):c.[*97=];[*97G>A], possibly with a given risk of misclassification.
EXAMPLE 3 The blood of a given person is of the blood group A within the ABO system, with a negligible risk of misclassification.

NOTE 3 The term "examination result" and the definition have been taken from [36] entry 3.4.

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6.14 [new]
examined value

value of a nominal property representing an **examination result**

NOTE 1 An examined value may be obtained indirectly through a process, which may involve examination results of other **nominal properties** or **measurement results**.

NOTE 2 The term “examined value” and the definition have been taken from [36] entry 3.5.

6.15 [new]
examination reliability

examination confidence

examination accuracy

probability that an **examined value** is the same as a **reference value of a nominal property**

NOTE 1 Examination reliability provides an indication of the quality of the **result of an examination**. It may be expressed in the form of a probability mass function. The metrological understanding of examination reliability is not well established, compared, for example, with **standard measurement uncertainty** and has to be agreed upon. Without such agreement the degree of belief in an examination result is often reported using an ordinal scale, for example “weak”, “fair”, “strong”, or “very strong” evidence. Requirements for examination reliability, for example in conformity assessment of **nominal properties** have to be stated for each case (see JCGM 106 [33]).

EXAMPLE 1 A tumour in urine bladder is categorized as urothelial type cancer with a stated examination reliability.

EXAMPLE 2 For the nominal property shape, and with the set of possible **reference values of a nominal property** {cube, prism, pyramid, other shape} and the reference value being cube, having repeated the **examination** of the shape of a given object five times, one of the examined values is prism, and the others are cube, the examination reliability of the examined value cube is 4/5 = 0.8.

NOTE 2 The definition has been adapted from [36] entry 3.8, where the term “examination trueness” is used.

6.16 [new]
examining system

set of one or more devices and other components used for **examination** of a **nominal property**

NOTE 1 The components mentioned in the definition may include reagents and supplies.

NOTE 2 The human sensory system can support the operation of an examining system.

NOTE 3 The term “examining system” has been taken, and the definition have been adapted from [36] entry 2.8.

6.17 [new]
examination standard

realization of the definition of a **nominal property**, with stated **value** and associated **examination reliability**, used as a reference

NOTE 1 An examination standard can be, for example, a **reference material**, a classification algorithm, or a class in a classification system.

EXAMPLE 1 EURM-020 is a certified reference material consisting of *Hippoglossus hippoglossus* (Atlantic halibut) fish powder from which the DNA can be extracted and used for fish identification methods using DNA-based techniques. During the certification process of EURM-020 it was proven that its DNA matches with multiple DNA sequences deposited in a database, which are linked to official vouchers of the well described fish species.

EXAMPLE 2 Reagents used for the identification of A and B antigen are CE marked according to the Regulation (EU) 2017/746 [3] and have the minimal potency as defined by WHO [38].

NOTE 2 The term “examination standard” and the definition has been taken from [36] entry 4.1.

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6.18 [new]
examination calibration

process that confers to an **examining system** the capability to provide **values of a nominal property**, and the **examination reliability** of each value, after having used the examining system with one or more **examination standards** under specified conditions

EXAMPLE 1 Process of enabling an examining system, using standardized procedures, for tissue staining used in light microscopy, in such a way that examined values for tumour type agree between qualified examiners and with given classifications.

EXAMPLE 2 Process of enabling an examining system to Identify the type of amino acids introduced into the system using a mass-spectrum based on mass of molecules and their fragments, as known from reference data.

EXAMPLE 3 Process of enabling an examining system, made of both an optical system and an artificial neural network, to identify the characters written on a given page, as selected from a given alphabet.

NOTE 1 An examining system to be calibrated can include a software system.

NOTE 2 The objective of examination calibration is to provide **examination traceability** of **examination results** obtained when using a calibrated examining system.

NOTE 3 The term "examination calibration" has been taken, and the definition has been adapted, from [36] entry 4.3.

6.19 [new]
examination traceability

property of an **examination result** whereby the result can be related to a reference through a documented unbroken chain of **examination calibrations**, each affecting the **examination reliability**

EXAMPLE 1 The examination result, which is the species *Pollachius virens*, with a given risk of misclassification, is traceable to a database of fish species, as concluded from a comparison of the obtained DNA sequence from a sample of the fish with the DNA sequences in that database where all materials and procedures have been validated for the purpose of traceability.

EXAMPLE 2 The examination result, which is A for an erythrocyte antigen within the ABO system, with a given risk of misclassification sufficiently low for patient safety, is traceable to the current classification of blood group systems as described by International Society of Blood Transfusion (ISBT) [10] where all reagents and procedures are validated and fulfil the specifications given by the European Commission [4].

NOTE 1 The reference mentioned in this definition might be thought of in different ways. One type of reference is an authenticated sample with a **reference value of a nominal property**. The reference could also be a **reference examination procedure** where the procedure has been established for providing **reference values of a nominal property**.

NOTE 2 The term "examination traceability" has been taken, and the definition has been adapted, from [36] entry 3.21.

6.20 [new]
comparability of examination results

property of **examination results**, for **nominal properties** of a given kind, where the results are traceable to the same reference

EXAMPLE 1 Examination results for eye colours of two different persons are comparable when they are both performed by trained examiners referring to the same classification system as a **nominal scale**.

EXAMPLE 2 Examination results belonging to the same blood group system and nominal scale are comparable.

NOTE The term "comparability of examination results" and the definition have been adapted from [36] entry 3.22.

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Annex: Significant changes with respect to the VIM3

This Annex introduces and justifies the most significant changes introduced in this edition of the VIM (VIM4) with respect to the previous edition (VIM3, [34]). For each change, a summary explanation of the reasons that led to the change is provided. Content-related changes are presented first, followed by changes in the structure of chapters, while the last section mentions all other significant changes. The first sections are organized into short sub-sections, one for each change or coordinated set of changes. For the reader's convenience, each sub-section begins with a table in which the relevant VIM3 and VIM4 texts are quoted and the changes highlighted.

Main content-related significant changes

Entry about metrology

VIM4 term and definition	VIM3 term and definition
2.2 metrology science of measurement and examination, and their applications	2.2 metrology science of measurement and its application

One of the most significant changes of the VIM4 with respect to the VIM3 is the inclusion of a chapter with several new entries about nominal properties and their examination, thus under the acknowledgement that metrology is still evolving and its scope is broadening. The observation that today most, if not all, National Metrology Institutes deal also with nominal properties and their examinations was considered a sufficient justification to expand the scope of metrology, and so the VIM4 encompasses them. However, considering this transitional stage, the adjective "metrological" has usually been maintained with its traditional meaning, thus referring to measurement-related entities only, as in the example of "metrological traceability".

Entries about quantity

VIM4 terms and definitions	VIM3 terms and definitions
1.1 quantity property for which comparability by ratio, or by difference, or by order applies 1.2 quantities of the same kind quantities that are comparable with each other	1.1 quantity property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference 1.2 kind of quantity aspect common to mutually comparable quantities
1.3 ratio quantity quantity for which comparability by ratio applies 1.4 interval quantity quantity for which comparability by difference but not by ratio applies 1.33 ordinal quantity quantity for which comparability by order and equivalence only applies	1.26 ordinal quantity quantity, defined by a conventional measurement procedure, for which a total ordering relation can be established, according to magnitude, with other quantities

	of the same kind, but for which no algebraic operations among those quantities exist
6.1 nominal property property for which comparability only by equivalence applies	1.30 nominal property property of a phenomenon, body, or substance, where the property has no magnitude

It is widely acknowledged that the term “quantity” is used with two related but distinct meanings: for example, it is accepted both that mass is a quantity (like when it is considered that mass is a base quantity in the International System of Quantities) and that any given mass is a quantity (like when it is considered that a measurand, such as the mass of a given object, is a quantity). On this matter the three previous editions of the VIM provide differing accounts:

– VIM1: “The term “quantity” may refer to a quantity in a general sense or to a specific quantity.” ([25] 1.01, Note 1);

– VIM2: “The term quantity may refer to a quantity in a general sense or to a particular quantity.” ([26] 1.1, Note 1);

– VIM3: “The generic concept ‘quantity’ can be divided into several levels of specific concepts ... These are generic concepts for the individual quantities …” ([34] 1.1, Note 1).

Hence, in the example above, mass would be called a “quantity in the general sense” (VIM1 and VIM2) and a given mass would be called a “specific quantity” (VIM1), or a “particular quantity” (VIM2), or an “individual quantity” (VIM3). Whether the definition of ‘quantity’ in the previous editions of the VIM is about the first or the second concept, or possibly both, remained implicit.

Furthermore, in order to highlight the distinction between the two meanings of “quantity” the VIM3 introduced an entry for ‘kind of quantity’, related to comparability of (individual) quantities and used in the sense ‘to be of the same kind as’ and ‘to be a given kind’: for example, the mass of an object and the mass of another object are said to be (individual) quantities of the same kind, their common kind being the quantity (in the general sense) mass.

With the aim of making this key concept clearer, while maintaining the traditional lexicon that uses “quantity” with both meanings, and thus maintaining terms that are as simple as possible, the VIM4 has one generic definition of ‘quantity’, explicitly encompassing both general quantities and individual quantities, and uses the qualified terms, “general quantity” or “individual quantity” whenever appropriate to avoid the ambiguity (for example in the entry about ‘system of quantities’ (1.5) Note 1 says “The quantities mentioned in the definition are general ratio or interval quantities.”). The same principle is applied to ‘ordinal quantity’ and ‘nominal property’, and to the newly added concepts ‘ratio quantity’ and ‘interval quantity’.

This change also solves the problem created in the VIM3 by the concept ‘magnitude’, which was introduced in the definition of ‘quantity’ to avoid the substantial circularity of the definitions in the VIM1 and the VIM2 (“attribute of a phenomenon, body or substance, which may be distinguished qualitatively and determined quantitatively”), where then ‘quantity’ was defined in terms of a quantitative determination. Three problems were identified regarding the undefined concept ‘magnitude’:

– according to the VIM3 quantities are properties that have a magnitude, but it is ambiguous whether what is referred to as having magnitudes are general or individual properties (e.g., does mass have a magnitude or does any given mass have a magnitude?), the two meanings being clearly different;

– contrary to the idea that (general or individual) quantities have magnitude, a different position is sometimes taken that magnitudes are quantities that vary in a continuous way, in contrast with multitudes, which are quantities that vary in a non-continuous way: accordingly, the relation between ‘magnitude’ and ‘quantity’ is that magnitudes are quantities, not that quantities have magnitudes; clearly, this is a source of possible confusion;

– the term “magnitude” is difficult to translate in some languages, and even the official French text of the VIM3 has the following definition for ‘quantity’ (“grandeur”), “*propriété d’un phénomène, d’un corps ou d’une substance, que l’on peut exprimer quantitativement sous forme d’un nombre et d’une référence*” (translated as “property of a phenomenon, body, or substance, where the property can be expressed quantitatively as a number and a reference”), in which a reference to ‘magnitude’ does not appear.

From this perspective, with an explicit reference to the conditions of invariance of comparison the five coordinated concepts now have an operational definition:

– quantities: comparability by ratio, or by difference, or by order;

– ratio quantities: comparability by ratio;

– interval quantity: comparability by difference but not by ratio;

– ordinal quantities: comparability by order and equivalence only;

– nominal properties: comparability only by equivalence.

Entries about scale

VIM4 terms and definitions	VIM3 terms and definitions
1.23 measurement scale function from a set of reference quantities of the same kind to a set of identifiers, where the function preserves the information of comparison about such quantities 1.34 ordinal scale measurement scale that preserves the information of comparison by order and equivalence only 6.4 nominal scale function from a set of reference nominal properties of the same kind to a set of identifiers, where the function preserves the information of comparison about such nominal properties	1.27 quantity-value scale *measurement scale* ordered set of quantity values of quantities of a given kind of quantity used in ranking, according to magnitude, quantities of that kind 1.28 ordinal quantity-value scale quantity-value scale for ordinal quantities 1.29 conventional reference scale quantity-value scale defined by formal agreement

The VIM3 introduced some entries about measurement scales, under the assumption that a scale is an ordered set of values. The VIM4 refines this position, by acknowledging that a measurement scale is a function from a set of reference quantities of the same kind to a set of identifiers, where, in the case of the scales for quantities having a unit, identifiers are numbers. For example, the scale of lengths in metres is a function mapping lengths to numbers, such that the metre and its multiples and submultiples are mapped to the number 1 and its multiples and submultiples. An example of an ordinal scale is the Mohs scale of mineral hardness, where the hardness of talc is associated with the ordinal identifier 1, the hardness of gypsum is associated with the ordinal identifier 2, and so on.

An analogous consideration applies to the case of nominal properties, with the difference that in this case, due to the absence of an algebraic structure among nominal properties, each nominal property of the reference set is mapped to a generic identifier instead of a number. For example, the scale of blood groups in the ABO system is a function mapping reference blood groups to the identifiers A, B, AB, O.

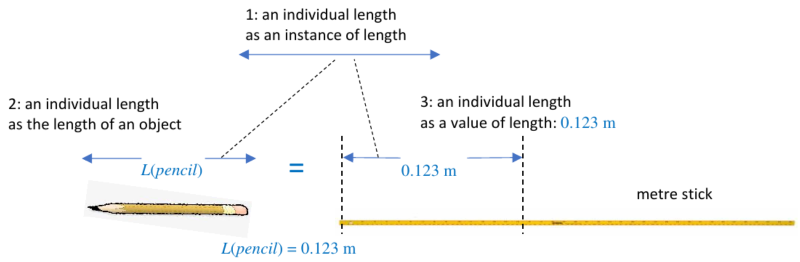
The somewhat unusual terms used in the VIM3 (“quantity-value scale” and “ordinal quantity-value scale”) are streamlined in the VIM4, as “measurement scale” and “ordinal scale” respectively. Finally, the VIM3 entry about conventional reference scales is removed, because the concept is unclear given that each scale is ultimately defined by convention, in particular the choice of the unit in the case of the scales for quantities having a unit.

Entries about value

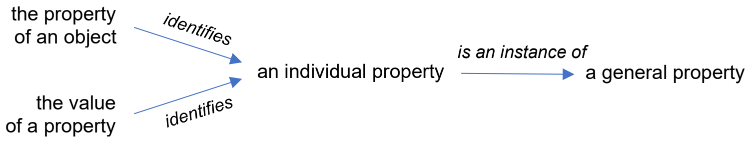
VIM4 terms and definition	VIM3 terms and definition
1.24 value of a quantity *quantity value* *value* individual quantity identified as the product of a number and a measurement unit or on an ordinal scale 1.35 value of an ordinal quantity *value* individual quantity identified on an ordinal scale 6.6 value of a nominal property *value* individual nominal property identified in a set of reference nominal properties of the same kind	1.19 quantity value *value of a quantity* *value* number and reference together expressing magnitude of a quantity

The VIM3 definition did not actually provide a superordinate for ‘value’, given that ‘number and reference’ is not a single concept. In order to fix this problem, and at the same time to provide a template for the new definitions of ‘value of an ordinal quantity’ and ‘value of a nominal property’, the new definition of ‘value of a quantity’ was chosen to be consistent with the understanding of units as individual quantities chosen by convention as reference quantities. In this sense, if, for example, the metre is a given length, the concatenation of two metres, i.e., the entity usually written “2 m”, is also a given length. This is consistent with the position, mentioned above, of avoiding any reference to the ambiguous concept ‘magnitude’.

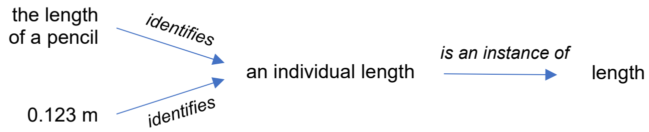
The basic idea that a value of a quantity is an individual quantity that, in the case of quantities having a unit, is identified with reference to a unit is depicted in the following figure.



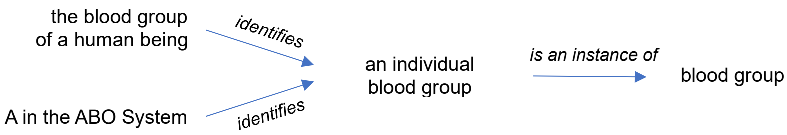
A more formal, and a bit more complete, representation is, generically:



that may easily be specified for quantities for example as:



and for nominal properties for example as:



This acknowledges that a relation like *L*(*pencil*) = 0.123 m, as in the figure above, is actually an equation. If measurement uncertainty can be neglected, such an equation is either true or false: it is true if the length of the pencil is the same as 0.123 times a length that was conventionally chosen and is called “metre”.

Essentially the same applies to values of an ordinal quantity and values of a nominal property, where in these cases no numbers are involved. Indeed, ordinal quantities have no numerical values, and the numeral in an expression of the value on some ordinal scales is not a numerical value of a quantity, but an identifier for the ordinal position of the individual quantity on the scale. For example, in the Mohs scale of mineral hardness the identifier 1 corresponds to the value 1 on the Mohs scale, which is the hardness of talc.

Moreover, in the VIM4 the more common term “value of a quantity” is accepted as the preferred term, and a Note mentions that “quantity value” may be used in order to take advantage of the adjectival use of a noun in the English language. Finally, the short term “value” is also allowed for values of ordinal quantities and nominal properties, whenever the linguistic context is sufficient to prevent the ambiguity.

Entries about measurement accuracy

VIM4 terms and definition (changes are underlined)	VIM3 terms and definition
3.15 measurement accuracy *accuracy* closeness of agreement between a measured value and a reference value of a measurand	2.12 measurement accuracy *accuracy of measurement* *accuracy* closeness of agreement between a measured quantity value and a true quantity value of a measurand
3.16 measurement trueness *trueness* closeness of agreement between the average of measured values obtained by replicate measurements and a reference value under specified conditions	2.13 measurement trueness *trueness of measurement* *trueness* closeness of agreement between the average of an infinite number of replicate measured quantity values and a reference quantity value

The role of true values in measurement in the VIM3 was based on a hybrid approach, where for example ‘measurement accuracy’ is defined as related to a true value but ‘measurement error’ as related to a reference value, which might be knowable or unknowable. In the VIM4 the general approach has been followed to adopt operational definitions whenever possible to be consistent in particular with the position of ISO 5725 [13].

Since ‘measurement accuracy’ is sometimes used in the metrology community as a knowable property, for example of measuring instruments, the VIM4 allows for this possibility by replacing “true quantity value”, as in the VIM3 definition, with “reference value”. When the reference value is a true value, measurement accuracy is usually unknown, whereas when the reference value is known, such as when it is a conventional value, then measurement accuracy is also known. For analogous reasons, in the VIM4 definition of ‘measurement trueness’ the average of measured values is no longer required to be computed on infinitely many values, as instead stated in the VIM3, and a Note has been added to highlight that the number of averaged values must be large enough to make random variability of the average negligible (and an analogous Note has also been added regarding ‘random measurement error’).

New Notes in the VIM4 highlight that measurement accuracy and measurement trueness can pertain to a measurement procedure or a measuring instrument / a measuring system, and in these cases reference values are usually known, but also to a single measured value or a set of measured values, and in these cases the reference value is a true value that is usually unknown.

Finally, the terms “accuracy of measurement” and “trueness of measurement”, admitted in the VIM3, have been removed in the VIM4 so as to minimize possible confusion that accuracy and trueness refer only to the process of measurement and not also to measurement procedures, or measuring instruments / measuring systems, or measured values.

Entries about nominal properties and their examination

VIM4 terms and definition	VIM3 terms and definition
6.1 nominal property *qualitative property*	1.30 nominal property property of a phenomenon, body, or substance, where the property has no magnitude

property for which comparability only by equivalence applies All other entries in Chapter 6	

While the VIM3 has only one entry for ‘nominal property’, a new chapter has been added to the VIM4 about nominal properties and the process of their evaluation, called “examination” as in the *Vocabulary on nominal property, examination, and related concepts for clinical laboratory sciences* (IFCC-IUPAC Recommendations 2017, [36]), from which several of new entries have been taken and adapted.

Other significant content-related changes

quantity dimension

VIM4 definition (1.9) (changes are underlined)	VIM3 definition (1.7)
<u>relation of a quantity</u> to the base quantities of a system of quantities as a product <u>of the base quantities each raised to a power</u>, omitting any proportionality factor	expression of the dependence of a quantity on the base quantities of a system of quantities as a product of powers of factors corresponding to the base quantities, omitting any numerical factor

The VIM3 definition presents dimensions as expressions, plausibly with an implicit reference to the mathematical meaning of “expression”, which is however generic. In the VIM4 the definition is phrased to emphasize that the dimension of a quantity is the relationship of the quantity to the base quantities of the chosen system of quantities, which is not a numerical equation.

quantity with unit one

VIM4 (1.10) first term (changes are underlined)	VIM3 (1.8) first term
quantity <u>with unit</u> one	quantity of dimension one

The conceptualization of the quantities traditionally called “dimensionless” is still open to debate, and not surprisingly a widely accepted term to designate them is not yet agreed. In the VIM4, the term “quantity with unit one” has been adopted instead of “quantity of dimension one”, in agreement with the use in the current (9^{th}) Edition of the SI Brochure [1]. In particular in the case of quantities whose values are obtained by counting, this choice is actually not only lexical, as it assumes a basic equation like

number of X in $Y = n$

instead of

number of entities to be specified in $Y = n\,X$

where in the former the unit is indeed implicitly 1, while in the latter the unit could be considered to be X.

Given the current lack of agreement on this subject, changes in the term or the definition are possible in the future, as explicitly acknowledged in a Note.

reference quantity

VIM4 definition (1.11)	VIM3
quantity identified and adopted by convention for empirically comparing it with other quantities of the same kind	not defined

This entry has been added to the VIM4, in acknowledgment of the importance of the concept to metrology.

International System of Units

VIM4 definition (1.19) (changes are underlined)	VIM3 definition (1.16)
system of units, based on a set of defining constants, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)	system of units, based on the International System of Quantities, their names and symbols, including a series of prefixes and their names and symbols, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)

An explicit reference has been introduced to highlight the fact that in its recent revision the SI now is based on defining constants. Furthermore, in the SI the names of the units and the prefixes are different in different languages, for example “kilogram” in English, “kilogramme” in French. To avoid possible misinterpretation that these differences imply that there are different systems, the reference to such names has been removed in the VIM4 definition. The rules mentioned in both definitions can be considered to include the names and symbols of the units and the prefixes: a Note has been expanded to make this explicit.

true value of a quantity

VIM4 (1.26) definition	VIM3 (2.11) definition
value of a quantity of a given object such that the equation relating the quantity and the value is true	quantity value consistent with the definition of a quantity

According to the VIM3 definition, the relationship that characterizes a true value is that between the value of a quantity and the definition of the quantity. This was considered unclear and contrary to the basic idea that a quantity “cannot be specified by a value but only by a description” (as in the GUM [30], D.1.1). Hence, the VIM4 definition has been rephrased to state that a value is true if the equation (quantity = value) is true, where the quantity could be the measurand, as it is defined.

measurement

VIM4 definition (2.1) (changes are underlined)	VIM3 (2.1) definition
process of experimentally obtaining one or more values that can reasonably be attributed to a quantity together with any other available relevant information	process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

The expression “together with any other available relevant information” has been added to the VIM4 definition to align it with the definition of ‘measurement result’ (“set of values being attributed to a measurand together with any other available relevant information”). In this way, the basic message that measurement is the process that produces measurement results is conveyed more clearly.

primary method of measurement

VIM4 definition (2.6)	VIM3
measurement method used to obtain a measurement result without reference to a measurement standard for a quantity of the same kind	not defined

This entry has been added to the VIM4, in acknowledgment of the importance of the concept to metrology.

correction

VIM4 definition (2.17) (changes are underlined)	VIM3 definition (2.53)
quantity, in a measurement model, compensating for an estimated systematic error	compensation for an estimated systematic effect

The definition has been rephrased to make it clear that the corrections are intended to be quantities, i.e., what is used for correcting, and not the actions to be performed. Moreover, the ambiguous term “systematic effect” has been changed to “systematic error”.

definitional uncertainty and target uncertainty

VIM4 definition (3.2) (changes are underlined)	VIM3 definition (2.27)
lower bound of measurement uncertainty resulting from the finite amount of detail in the definition of a measurand	component of measurement uncertainty resulting from the finite amount of detail in the definition of a measurand

VIM4 definition (3.3) (changes are underlined)	VIM3 definition (2.34)
upper limit of measurement uncertainty decided on the basis of the intended use of measurement results	measurement uncertainty specified as an upper limit and decided on the basis of the intended use of measurement results

These definitions have been rephrased to make it clear that neither definitional uncertainty not target uncertainty are components of measurement uncertainty.

coverage interval

VIM4 definition (3.12) (changes are underlined)	VIM3 definition (2.36)
interval containing the value of a measurand with a stated probability, based on the information used	interval containing the set of true quantity values of a measurand with a stated probability, based on the information available

The new definition, which is consistent with the general idea of not referring explicitly to ‘true value’ in definitions (see the related explanation in the entry about ‘measurement accuracy’), has been taken and slightly adapted from [31], 3.12.

coverage probability

VIM4 definition (3.13) (changes are underlined)	VIM3 definition (2.37)
probability that the value of a measurand is contained within a specified coverage interval	probability that the set of true quantity values of a measurand is contained within a specified coverage interval

The new definition, which is consistent with the general idea of not referring explicitly to ‘true value’ in definitions (see the related explanation in the entry about ‘measurement accuracy’), has been taken and slightly adapted from [31], 3.13.

repeatability conditions of measurement

VIM4 term and definition (3.22) (changes are underlined)	VIM3 term and definition (2.20)
repeatability conditions of measurement specified conditions of measurement where indications or measured values are obtained by replicate measurements with the same measurement method on the same or similar objects in the same laboratory by the same operator using the same measuring system within a short period of time	repeatability condition of measurement condition of measurement, out of a set of conditions that includes the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate measurements on the same or similar objects over a short period of time

The definition has been rephrased to make it clearer.

operating condition

VIM4 definition (4.19)	VIM3
state and configuration of a measuring instrument or measuring system, including its environment, when it is in operation	not defined

This entry has been added to the VIM4, in acknowledgment of the importance of the concept to metrology.

selectivity

VIM4 definition (4.24) (changes are underlined)	VIM3 definition (4.13)
property of a measuring instrument or measuring system, used with a specified measurement procedure, whereby it provides indications that are independent of quantities other than the quantity being measured but that are of the same kind as the measurand	property of a measuring system, used with a specified measurement procedure, whereby it provides measured quantity values for one or more measurands such that the values of each measurand are independent of other measurands or other quantities in the phenomenon, body, or substance being investigated

The VIM3 definition has been simplified and made more specific: in particular it acknowledges that selectivity is a property that also applies to non-calibrated instruments and as such it relates to indications, and not only to measured values.

instrumental drift

VIM4 definition (4.31)	VIM3 definition (4.21)

gradual change over time in indication of a measuring instrument due to its limited stability	continuous or incremental change over time in indication, due to changes in metrological properties of a measuring instrument

The VIM3 definition has been simplified and more explicitly connected to the lack of sufficient stability of the relevant instrument.

international measurement standard

VIM4 definition (5.2) (changes are underlined)	VIM3 definition (5.2)
measurement standard recognized by signatories to an international agreement and intended to serve worldwide and used as the basis for assigning values to other measurement standards for the kind of quantity concerned	measurement standard recognized by signatories to an international agreement and intended to serve worldwide

The VIM3 definition has been expanded to make the concept clearer.

certified reference material

VIM4 definition (5.12)	VIM3 definition (5.14)
reference material, characterized by a metrologically valid approach for one or more specified properties, accompanied by an RM certificate that provides the values of the specified properties, associated uncertainties, and statements of metrological traceability	reference material, accompanied by documentation issued by an authoritative body and providing one or more specified property values with associated uncertainties and traceabilities, using valid procedures

The new definition has been taken and adapted from [11], where the term “metrological traceability” is used as being related to both measurement and examination.

certified value of a CRM

VIM4 definition (5.13)	VIM3
value, assigned to a property of a certified reference material (CRM) that is accompanied by a measurement uncertainty or examination reliability and a statement of metrological traceability or examination traceability identified as such in the RM certificate	not defined

This entry has been added to the VIM4, in acknowledgment of the importance of the concept to metrology, by taking and adapting an analogous definition from [11], for ‘certified value’, where the term “metrological traceability” is used as being related to both measurement and examination.

calibration

VIM4 definition (5.17)	VIM3 (2.39)
process carried out on a measuring instrument, a measuring system, or a material measure that, under specified conditions 1. establishes a relation between the values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and	operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

2. uses this information to establish a relation for obtaining a measurement result from an indication	

This crucial definition has been slightly restructured to make it more understandable. A specification has been added to show that objects of calibration are measuring instruments or measuring systems.

calibration function

VIM4 definition (5.18) (changes are underlined)	VIM3 (4.31)
functional relation between indications and corresponding measured values	expression of the relation between indication and corresponding measured quantity value

The VIM3 definition uses the phrase "expression of a relation", plausibly with an implicit reference to the mathematical meaning of "expression", which is generic. In the VIM4 the definition is made more explicit, in terms of "functional relation".

New entries

The following VIM4 entries did not appear in the VIM3:

– quantities of the same kind (1.2)

– ratio quantity (1.3)

– interval quantity (1.4)

– reference quantity (1.11)

– value of an ordinal quantity (1.35)

– primary measurement method (2.6)

– operating condition (4.19)

– certified value of a CRM (5.13)

– all entries of Chapter 6 except 6.1

Deleted entries

The following VIM3 entries do not appear in the VIM4:

– kind of quantity (1.2): see the explanation in Entries about quantity;

– conventional reference scale (1.29): see the explanation in Entries about scale;

– range of a nominal indication interval (4.5): considered redundant;

– resolution of a displaying device (4.15): considered redundant;

– variation due to an influence quantity (4.22): considered redundant;

– zero error (4.28): considered redundant;

– calibrator (5.12): included as a specific case of working measurement standard (VIM4, 5.7).

Changes in the structure of chapters

The VIM entries are organized into chapters, where each chapter covers a key subject of metrology. Each new edition of the VIM was seen as an opportunity to revise and improve this structure. This process continued in the VIM4, including the addition of a new chapter about nominal properties and examinations.

The starting point was the VIM3 structure:

VIM3 structure
1 Quantities and units: 33 entries 2 Measurement: 52 entries 3 Devices for measurement: 12 entries 4 Properties of measuring devices: 28 entries 5 Measurement standards (Etalons): 17 entries

In this structure the following points were noted:

– Chapter 2 includes very diverse contents: the criterion of inclusion is not always clear;

– Chapter 3 has very specific contents: it includes entries for measuring devices but not their properties;

– Chapter 4 has very diverse contents, including a few entries about uncertainty and calibration, both defined in entries in Chapter 2;

– Chapter 5 artificially separates measurement standards from their usage, i.e., calibrations, and context, i.e., traceability chains.

According to this analysis, the following structure has been adopted for the VIM4:

VIM4 structure (*with respect to VIM3*)
1 Quantities and units: 35 entries (*no structural changes*): devoted to the characterization of quantities, both quantities having a unit and ordinal quantities, thus including units, scales, and values 2 Measurement: 17 entries (*subset of Ch 2*): devoted to the characterization of the structure of measurement, thus including measurement principle, method, procedure, and model 3 Measurement quality: 30 entries (*merged part of Ch 2 and part of Ch 4*): devoted to the characterization of the quality of measuring instruments and systems, and of measurement and its results, thus including measurement uncertainty and measurement accuracy and error 4 Measuring devices and their properties: 33 entries (*merged Ch 3 and part of Ch 4*): devoted to the characterization of measuring instruments and systems, thus including properties such as sensitivity, selectivity, resolution, and stability 5 Measurement standards (etalons) and metrological traceability: 27 entries (*merged Ch 5 and parts of Ch 2 and 4*): devoted to the characterization of metrological systems, thus including measurement standards and calibration, and what is required to guarantee the metrological traceability of the outcomes of measuring systems 6 Nominal properties and examinations: 20 entries (*new*): devoted to the characterization of nominal properties and the process of their evaluation

Other changes

– Several definitions and Notes have been simplified.

– Simpler / shorter terms have been used whenever appropriate (e.g., “value” instead of “value of a quantity” or “quantity value”).

– Explicit references to concepts have been removed (e.g., “quantities can be classified as...” instead of “the concept ‘quantity’ may be generically divided into...”).

– Terms for quantities have been formatted in italic whenever it improves the readability (e.g., “the quantity *number of entities* can be regarded...”).

– Bibliographical references have been updated and expanded.

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