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International vocabulary of basic and general terms in metrology (VIM)

Vocabulaire international des termes fondamentaux et généraux de métrologie (VIM)

[Revision of the 1993 edition, *International vocabulary of basic and general terms in metrology (VIM)*]

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Please see the administrative notes on page iii

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Draft April 2004

International Vocabulary of Basic and General Terms in Metrology (VIM)

3rd Edition

CONTENTS

FOREWORD

The evolution of the treatment of metrological uncertainty from a Classical Approach (CA) to an Uncertainty Approach (UA) necessitated reconsideration of the related definitions in the 2nd edition (1993) of the VIM . The CA took it for granted that a measurand can ultimately be described by a single true value, but that instruments and measurements do not yield this value due to additive “errors”, systematic and random. These errors had to be treated differently in “error propagation” and it was assumed that they may always be distinguished. The notions of “random uncertainty” and “systematic uncertainty” were introduced without well-founded methods of combination and interpretation. Then, instead of random and systematic uncertainties, the unifying concept of “uncertainty” in measurement was introduced, an approach acknowledged by BIPM Recommendation INC-1 (1980), on the basis of which a detailed *Guide to the Expression of Uncertainty in Measurement* (GUM) (1993, corrected 1995) was developed.

In this operational approach to the evaluation of measurement uncertainties there is a shift of perception such that the notion of error no longer plays a role. As a consequence, there is finally only one uncertainty of measurement, ensuing from various components. It characterizes the extent to which the unknown value of the measurand is known after measurement, taking account of the given information from the measurement. The concepts and terms presented in Chapters 1-5 of this 3rd edition of the VIM reflect this UA. Note that it is beyond the scope of this Vocabulary to provide details for several of the concepts applying to the UA; for such details the interested reader is requested to consult the GUM.

There are certain concepts in the 2nd edition of the VIM that apply mostly to the CA, but also reflect some aspects of the UA. These concepts are avoided in the GUM, but are nonetheless considered to be of sufficient importance and common usage to be included in this Vocabulary. They are presented in Annex A, but in such a way as to be consistent with the CA. Some additional terms pertaining to the CA are also included in Annex A.

A number of concepts which figured in the 2nd edition of the VIM no longer appear in this 3rd edition. These are concepts which can probably no longer be considered as basic or general. Some new concepts reflecting the evolution of metrology have been introduced, in particular concepts related to measurement uncertainty or measurement traceability. Also, the various aspects of measurements in chemistry as well as in physics were considered when establishing this 3rd edition. As a result, a number of examples covering the fields of measurements in chemistry and in laboratory medicine have been added.

A few definitions in this draft are marked “*preliminary definition*” for they are still under study by JCGM-WG2. Concepts figuring in both the 2nd and 3rd editions have a double reference number; the 3rd edition reference number in bold font and, in parenthesis and in light font, the earlier reference from the 2nd edition.

The definitions proposed in this 3rd edition comply as far as possible with the rules to be applied in terminology work, as outlined in standards ISO 704, ISO 1087-1, and ISO 10241. In particular, the substitution principle should apply; it is possible in every definition to replace any term defined elsewhere in the VIM by its definition without introducing contradiction or circularity. Such terms are indicated in bold font in the definitions and notes.

To facilitate the understanding of the different relations between the various concepts given here, concept diagrams have been introduced in this 3rd edition. They are given in an Informative Annex.

Chapter 1: QUANTITIES AND UNITS

1.1
(1.1)
quantity

property of a phenomenon, body, or substance, to which a magnitude can be assigned

NOTES

1 The concept ‘quantity’ can be subdivided in two levels, general concept and individual concept.

EXAMPLES

General concept (name and symbol)			**Individual concept** (name and symbol)
quantity, Q	length, l	radius, r	radius of circle A, r_A or r(A)
		wavelength, λ	wavelength of the sodium D radiation, λ_D or λ(D; Na)
	energy, E	kinetic energy, T	kinetic energy of particle i in a given system, T_i
		heat, Q	heat of vaporisation of sample i of water, Q_i
	electric charge, Q		electric charge of the proton, e
	electric resistance, R		electric resistance of resistor i in a given circuit, R_i
	amount-of-substance concentration of entity B, c_B		amount-of-substance concentration of ethanol in wine sample i, $c_i(C_2H_5OH)$
	number concentration of entity B, C_B		number concentration of erythrocytes in blood sample i, C(Erys; B_i)
	Rockwell C hardness, HRC		Rockwell C hardness of steel sample i, HRC(i)

2 Symbols for quantities are given in the International Standard ISO 31:1992, *Quantities and units*.

3 In laboratory medicine, where lists of individual quantities are presented, each designation is conventionally given in the exhaustive and unambiguous IUPAC/IFCC format “System — Component; kind-of-quantity”, where 'System' is the object under consideration, mostly having a component of special interest, and 'kind-of-quantity' (or 'kind-of-property' if nominal properties are included) is a label for general concepts such as ‘length’, ‘diameter’, and ‘amount-of-substance concentration’. An example of an individual concept under ‘quantity’ could be 'Plasma (Blood) — Sodium ion; amount-of-substance concentration equal to 143 mmol/l in a given person at a given time’.

4 A vector or a tensor can also be a quantity if all its components are quantities.

1.2
(Note 2 to 1.1)
quantities of the same kind

quantities that can be placed in order of magnitude relative to one another

NOTES

1 Quantities of the same kind within a given **system of quantities** have the same **dimension**.

2 The subdivision of quantities into quantities of the same kind is to some extent arbitrary. For example, moment of force and energy are, by convention, not regarded as being of the same kind, although they have the same dimension, nor are heat capacity and entropy.

EXAMPLES

a) All lengths, such as diameters, circumferences and wavelengths, are generally considered as quantities of the same kind.

b) All energies, such as work, heat, kinetic energy and potential energy, are generally considered as quantities of the same kind.

1.3
(1.2)
system of quantities

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

NOTE
Ordinal quantities, such as Rockwell C hardness, are usually not considered to be part of a system of quantities because they are related to other quantities through empirical relations only.

1.4
International System of Quantities
ISQ

system of quantities, together with the equations relating the **quantities,** on which the **SI** is based

NOTE
At present the ISQ is published in the International Standard ISO 31:1992, *Quantities and units*.

1.5
(1.3)
base quantity

quantity, chosen by convention, used in a **system of quantities** to define other **quantities**

NOTES
1 There exist no equations relating the base quantities of a system of quantities.

2 “Number of entities” can be regarded as a base quantity in any system of quantities.

EXAMPLE
The base quantities corresponding to the base units of the International System of Units (SI) are given in the note to 1.16.

1.6
(1.4)
derived quantity

quantity, in a **system of quantities**, defined as a function of **base quantities**

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

1.7
(1.5)
quantity dimension
dimension of a quantity
dimension

dependence of a given **quantity** on the **base quantities** of a **system of quantities**, represented by the product of powers of factors corresponding to the **base quantities**

NOTES

1 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 powers of the dimensions of the base quantities according to the definition of the derived quantity.

2 Quantities having the same dimension are not necessarily **quantities of the same kind**.

3 In deriving the dimension of a quantity, no account is taken of any numerical factor, nor of its scalar, vector or tensor character.

4 The dimension of a base quantity is generally referred to as 'base dimension', and similarly for a 'derived dimension'.

EXAMPLES

a) In the ISQ, where L, M and T denote the dimensions of the base quantities length, mass, and time, the dimension of force is LMT^{-2}.

b) In the same system of quantities ML^{-3} is the dimension of mass concentration and also of volumic mass (mass density).

1.8
(1.6)
quantity of dimension one
dimensionless quantity

quantity for which all the exponents of the factors corresponding to the base quantities in the representation of its **dimension** are zero

NOTES

1 The **values** of quantities of dimension one are simply numbers.

2 The term 'dimensionless quantity' is for historical reasons commonly used. It stems from the fact that all exponents are zero in the symbolic representation of the dimension for such quantities. However, the term 'quantity of dimension one' reflects the convention in which the symbolic representation of the dimension for such quantities is the symbol 1 (see ISO 31-0 :1992, subclause 2.2.6).

EXAMPLES

Plane angle, solid angle, linear strain, friction factor, refractive index, mass fraction, amount-of-substance fraction, Mach number, Reynolds number, degeneracy in quantum mechanics, number of turns in a coil, number of molecules.

1.9
(1.7)
unit
measurement unit

unit of measurement

scalar **quantity**, defined and adopted by convention, with which other **quantities of the same kind** are compared in order to express their magnitudes

NOTES

1 Units are designated by conventionally assigned names and symbols.

2 Units of quantities of the same **dimension** may be designated by the same name and symbol even when the quantities are not of the same kind. For example the joule per kelvin, J/K, is the name and symbol of both a unit of heat capacity and a unit of entropy, which are generally not considered to be quantities of the same kind.

3 Units of **quantities of dimension one** are simply numbers. In some cases these numbers are given special names, e.g. radian and steradian, or are expressed by quotients such as millimole per mole.

1.10
(1.18)
quantity value
value of a quantity
value

magnitude of a **quantity** represented by a number and a reference

NOTES

1 A quantity value can be expressed as:
- a product of a number and a **unit**, or
- a number for a **quantity of dimension one** (the unit one is generally not written out), or
- a reference to a **measurement procedure** and an ordinal number.

2 A quantity value can be expressed in more than one way.

EXAMPLES

a) Length of a given rod:	5.34 m or 534 cm
b) Mass of a given body:	0.152 kg or 152 g
c) Celsius temperature of a given sample:	–5 °C
d) Electric impedance of a given circuit element at a given frequency:	(7 + 3j) Ω
e) Refractive index of a given sample of glass:	1.52
f) Rockwell C hardness of a given sample (150 kg load):	HRC(150 kg) 43.5
g) Mass fraction of cadmium in copper:	3 μg/kg or 3×10^{-9}
h) Amount-of-substance content of Pb^{++} in water:	1.76 mmol/kg

1.11
(1.13)
base unit
base measurement unit

unit that is conventionally and uniquely adopted for a **base quantity** in a given **system of quantities**

NOTE

A base unit may also serve for a **derived quantity** of the same **dimension**.

Example

Rain fall, defined as areic volume (volume per area), has the metre as a coherent derived unit.

EXAMPLE

In the **ISQ** length is a base quantity, and in the SI the metre is the base unit of length. The centimetre and the kilometre are also units of length, but they are not base units in the SI.

1.12
(1.14)
derived unit

unit for a **derived quantity**

EXAMPLES

In a **system of quantities** where length and time are **base quantities**, the metre per second, symbol m/s, the kilometre per hour, km/h, and the knot, equal to one nautical mile per hour, are derived units of velocity.

1.13
(1.10)
coherent derived unit

derived unit that, for a given **system of quantities** and for a chosen set of **base units**, is a product of powers of **base units** with the proportionality factor one

NOTES

1 Coherence can be determined only with respect to a particular system of quantities and a given set of base units.

Examples

If the metre, the second, and the mole are base units, the metre per second is the coherent derived unit of velocity when velocity is defined by the **quantity equation** $\boldsymbol{v} = \mathrm{d}\boldsymbol{r}/\mathrm{d}t$, and the mole per cubic metre is the coherent derived unit of amount-of-substance concentration when amount-of-substance concentration is defined by the quantity equation $c = n/V$. The kilometre per hour and the knot, given as examples of derived units in **1.12**, are not coherent derived units in such a system.

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

3 The **coherent derived unit** for every **quantity of dimension one** in any system of quantities is the number one, symbol 1.

1.14
(1.9)
system of units

conventionally selected set of **base units** and **derived units**, and also their **multiples** and **submultiples**, together with a set of rules for their use

1.15
(1.11)
coherent system of units

system of units, based on a given **system of quantities**, in which the **unit** for each **derived quantity** is a **coherent derived unit**

NOTE
A system of units can be coherent only with respect to the **base units** and the system of equations that define the **quantities** involved.

EXAMPLES
a) The CGS system (based on the centimetre, gram, and second) in classical mechanics.

b) The International System of Units.

1.16
(1.12)
International System of Units
SI

coherent system of units based on the **ISQ**, their names and symbols, and 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)

NOTE
The SI is founded on the following seven base quantities and base units:

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

1.17
(1.16)
multiple of a unit

unit formed from a given **unit** by multiplying by an integer greater than one

EXAMPLES
a) The kilometre is a decimal multiple of the metre.

b) The hour is a non-decimal multiple of the second.

1.18
(1.17)
submultiple of a unit

unit formed from a given unit by dividing by an integer greater than one

EXAMPLES
a) The millimetre is a decimal submultiple of the metre.

b) The arc second is a non-decimal submultiple of the arc minute.

1.19
(1.20)
conventional quantity value
conventional value of a quantity
conventional value

value attributed by formal agreement to a **quantity** for a given purpose

EXAMPLES
a) Standard acceleration of free fall, g_n = 9.806 65 m s^{-2}.
NOTE
'Standard acceleration of free fall' was formerly called 'standard acceleration due to gravity'.

b) The conventional value for the Josephson constant, $K_{J\text{-}90}$ = 483 597.9 GHz V^{-1}.

1.20
(1.21)
numerical quantity value
numerical value of a quantity
numerical value

number in the representation of a **quantity value**

NOTE
For **quantities** that have a **unit**, the **numerical value** is frequently denoted $\{Q\} = Q/[Q]$, where Q is the symbol for the quantity and $[Q]$ is the symbol for the unit.

1.21
quantity equation

equation relating **quantities**

EXAMPLES
a) $Q = \zeta\, Q_1\, Q_2$, or $\{Q\}\,[Q] = \zeta\,\{Q_1\}\,[Q_1]\,\{Q_2\}\,[Q_2]$, or $\{Q\}\,[Q] = \zeta\,\{Q_1\}\,\{Q_2\}\,[Q_1]\,[Q_2]$, where $\{Q\}$, $\{Q_1\}$,and $\{Q_2\}$ denote the numerical values of the quantities Q, Q_1, and Q_2 expressed in terms of units $[Q]$, $[Q_1]$, and $[Q_2]$, respectively, and where ζ is a numerical factor.

b) $T = (1/2)\, mv^2$, where T is the kinetic energy, m is the mass, v the speed of a specified particle.

c) $n = I.t\,/\,F$ where n is the amount of substance, I the electric current, t the duration, and F the Faraday constant.

1.22
unit equation

equation relating **units**

EXAMPLES

a) $[Q] = [Q_1]\,[Q_2]$ for the quantity equation given in the first example of **1.21** under the condition that the units $[Q]$, $[Q_1]$, and $[Q_2]$ are coherent.

b) $\mathrm{J} = \mathrm{kg\ m^2\ s^{-2}}$, where J, kg, m, and s are the symbols for the joule, kilogram, metre, and second, respectively.

c) $[\rho_B] = \mathrm{g/l}$, where $[\rho_B]$ is a symbol for a unit of mass concentration of substance B, and g and l are the symbols for the gram and litre.

1.23
numerical value equation
numerical quantity value equation

equation relating **numerical quantity values**

EXAMPLES

a) $\{Q\} = \zeta\,\{Q_1\}\,\{Q_2\}$ for the quantity equation given in the first example of **1.21** under the condition that the units $[Q]$, $[Q_1]$, and $[Q_2]$ are coherent.

b) In the equation for kinetic energy of a particle, $T = (1/2)\,mv^2$, if $m = 2$ kg and $v = 3$ m/s, so that $T = 9$ J, then $9 = (1/2) \times 2 \times 3^2$ is a numerical value equation.

1.24
quantity calculus

formalism for algebraic manipulation of symbols representing **quantities**

NOTE

In this formalism, equations between quantities have the advantage over equations between numerical values of being independent of the choice of units (see ISO 31-0:1992, subclause 2.2.2).

1.25
conversion factor between units

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

EXAMPLES

a) km/m = 1000 and thus 1 km = 1000 m

b) h/s = 3600 and thus 1 h = 3600 s

c) (km/h)/(m/s) = (1/3.6) and thus 1 km/h = (1/3.6) m/s

1.26
ordinal quantity

quantity, defined by a conventional **measurement procedure**, for which a total ordering relation with other **quantities of the same kind** is defined, but for which no algebraic operations among those **quantities** are defined

NOTES

~~1~~ Ordinal quantities can enter into empirical relations only and have no **dimension**.

2 Ordinal quantities are arranged according to **conventional reference measurement scales** (see **2.34**).

EXAMPLES

a) Rockwell C hardness

b) Octane number for petroleum fuel

c) Earthquake strength on the Richter scale

Chapter 2: MEASUREMENT

2.1
(2.1)
measurement

process of experimentally obtaining information about the magnitude of a **quantity**

NOTES
1 Measurement implies a **measurement procedure**, based on a theoretical model.

2 In practice, measurement presupposes a calibrated **measuring system**, possibly subsequently verified.

2.2
(2.2)
metrology

field of knowledge concerned with **measurement**

NOTE
Metrology includes all theoretical and practical aspects of measurement, whichever the **measurement uncertainty** and field of application.

2.3
(2.6)
measurand

quantity intended to be measured

NOTES
1 The **measurement** can change the phenomenon, body, or substance under study such that the quantity that is actually measured differs from the **measurand**.

Example
The potential difference between the terminals of a battery may decrease when using a voltmeter with a significant internal conductance to perform the measurement. The open-circuit potential difference can be calculated from the internal resistances of the battery and the voltmeter.

2 Observe that this definition differs from that in VIM, 2nd Edition, Item 2.6, and some other vocabularies, that define the measurand as the quantity subject to measurement.

3 The description of a measurand requires specification of the state of the phenomenon, body, or substance under study.

2.4
(2.3)
measurement principle
principle of measurement

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

NOTE

The measurement principle can be a physical, chemical, or biological phenomenon.

EXAMPLES

a) Thermoelectric effect applied to the measurement of temperature.

b) Energy absorption applied to the measurement of amount-of-substance concentration.

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

2.5
(2.4)
measurement method
method of measurement

generic description of a logical sequence of operations used in a **measurement**

NOTES

1. Measurement methods may be qualified in various ways such as:
   - substitution measurement method
   - differential measurement method
   - null measurement method
   - direct measurement method
   - indirect measurement method

   See IEC 60050-300:2001

2. A measurement often requires the sequential or parallel use of several pieces of equipment or reagents or both. Then the measurement method consists of a short presentation of the procedural structure.

2.6
(2.5)
measurement procedure

detailed description of a **measurement** according to one or more **measurement principles** and to a given **measurement method**

NOTE

The measurement procedure is usually documented in sufficient detail to enable an operator to perform a measurement.

2.7
primary measurement procedure
primary procedure

measurement procedure used to realize the definition of a **measurement unit** and obtain the **quantity value** and **measurement uncertainty** of a **primary measurement standard**

NOTES

1 CCQM uses the term ‘direct primary method of measurement’ for this concept.

2 Definitions of two subordinate concepts, which could be termed ‘direct primary reference measurement procedure’ and ‘ratio primary reference measurement procedure’, are given by CCQM (5th Meeting, 1999).

2.8
measurement scale

ordered set of **values** of **quantities** of a given kind, continuous or discrete, used in arranging **quantities of the same kind** by magnitude

2.9
(1.22)
conventional reference measurement scale
conventional reference scale

measurement scale, defined by general agreement

NOTES

1 A conventional reference scale may be established by measurements according to a measurement procedure.

2 Ordinal quantities are arranged according to conventional reference scales (see **1.26**).

EXAMPLES

a) Rockwell C hardness scale;

b) pH scale in chemistry;

c) scale of octane numbers for petroleum fuel;

d) International Temperature Scale of 1990 (ITS-90).

2.10
(3.1)
measurement result
result of measurement

information about the magnitude of a **quantity**, obtained experimentally

NOTES

1 The information consists of a set of **quantity values** reasonably being attributed to the **measurand**, usually summarized as a single quantity value and a **measurement uncertainty**. The single quantity value is an estimate, often an average or the median of the set.

2 If the measurand is considered to be sufficiently well described by a single quantity value (see GUM, 1993, 1.2), it is common practice to have the term ‘measurement result’ comprise the estimated value only. The measurement uncertainty associated with this ‘measurement result’ is then stated separately.

3 If the measurement uncertainty is considered to be negligible for some purpose, the information may be reduced to a single quantity value. In many fields this is the most common way of expressing a measurement result.

2.11
(3.9)
measurement uncertainty
uncertainty of measurement
uncertainty

parameter that characterizes the dispersion of the **quantity values** that are being attributed to a **measurand**, based on the information used

NOTES

1 Measurement uncertainty quantitatively characterizes the knowledge about the measurand, based on the information used.

2 Measurement uncertainty characterizes the dispersion of a set or distribution of quantity values for the measurand, obtained by available information. The dispersion is due to **definitional uncertainty** of the measurand and random and systematic effects in the **measurement**.

3 If a single quantity value as an estimate of the measurand is changed, the associated measurement uncertainty may also change.

4 The parameter may be, for example, a standard deviation called **standard measurement uncertainty** (or a given multiple of it), or the half-width of an interval, having a stated coverage probability.

5 Measurement uncertainty comprises, in general, many components. Some of these components may be evaluated by **Type A evaluation of measurement uncertainty** from the statistical distribution of the quantity values from series of measurements and can be characterized by experimental standard deviations. The other components, which may be evaluated by **Type B evaluation of measurement uncertainty**, can also be characterized by standard deviations, evaluated from assumed probability distributions based on experience or other information.

6 It is understood that the quantity value of a **measurement result** is the best estimate of the value of the measurand (see Note 2 of **2.10**), and that all components of measurement uncertainty, including those arising from systematic effects, such as components associated with corrections and the assigned values of **measurement standards**, contribute to the dispersion.

7 Depending upon its intended use, an **expanded measurement uncertainty** of a measurement result may be given with a stated **coverage factor**, giving a **coverage interval** intended to contain the value of the measurand with high probability, or encompass a stated large fraction of the dispersed quantity values that are being attributed to the measurand.

2.12
definitional measurement uncertainty
definitional uncertainty

component of **measurement uncertainty** resulting from the inherently finite amount of detail in the definition of a **measurand**

NOTES

1 Any change in the descriptive detail of a measurand, through the corresponding change in the **measurement function**, produces a new measurand having a new definitional measurement uncertainty.

2 Defining the measurand is the first step of any **measurement procedure**. The ensuing definitional uncertainty can therefore be considered as a part of the measurement uncertainty.

3 The definitional uncertainty is a lower limit for the measurement uncertainty (see GUM).

2.13
Type A evaluation of measurement uncertainty
Type A evaluation

method of evaluation of a component of **measurement uncertainty** by a statistical analysis of **quantity values** obtained by **measurements** under **repeatability conditions**

NOTE
For information about statistical analysis, see the GUM.

2.14
Type B evaluation of measurement uncertainty
Type B evaluation

method of evaluation of a component of **measurement uncertainty** by means other than a statistical analysis of **quantity values** obtained by **measurement**

EXAMPLES
The component of measurement uncertainty may be:

- associated with published quantity values;
- associated with the quantity value of a **certified reference material**;
- obtained from a calibration certificate and incorporation of drift;
- obtained from the **accuracy class** of a verified **measuring instrument**;
- obtained from limits deduced through personal experience.

2.15
standard measurement uncertainty
standard uncertainty of measurement
standard uncertainty

measurement uncertainty expressed as a standard deviation

NOTE
Sometimes the standard measurement uncertainty characterizing a **measurement result** is obtained by taking into account standard measurement uncertainties and covariances of the **input quantities to the measurement function**. This standard measurement uncertainty is termed ‘combined standard uncertainty’ in the GUM.

2.16
combined standard measurement uncertainty
combined standard uncertainty

standard measurement uncertainty of the **measurement result** when that result is obtained from the **values** of a number of other **quantities**, equal to the positive square root of a sum of terms, the terms being the variances and/or covariances of the values of these other quantities weighted according to how the measurement result varies with changes in these quantities

2.17
coverage factor

number by which a **standard measurement uncertainty** of a **measurement result** is multiplied to obtain an **expanded measurement uncertainty**

2.18
expanded measurement uncertainty
expanded uncertainty

half-width of a symmetric **coverage interval**, centered around the estimate of a **quantity**, with a specified **coverage probability**

NOTES

1 Expanded measurement uncertainty is defined only for unimodal, symmetric probability density functions.

2 Expanded measurement uncertainty is termed 'overall uncertainty' in paragraph 5 of Recommendation INC-1 (1980).

3 In practice, expanded measurement uncertainty is usually a stated multiple of the **standard measurement uncertainty** of a **measurement result**.

2.19
coverage interval

interval of **values** which can be attributed to a **quantity** and, based on the available information, is associated with a stated high probability

2.20
coverage probability

probability associated with a **coverage interval**

NOTE

The coverage probability is sometimes termed 'level of confidence' (see GUM).

2.21
target measurement uncertainty
target uncertainty

measurement uncertainty formulated as a goal and decided on the basis of a specified intended use of **measurement results**

2.22
(6.11)
calibration of a measuring system

calibration

definition (a)

operation establishing the relation between **quantity values** provided by **measurement standards** and the corresponding **indications of a measuring system**, carried out under specified conditions and including evaluation of **measurement uncertainty**

definition (b)

operation that establishes the relation, obtained by reference to one or more **measurement standards**, that exists under specified conditions, between the **indication of a measuring system** and the **measurement result** that would be obtained using the **measuring system**

NOTES

1 The relations referred to in definitions (a) and (b) can be expressed by calibration diagrams, calibration functions, or calibration tables.

2 Definition (b) is consistent with the definition of 'calibration' in IEC 60050-300, item 311-01-09.

3 See NOTE to **2.28** concerning **verification**.

2.23
calibration hierarchy

sequence of **calibrations of measuring systems** between a stated metrological reference and the final **measuring system**

NOTES

1 The elements of a calibration hierarchy are one or more **measurement standards** (**calibrators**) and measuring systems operated according to **measurement procedures**.

2 For this definition, the 'stated metrological reference' can be a definition of a **measurement unit** through its practical realization, or a measurement procedure, or a measurement standard.

3 If the metrological reference of a calibration hierarchy is a measurement standard, it is always a **primary measurement standard**.

2.24
(6.10)
metrological traceability

property of a **measurement result** relating the result to a stated metrological reference through an unbroken chain of **calibrations of a measuring system** or comparisons, each contributing to the stated **measurement uncertainty**

NOTES

1 For this definition, a 'stated metrological reference' can be a definition of a **measurement unit** through its practical realization, or a **measurement procedure**, or a **measurement standard**.

2 A prerequisite to metrological traceability is a previously established **calibration hierarchy.**

3 Specification of the stated metrological reference must include the time at which the stated metrological reference was used when establishing the calibration hierarchy.

4 The abbreviated term ‘traceability’ is sometimes used for “metrological traceability” as well as for other concepts, such as “sample traceability” or “document traceability” or “instrument traceability”, where the history (‘trace’) of an item is meant. Therefore, the full term should be preferred.

5 For **measurements** with more than one **input quantity to the measurement function**, each of the input quantities should itself be metrologically traceable.

2.25
metrological traceability chain
traceability chain

chain of alternating **measuring systems** with associated **measurement procedures** and **measurement standards**, from a **measurement result** to a stated metrological reference

NOTE
A metrological traceability chain is defined through a **calibration hierarchy** from the measurement result to the stated metrological reference.

2.26
metrological traceability to a measurement unit
metrological traceability to a unit

metrological traceability of a **measurement result** to the definition of a **measurement unit** through a stated metrological traceability chain

NOTE
The phrase “traceability to the SI” is sometimes used; it means **metrological traceability to a unit** of the **International System of Units**.

2.27
verification

confirmation through examination of a given item and provision of objective evidence that it fulfils specified requirements

[modified from ISO 9000:2000, item 3.8.4]

NOTE
Verification should not be confused with **calibration** of a **measuring system**, or *vice versa*.

EXAMPLES
a) Demonstration that a given **reference material** as claimed is homogeneous down to samples having a mass of 10 mg for the **quantity** and **measurement procedure** concerned.

b) Demonstration that stated performance properties of a **measuring system** are achieved.

2.28
validation

confirmation through examination of a given item and provision of objective evidence that it fulfils the requirements for a stated intended use

[modified from ISO 9000:2000, item 3.8.5]

EXAMPLE

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

2.29
comparability of measurement results
comparability

property of **measurement results** enabling them to be compared because they are metrologically traceable to the same stated metrological reference

NOTE

Comparability does not necessitate that the **quantity values** compared are of the same order of magnitude.

EXAMPLES

a) Measurement results, for the distances from Earth to Moon and from Paris to London, are comparable when (which is often the case) they are both metrologically traceable to the same **unit**, for instance the metre.

b) Measurement results for amount-of-substance concentrations of a normal and a dangerous level of cholesterol in human serum are comparable when they are both metrologically traceable to the same unit, for instance mole per litre.

2.30
compatibility of measurement results
compatibility

property satisfied by all the **measurement results** of the same **quantity**, characterized by an adequate overlap of their corresponding sets of **quantity values**

NOTE

See IEC 60050-300:2001, item 311-01-14.

2.31
(2.7)
influence quantity

quantity which, in a direct **measurement**, is neither the **measurand** nor the quantity being measured, but whose change affects the relation between the **indication of the measuring system** and the **measurement result**

NOTES

1 Definition of direct measurement can be found in IEC 60050-300:2001.

2 In the GUM, the term ‘influence quantity’ covers both the sense given in the above definition and a quantity that is not the measurand but that affects the measurement result.

3 An indirect measurement involves a combination of direct measurements, each of which may be affected by influence quantities.

EXAMPLES

a) frequency in the measurement of the amplitude of an alternating current;

b) bilirubin amount-of-substance concentration in the measurement of haemoglobin concentration in human blood plasma;

c) temperature of a micrometer used for measurement of length of a rod, but not the temperature of the rod itself;

d) temperature in the measurement of pH;

e) background pressure in the ion source of a mass spectrometer during a measurement of amount-of-substance fraction.

2.32
(3.14)
correction

modification applied to a **quantity value** obtained from **measurement**, to compensate for a systematic effect

NOTES

1 See GUM 3.2.3 (1995) for explanation of ‘systematic effect’.

2 The correction can take different forms, such as an addend or a multiplicative factor.

2.33
measurement function

function expressing the mathematical relation between one or more **measurands** and the **quantity** or quantities that must be measured, or whose **values** can be otherwise obtained, to calculate a value of each measurand

NOTE

The general measurement function, f, for a single measurand, Y, can be expressed as $Y = f(X1, X2, \ldots, Xn)$, where $X1, X2, \ldots, X$n are the **input quantities to the measurement function**, as explained in the GUM (4.1).

2.34
input quantity to a measurement function

quantity that must be measured, or whose **value** can be otherwise obtained, to calculate a value of a **measurand** as an output of the **measurement function**

NOTE

Indications of a measuring system, corrections, and influence quantities are input quantities to a measurement function.

EXAMPLES

a) Temperature of a rod the length of which is being measured, and its thermal expansion coefficient.

b) Mass and volume, when measuring volumic mass (mass density) by indirect measurement.

2.35
measurement precision
precision

closeness of agreement between **quantity values** obtained by replicate **measurements** of a **quantity**, under specified conditions

NOTE

Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.

2.36
(3.6 NOTE 2)
repeatability condition of measurement
repeatability condition

condition of **measurement** in a set of conditions including the same **measurement procedure**, same operator, same **measuring system**, same operating conditions and same location, and replicated measurements over a short period of time

2.37
(3.6)
measurement repeatability
repeatability

measurement precision under **repeatability conditions of measurement**

2.38
intermediate precision condition of measurement
intermediate precision condition

condition of **measurement** in a set of conditions including the same **measurement procedure**, same location, and replicated measurements over an extended period of time

NOTES

1 Changes within a given type of **calibration**, operator, and **measuring system** are allowed.

2 A specification should contain the conditions changed and unchanged, to the extent practical.

2.39

intermediate measurement precision
intermediate precision

measurement precision under **intermediate precision conditions of measurement**

2.40
(3.7 NOTE 2)
reproducibility condition of measurement
reproducibility condition

condition of **measurement** in a set of conditions including different locations, operators, and **measuring systems**

NOTES

1 The different measuring systems may use different **measurement procedures**.

2 A specification should give the conditions changed and unchanged, to the extent practical.

2.41
(3.7)
measurement reproducibility
reproducibility

measurement precision under **reproducibility conditions of measurement**

2.42 (*preliminary definition*)
selectivity of a measuring system
selectivity

<chemistry> capability of a **measuring system**, using a specified **measurement procedure**, to provide **measurement results** for two or more **quantities of the same kind** involving different components in a system undergoing **measurement**, without interference from each other or from other **quantities** in the same system

EXAMPLE

Capability of a mass spectrometer to measure two specified ion currents in a mass spectrum without each being disturbed by the presence of other quantities.

<physics> capability of a **measuring system** to provide a **measurement result** for a given **quantity** in the presence of other **quantities of the same kind** in the system undergoing **measurement**

EXAMPLES

a) Capability of a measuring system to measure the power of a signal component at a given frequency without being disturbed by signal components or other signals at other frequencies.

b) Capability of a receiver to discriminate between a wanted signal and unwanted signals, often having frequencies slightly different from the frequency of the wanted signal.

c) Capability of a detector of ionizing radiation to respond to a radiation to be measured in the presence of concomitant radiation.

NOTE

“Selectivity” used in physics is a concept close to “specificity” used in chemistry.

2.43 (*preliminary definition*)
specificity of a measuring system
specificity

<chemistry> capability of a **measuring system**, using a specified **measurement procedure**, to provide a **measurement result** for a **quantity** involving a specified component in a system undergoing **measurement**, without interference from other components in the same system

EXAMPLES

a) Capability of a mass spectrometer to measure the electric current generated by a specified substance in a mass spectrum, without being disturbed by any other source of electric current.

b) Capability of a measuring system to measure the amount-of-substance concentration of creatininium in blood plasma by a Jaffé-procedure without interference from the glucose, urate, ketone, and protein concentrations.

c) Capability of a mass spectrometer to measure the amount-of-substance abundance of the ^{28}Si isotope.

NOTE

A concept close to “specificity” used in chemistry is “selectivity” used in physics.

Chapter 3: DEVICES FOR MEASUREMENT

This Chapter defines only a selection of important concepts. Further concepts are found in IEC 60050.

3.1
(4.1)
measuring instrument

device or combination of devices designed for **measurement** of **quantities**

3.2
(4.2)
material measure

device reproducing or supplying, in a permanent manner during its use, **quantities** of given kinds, each with an assigned **value**

EXAMPLES

a) A weight.

b) A volume measure (supplying one or several quantity values, with or without a measurement scale).

c) A standard electric resistor.

d) A line scale (ruler).

e) A gauge block.

f) A standard signal generator.

g) A reference material.

3.3
(4.3)
measuring transducer

device that provides at its output a **quantity** having a determined relation to the quantity at its input

EXAMPLES

a) Thermocouple.

b) Current transformer.

c) Strain gauge.

d) pH electrode.

e) Bourdon tube.

f) Bimetal strip.

3.4
(4.4)
measuring chain

series of elements of a **measuring system** constituting one single path of the measurement signal

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

3.5
(4.5)
measuring system
measurement system

set of **measuring instruments** and other devices or substances assembled and adapted to the **measurement** of **quantities** of specified kinds within specified intervals of **values**

NOTE
The substance can be a chemical reagent.

3.6
(4.6)
indicating measuring instrument

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

NOTES
1 See Notes to **4.1**.

2 An indicating measuring instrument may provide a record of the **indication** it provides.

3 The **indication** may be supplied in visual form or transmitted to another device.

3.7
(4.12)
displaying device
device providing the **indication of a measuring system** in visual form

NOTE
A displaying device may be the device by which the **quantity value** supplied by a **material measure** is displayed or set.

3.8
(4.14)
sensor

element of a **measuring system** that is directly affected by the phenomenon, body, or substance carrying the **quantity** to be measured

NOTE
In some fields the term ‘detector’ is used for this concept.

EXAMPLES
a) Measuring junction of a thermoelectric thermometer.

b) Rotor of a turbine flow meter.

c) Bourdon tube of a pressure gauge.

d) Float of a level-measuring instrument.

e) Photocell of a spectrophotometer.

f) Thermotropic liquid crystal which changes colour as a function of temperature.

3.9
(4.15)
detector

device or substance that indicates the presence of a phenomenon, body, or substance when a threshold **value** of an associated **quantity** is exceeded

NOTES
1 In some fields the term “detector” is used for the concept of **sensor**.

2 In chemistry the term “indicator” is frequently used for this concept.

EXAMPLES
a) Halogen leak detector.

b) Litmus paper.

3.10
(4.17)
scale of a displaying device
scale

part of a **displaying device** consisting of an ordered set of marks, together with any associated numbers or **quantity values**

NOTE
Related terms and definitions can be found in IEC 60050-300, Part 314.

3.11
(4.30)
adjustment of a measuring system
adjustment

set of operations carried out on a **measuring system** in order that it provide prescribed **indications** corresponding to given **values** of the **quantity** to be measured

NOTE

Adjustment of a measuring system should not be confused with **calibration of a measuring system**.

3.12
zero adjustment of a measuring system
zero adjustment

adjustment of a measuring system providing a null **indication** corresponding to a null **value** of the **quantity** to be measured

Chapter 4: CHARACTERISTICS OF MEASURING SYSTEMS

4.1
(3.2)
indication of a measuring system
indication

quantity value provided as the output of a **measuring system**

NOTES
1 The indication is given by the position on the display for analogue outputs, the displayed number for digital outputs, the code pattern for code outputs, the nominal or stated value for **material measures**.

2 The indication and the value of the **quantity** being measured are not necessarily values of **quantities of the same kind**.

4.2
(4.19)
indication interval

set of **quantity values** bounded by the extreme possible **indications of a measuring system**

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

2 In some fields the term is 'range of indications'.

4.3
(5.1)
nominal indication interval
nominal interval

set of **quantity values,** bounded by rounded or approximate extreme **indications** obtainable with a particular setting of the controls of a **measuring system** and used to designate this setting

NOTES
1 A nominal interval is usually stated as its smallest and greatest quantity values, for example, "100 V to 200 V". Where one of the extreme quantity values is zero, the nominal interval is sometimes stated solely as the greatest quantity value, for example a nominal interval of 0 V to 100 V is expressed as "100 V".

2 In some fields the term is "nominal range"

4.4
(5.2)
span of a nominal interval
span

absolute value of the difference between the extreme **quantity values** of a **nominal indication interval**

EXAMPLE
For a nominal interval of −10 V to +10 V, the span is 20 V.

4.5
(5.3)
nominal quantity value
nominal value

rounded or approximate **quantity value** of a characteristic of a **measuring system** that provides a guide to its use

EXAMPLES
a) 100 Ω as the quantity value marked on a standard resistor.

b) 100 cl as the value marked on a single-mark volumetric flask.

c) 0.1 mol/l as the value for amount-of-substance concentration of a solution of hydrogen chloride, HCl.

d) 25 °C as the set point of a thermostatically controlled bath.

e) 40 °C as a maximum temperature for storage.

4.6
(5.4)
measuring interval
working interval

set of **values** of the **quantities of the same kind** that can be measured by a given **measuring system**, with specified **measurement uncertainty** under defined conditions

NOTE
In some fields the term is 'measuring range'

4.7
steady state condition for a measuring system
steady state condition

operating condition of a **measuring system** in which the possible variation with time of the **quantity** being measured is such that a **calibration of the measuring system** carried out with a **measurand** constant with time remains valid

4.8
(5.5)
rated operating condition for a measuring system
rated operating condition

condition that must be fulfilled during **measurement** in order that a **measuring system** perform as designed

NOTE

The rated operating condition generally specifies intervals of **values** for the **quantity** being measured and for any **influence quantity**.

4.9
(5.6)
limiting condition for a measuring system
limiting condition

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

NOTES

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

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

4.10
(5.7)
reference condition for a measuring system
reference condition

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

NOTES

1 Reference conditions generally specify intervals of **values** for any **influence quantity.**

2 In IEC 60050-300, item 311-06-02, this term is used for a concept related to **optimum condition**.

4.11
optimum condition for a measuring system
optimum condition

condition of use for a **measuring system**, under which its contribution to **measurement uncertainty** is minimum

NOTE

In IEC 60050-300, item 311-06-02, a related concept is termed ‘reference conditions’.

4.12
(5.10)
sensitivity of a measuring system
sensitivity

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

NOTES

1 The sensitivity can depend on the value of the quantity being measured.

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

4.13
resolution of a measuring system

smallest change, in the **value** of a **quantity** being measured by a **measuring system,** that causes a perceptible change in the corresponding **indication**

NOTE
The resolution of a measuring system may depend on, for example, noise (internal or external) or friction. It may also depend on the value of the quantity being measured.

4.14
(5.12)
resolution of a displaying device
smallest difference between **indications** of a **displaying device** that can be meaningfully distinguished

4.15
(5.11)
discrimination threshold

largest change in the **value** of a **quantity** being measured by a **measuring system** that causes no detectable change in the corresponding **indication**

NOTE
The discrimination threshold may depend on, for example, noise (internal or external) or friction. It may also depend on the value of the quantity being measured.

4.16
(5.13)
dead band of a measuring system
dead band

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

NOTE
The dead band can depend on the rate of change.

4.17
(5.14)
stability of a measuring system
stability

ability of a **measuring system** to maintain its metrological characteristics constant with time

4.18
(5.16)
drift of a measuring system
drift

change in the **indication of a measuring system**, generally slow and continuous, related neither to a change in the **quantity** being measured nor to a change of an **influence quantity**

NOTE

For a **material measure** the drift is a change of the **value** of the supplied quantity that is not due to a change of an influence quantity.

4.19
variation due to an influence quantity

difference between the **indications of a measuring system** for the same **value** of the **quantity** being measured when an **influence quantity** assumes, successively, two different values

NOTE

For a **material measure**, the variation due to an influence quantity is the difference between the values of the supplied quantity when the influence quantity assumes two different values.

4.20
(5.17)
step-change response time of a measuring system
step-change response time

duration between the instant when a **quantity value** at the input of a **measuring system** is subjected to a step change between two specified steady states and the instant when the corresponding **indication** settles within specified limits around its final steady value

4.21
(5.27)
repeatability of a measuring system
repeatability

property of a **measuring system** to provide closely similar **indications** for replicated **measurements** of the same **quantity** under **repeatability conditions**

NOTE

Repeatability can be expressed quantitatively in terms of the dispersion parameters of the indications of the measuring system.

4.22
instrumental uncertainty
component of **measurement uncertainty** attributed to a **measuring instrument** and determined by its **calibration**

NOTES

1 The instrumental uncertainty is used as a component of measurement uncertainty in a subsequent Type B evaluation.

2 This definition is consistent with the IEC terminology, for instance IEC 60050-300, item 311-03-09.

3 Instrumental uncertainty is useful when the measuring instrument is used to perform a single measurement, however, caution must be taken not to overestimate or underestimate the measurement uncertainty when repeated measurements are performed.

4.23
accuracy class
<uncertainty approach> class of **measuring instruments** that meet stated metrological requirements which are intended to keep **instrumental uncertainty** within specified limits under specified operating conditions

NOTE
Related concepts are **accuracy class** <classical approach> and **accuracy of measurement**.

Chapter 5: MEASUREMENT STANDARDS, ETALONS

In science and technology, the English word “standard” is used with two different meanings: as a widely adopted written standard, specification, technical recommendation or similar document (in French “norme”) and as a measurement standard (in French “étalon”). This Vocabulary is concerned solely with the second meaning.

5.1
(6.1)
measurement standard
standard
etalon

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

NOTES

1 The ‘realization of the definition of a given quantity’ can consist of a **measuring system**, a **material measure**, or a **reference material**.

2 A measurement standard is frequently used as a reference to assign **measurement results** to other **quantities of the same kind**.

3 In many cases, measurement standards are realizations of the definition of a **unit**.

4 The stated measurement uncertainty of a measurement standard can be given as either a **standard measurement uncertainty** or an **expanded measurement uncertainty** with a **coverage factor**.

5 The standard measurement uncertainty of a measurement standard is always a component of the **combined standard uncertainty** (see Note to **2.15**) associated with a measurement result obtained using the measurement standard. Frequently, this component is small compared to other components of the combined standard uncertainty.

6 Several quantities of the same kind or of different kinds may be realized in one device which is commonly also called a measurement standard.

7 The word ‘embodiment’ is sometimes used in the English language instead of ‘realization’.

EXAMPLES

a) 1 kg mass standard.

b) 100 Ω standard resistor.

c) Standard ammeter.

d) Caesium frequency standard.

e) Standard hydrogen electrode.

f) Set of reference solutions of cortisol in human serum having certified concentrations.

g) Reference material providing certified values with measurement uncertainties for the mass concentration of each of ten different proteins.

5.2
(6.3)
national measurement standard
national standard

measurement standard designated as a national stated metrological reference

5.3
(6.4)
primary measurement standard
primary standard

measurement standard whose **quantity value** and **measurement uncertainty** are established without relation to another measurement standard for a **quantity of the same kind**

NOTES

1 This definition implies that the establishment of a primary measurement standard has to refer to the definition of any **unit** concerned, particularly an SI unit.

2 The first measurement standard of a **calibration hierarchy** is always a primary measurement standard.

3 See Note 6 in **5.1** (measurement standard).

EXAMPLES

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

b) Primary measurement standard for pressure based on separate measurements of force and area.

c) Primary measurement standard for isotope amount-of-substance ratio **measurements**, prepared by mixing known amounts of substance of specified isotopes.

5.4
(6.5)
secondary measurement standard
secondary standard

measurement standard whose **quantity value** and **measurement uncertainty** are assigned through **calibration** against, or comparison with, a **primary measurement standard** for a **quantity of the same kind**

NOTES

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

2 A measurement standard having its quantity value assigned by a ratio **primary measurement procedure** is a secondary measurement standard.

5.5
(6.6)
reference measurement standard
reference standard

measurement standard used for the calibration of **working measurement standards** in a given organization or at a given location

5.6
(6.7)
working measurement standard
working standard

measurement standard that is used routinely to calibrate, verify, or check **measuring systems**, **material measures**, or **reference materials**

NOTE
A working measurement standard is usually calibrated with a **reference measurement standard**.

5.7
(6.9)
travelling measurement standard
travelling standard

measurement standard, sometimes of special construction, intended for transport between different locations

EXAMPLE
A portable battery-operated caesium 133 frequency standard

5.8
(6.8)
transfer measurement device
transfer device

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

5.9
intrinsic measurement standard
intrinsic standard

measurement standard based on a sufficiently stable and reproducible property of a phenomenon or substance

NOTES
1 The **quantity value** of an intrinsic standard is assigned by consensus and does not need to be established by relating it to another measurement standard of the same type. Its **measurement uncertainty** is determined by considering two components: (A) that associated with its consensus quantity value and (B) that associated with its construction, implementation and maintenance.

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 include **corrections** necessitated by the implementation.

3 The quantity value of an intrinsic standard may depend on the consensus value of a fundamental constant.

4 The stability and **measurement reproducibility** of some intrinsic standards come from the fact that the phenomenon used is a quantum phenomenon.

5 The adjective 'intrinsic' does not mean that this standard may be used without special care or that this standard is immune to spurious effects.

EXAMPLES

a) Triple-point-of-water cell as an intrinsic standard of thermodynamic temperature.

b) Intrinsic standard of electric potential difference based on the Josephson effect.

c) Sample of copper as an intrinsic standard of electric conductivity.

5.10
(6.7 NOTE)
check measurement device
check device

measurement device used routinely for verifying the functioning of a **measuring system**

5.11
(6.12)
conservation of a measurement standard

operation or set of operations necessary to preserve the metrological properties of a **measurement standard** within stated limits

NOTE
Conservation commonly includes periodic **verification** or **calibration**, storage under suitable conditions, and specified care in use.

5.12
calibrator

measurement standard used in the **calibration** of a **measuring system**

5.13
(6.13)
reference material
RM

material, sufficiently homogeneous and stable with respect to one or more specified **quantities**, used for the **calibration of a measuring system**, or for the assessment of a **measurement procedure**, or for assigning **values** and **measurement uncertainties** to **quantities of the same kind** for other materials

NOTES

1 The term ‘reference material’ designates a family of materials without necessarily implying a hierarchy according to the magnitude of the **measurement uncertainty**.

2 “Reference material” comprises both “precision control material”, which needs not have an assigned **quantity value**, and **measurement standard** functioning as “trueness control material” or **calibrator**.

3 A reference material can be in the form of, e.g. a pure or mixed gas, liquid, solid or suspension.

4 The term ‘reference material’ is also used for materials realizing nominal properties, such as colour.

EXAMPLES

a) Water for the calibration of viscometers.

b) Sapphire as a heat-capacity calibrator in calorimetry.

c) Human serum containing cholesterol without assigned quantity value, used only as a precision control material.

5.14
(6.14)
certified reference material
CRM

reference material, accompanied by an authenticated certificate, having for each specified **quantity** a **value**, **measurement uncertainty**, and stated **metrological traceability chain**

NOTES

1 A certificate should refer to a protocol describing the certification process.

2 A definition of “reference material certificate” is given in ISO Guide 30:1992.

3 Certified reference materials are generally prepared in batches. For a given batch, **quantity values** and measurement uncertainties are obtained by **measurements** on samples representative of the batch.

4 The quantity values assigned to a certified reference material are sometimes conveniently and reliably obtained when the material is incorporated into a specially fabricated device. The quantity value is sometimes the output of a device. Such devices may also be considered as CRMs.

EXAMPLES

a) A substance of known triple-point in a triple-point cell.
b) A glass of known optical density in a transmission filter holder.
c) Spheres of uniform particle size mounted on a microscope slide.
d) An array of Josephson junctions.

5 Procedures for the production and certification of certified reference materials are given in ISO Guides 34 and 35.

6 A certified reference material lies within the definition of a **measurement standard**.

7 Some reference materials and certified reference materials have quantities which, because they cannot be correlated with an established chemical structure or for other reasons, cannot be measured according to **measurement procedures** giving measurement results that are metrologically traceable to **measurement units** of the **International System of Units** (SI) or another **system of units**. Such materials include certain biological materials such as vaccines to which International Units (IU) have been assigned by the World Health Organization.

5.15
commutability of a reference material

property of a given **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 two given **measurement procedures**, and the relation obtained among the measurement results for other specified materials

NOTES

1 The material in question is usually a **calibrator**.

2 At least one of the two given measurement procedures is usually a high-level measurement procedure.

5.16
reference data

data that is critically evaluated and verified, obtained from an identified source, and related to a property of a phenomenon, body, or substance, or a system of components of known composition or structure

NOTE

Here the word ‘data’ is used in the singular sense, instead of using the word ‘datum’.

5.17
standard reference data

reference data issued by a stated recognized authority

EXAMPLE

CODATA (1998) recommended values of the fundamental physical constants.

5.18
reference quantity value
reference value

quantity value, generally accepted as having a suitably small **measurement uncertainty**, to be used as a basis for comparison with values of **quantities of the same kind**

NOTES

1 A reference quantity value with associated measurement uncertainty is usually referred to

- a material, e.g. a **certified reference material**,
- a device, e.g. a stabilized laser,
- a reference **measurement procedure**.

2 A reference quantity value must be metrologically traceable.

Annex A:
CONCEPTS USED IN THE CLASSICAL APPROACH (CA) TO MEASUREMENT

A1
(1.19)
true value of a quantity
true value

quantity value consistent with the definition of a quantity

NOTES
1 Within the Classical Approach a unique quantity value is thought to describe the **measurand**. The true value would be obtainable by a perfect **measurement**, that is a measurement without **measurement error**. The true value is by nature unobtainable.

2 Due to **definitional measurement uncertainty**, there is a distribution of true values consistent with the definition of a measurand. This distribution is by nature unknowable. The concept of "true value" is avoided in the Uncertainty Approach (D.3.5 in the GUM).

A2
(3.5)
accuracy of measurement
accuracy

closeness of agreement between a **quantity value** obtained by **measurement** and the **true value** of the **measurand**

NOTES
1 Accuracy cannot be expressed as a **numerical value**.

2 Accuracy is inversely related to both **systematic error** and **random error**.

3 The term 'accuracy of measurement' should not be used for **trueness of measurement** and the term 'measurement precision' should not be used for "accuracy of measurement".

A3
(5.18)
accuracy of a measuring system
accuracy

ability of a **measuring system** to provide a **quantity value** close to the **true value** of a **measurand**

NOTES
1 Accuracy is greater when the quantity value is closer to the true value.

2 The term 'precision' should not be used for "accuracy".

3 This concept is related to **accuracy of measurement**.

A4
trueness of measurement

trueness

closeness of agreement between the average that would ensue from an infinite number of **quantity values** obtained under specified **measurement** conditions and the **true value** of the **measurand**

NOTES

1 Trueness cannot be expressed as a **numerical value**.

2 Trueness is inversely related to **systematic error** only.

3 The term 'trueness of measurement' should not be used for **accuracy of measurement**.

A5
(3.10)
error of measurement
error

difference of **quantity value** obtained by **measurement** and **true value** of the **measurand**

NOTE
It is necessary to distinguish "error of measurement" from **relative error of measurement**.

A6
(5.20)
error of indication

difference of **indication of a measuring system** and **true value** of the **measurand**

NOTE
In the Classical Approach, "indication of a measuring system" and the **value** of the measurand are assumed to be values of **quantities of the same kind**.

A7
(3.13)
random error of measurement
random error

difference of **quantity value** obtained by **measurement** and average that would ensue from an infinite number of replicated measurements of the same **measurand** carried out under **repeatability conditions**

NOTES

1 Random errors of a set of replicated measurements form a distribution that can be described by a variance, and has an expectation of zero.

2 Random error equals the difference of **error of measurement** and **systematic error of measurement**.

A.8
(3.14)
systematic error of measurement

systematic error

difference of average that would ensue from an infinite number of replicated **measurements** of the same **measurand** carried out under **repeatability conditions** and **true value** of the measurand

NOTES

1 Systematic error, and its causes, can be known or unknown. Correction should be applied for systematic error, as far as it is known.

2 Systematic error equals the difference of **error of measurement** and **random error of measurement**.

A9
(5.19)
accuracy class
<classical approach> class of **measuring instruments** that meet stated metrological requirements which are intended to keep **errors of indication** within specified limits under specified operating conditions

NOTES

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

2 Related concepts are **accuracy class** <uncertainty approach> and **accuracy of measurement**.

A10
(5.21)
maximum permissible error
limit of error

one of the two extreme **values** of the **error of indication** permitted by specifications or regulations for a given **measuring system**

A11
(5.22)
datum error of a measuring system
datum error

error of indication of **a measuring system** at a specified **indication** or a specified **value** of the **measurand**

A12
(5.23)
zero error of a measuring system
zero error

datum error for zero **value** of the **measurand**

A13
(5.24)

intrinsic error of a measuring system
intrinsic error

error of indication when determined under **reference conditions**

A14
(5.25)
bias of a measuring system
bias

systematic **error of indication** of a **measuring system**

NOTE
The bias of a measuring system is the average of the **errors of indication** that would ensue from an infinite number of **measurements** of the same **measurand** carried out under **repeatability conditions**.

Annexe B CONCEPT DIAGRAMS

The concept diagrams in this Annexe are intended to provide

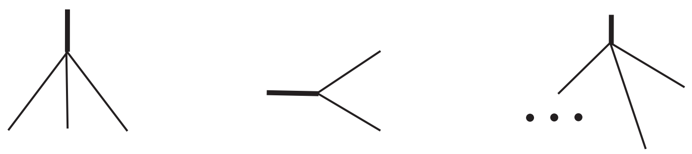
- a visual presentation of the relations between the concepts defined and termed in the preceding chapters;
- a possibility for checking whether the definitions offer adequate relations;
- a background for identifying further needed concepts; and
- a check that terms are sufficiently systematic.

It should be recalled, however, that a given concept may be describable by many characteristics and only essential delimiting characteristics are included in the definition.

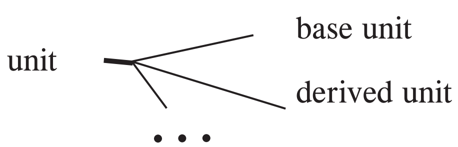
The area available on a page limits the number of concepts that can be presented legibly, but all diagrams in principle are interrelated as shown by some overlapping concepts with reference.

The relations used are of three types as defined by ISO 704 and ISO 1087-1. Two are hierarchical, ie having superordinate and subordinate concepts, the third is non-hierarchical.

The hierarchical generic relation (or genus-species relation) connects a generic concept and a specific concept; the latter inherits all characteristics of the former. The diagrams show such relations as a tree,

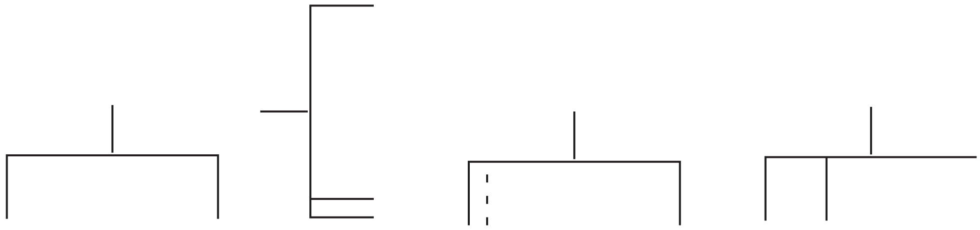


where a short branch with three dots indicates that one or more other specific concepts exist, but are not included for presentation. For example,

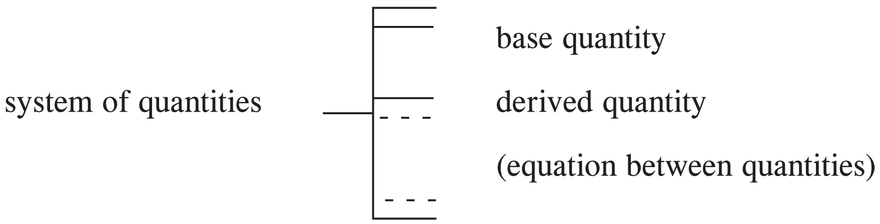


where the third concept might be ”off-system unit”.

The partitive relation (or part-whole relation) is also hierarchical and connects a comprehensive concept to two or more partitive concepts which fitted together constitute the parent concept. The diagrams show such relations as a rake or bracket,



where a close-set double line indicates that several partitive concepts of a given type are involved and a broken line shows that such plurality is uncertain. For example,



where the parenthetic term indicates a concept that is not defined in the Vocabulary, but is taken as a primitive which is assumed to be generally understood. A continued backline without a tooth means one or more further partitive concepts that are not discussed.

The associative relation (or pragmatic relation) is non-hierarchical and connects two concepts which are in some sort of thematic association. There are many subtypes of associative relation, but all are indicated by a double-headed arrow. For example,

quantity $\longleftrightarrow$ quantity calculus

measurement $\longleftrightarrow$ measurement result

measurement procedure $\longleftrightarrow$ measurement

To avoid too complicated diagrams, they do not show all the possible associative relations.

The diagrams will demonstrate that fully systematic derived terms have not been created, often because metrology is an old discipline with a vocabulary evolved by accretion rather than as a comprehensive de novo structure.

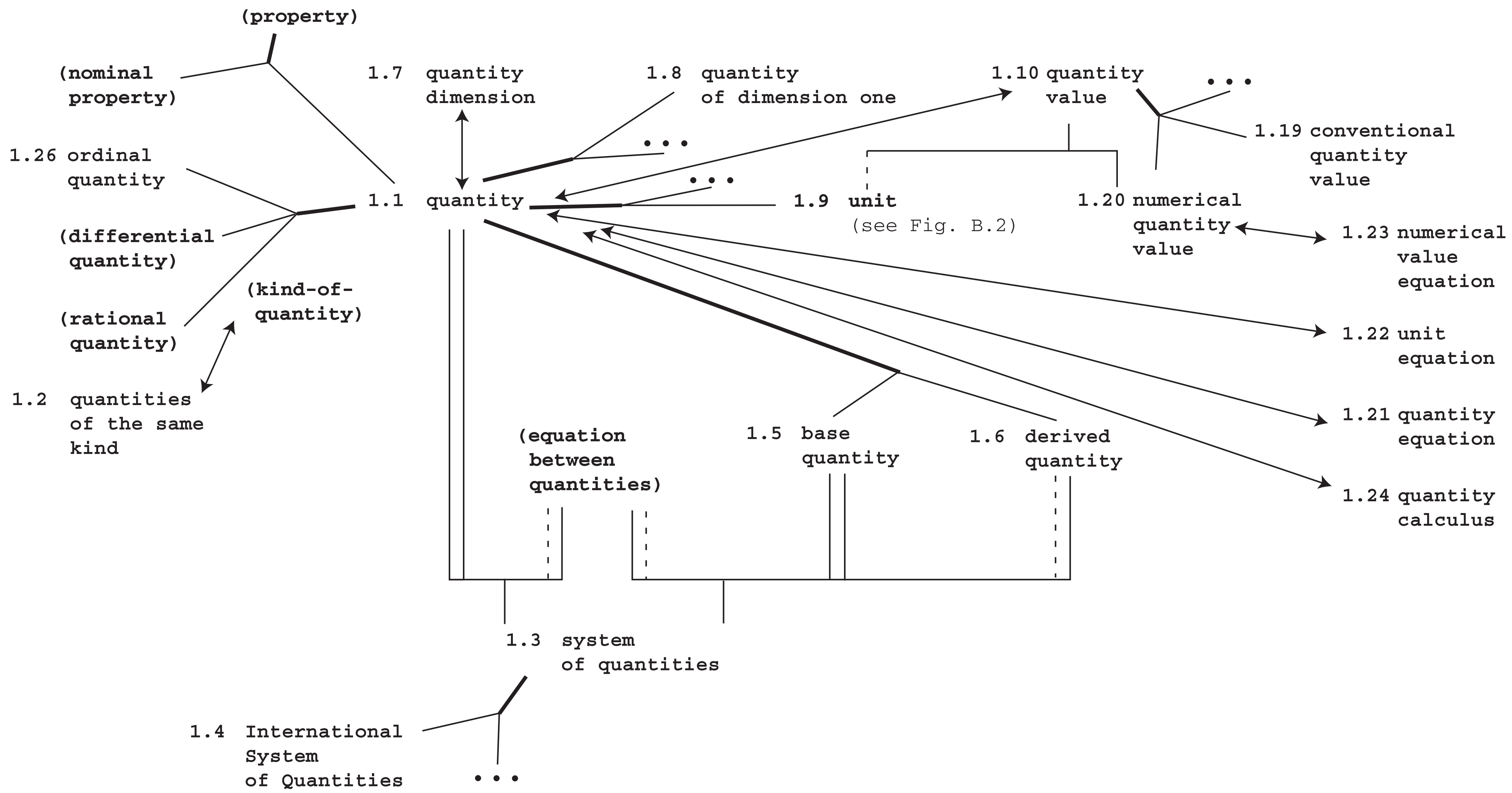


Figure B.1 Concept diagram for part of Chapter 1, centred on "quantity"

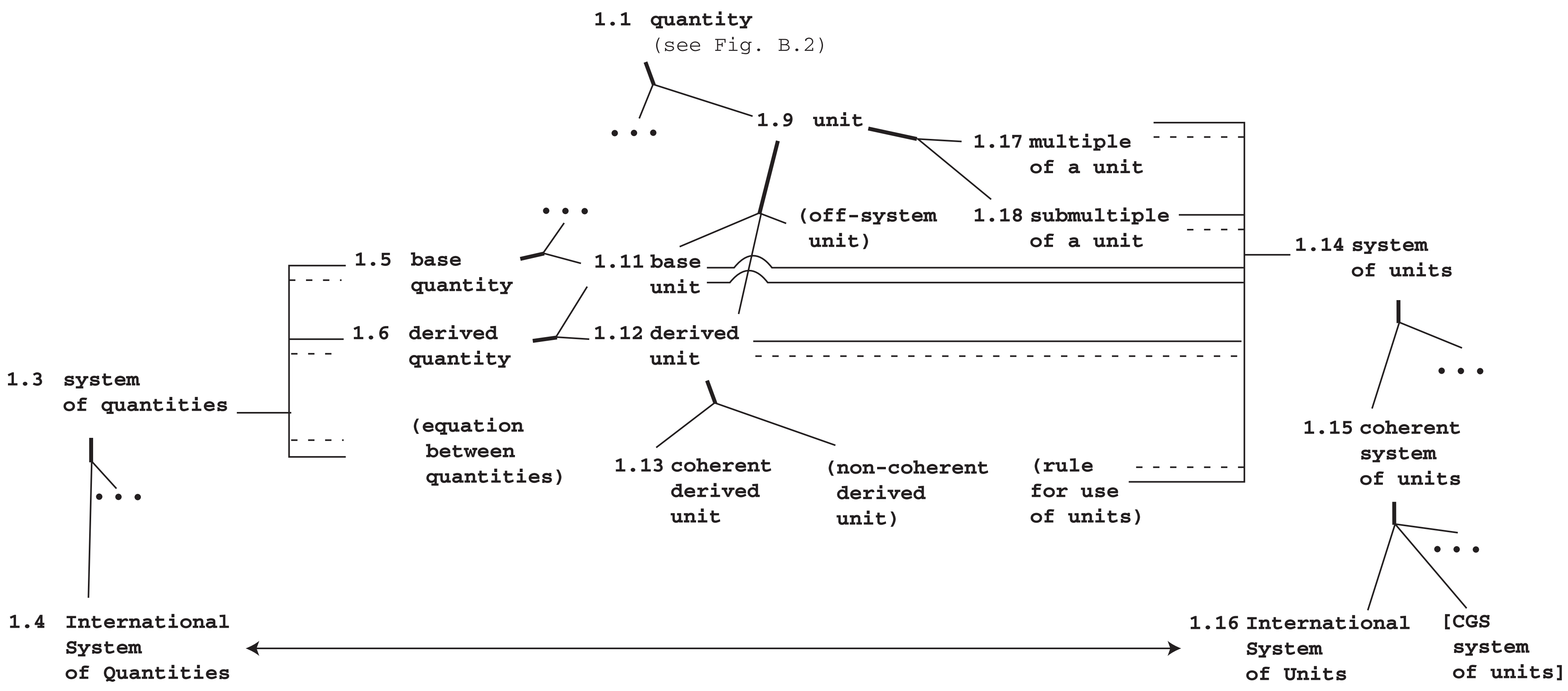


Figure B.2 Concept diagram for part of Chapter 1, centred on "unit"

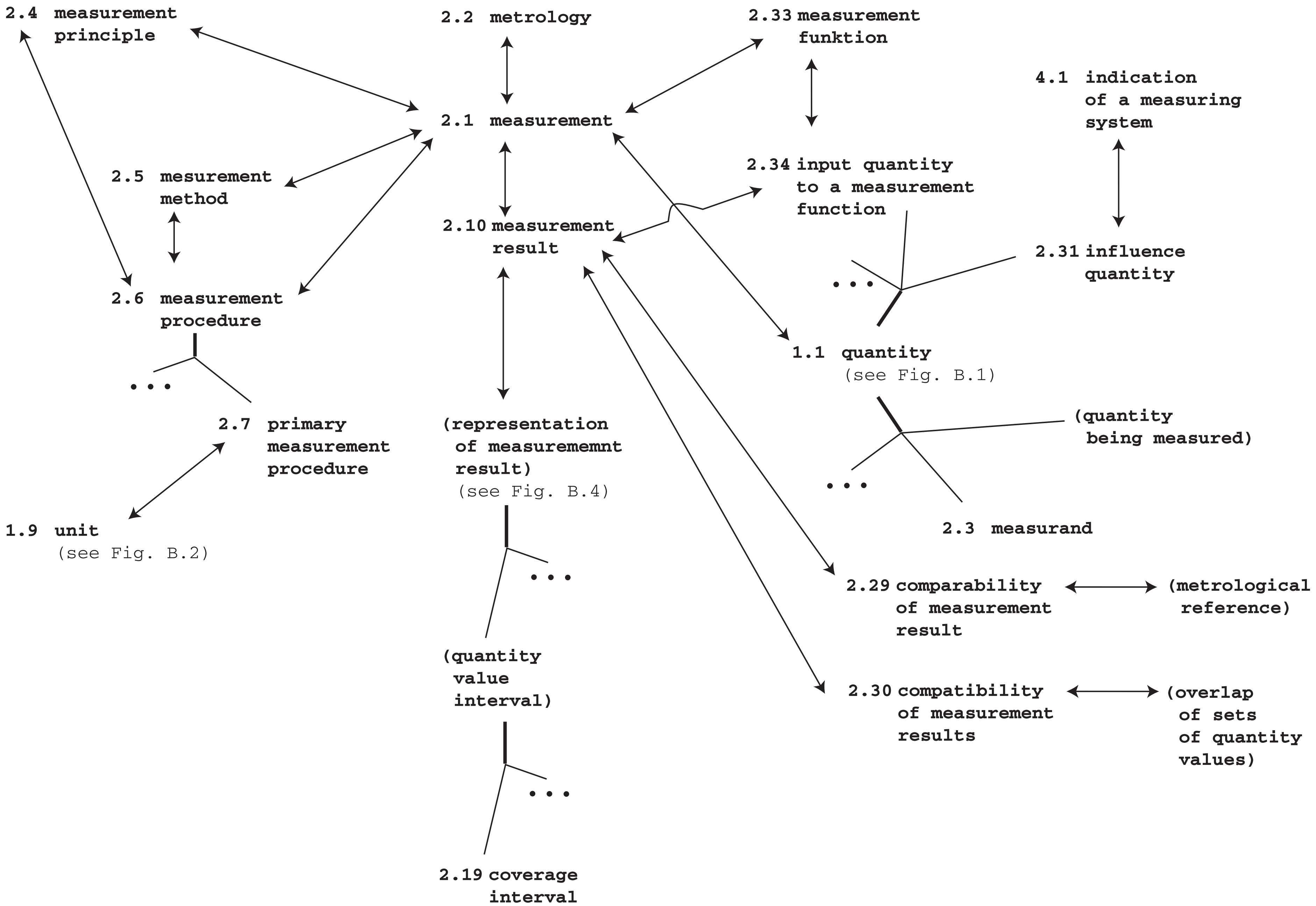


Figure B.3 Concept diagram for part of Chapter 2, centred on "Measurement"

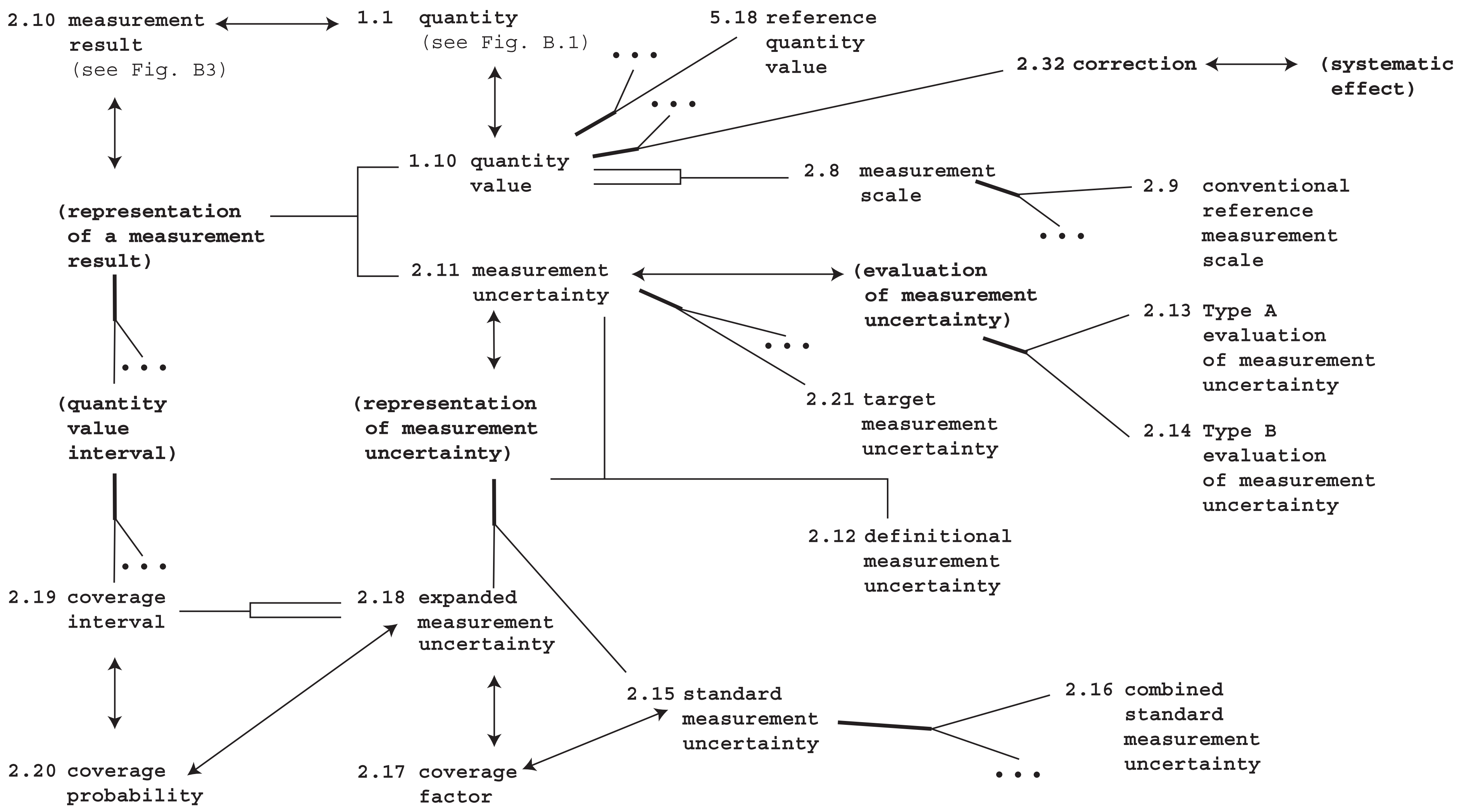


Figure B.4 Concept diagram for part of Chapter 2, centred on "measurement uncertainty"

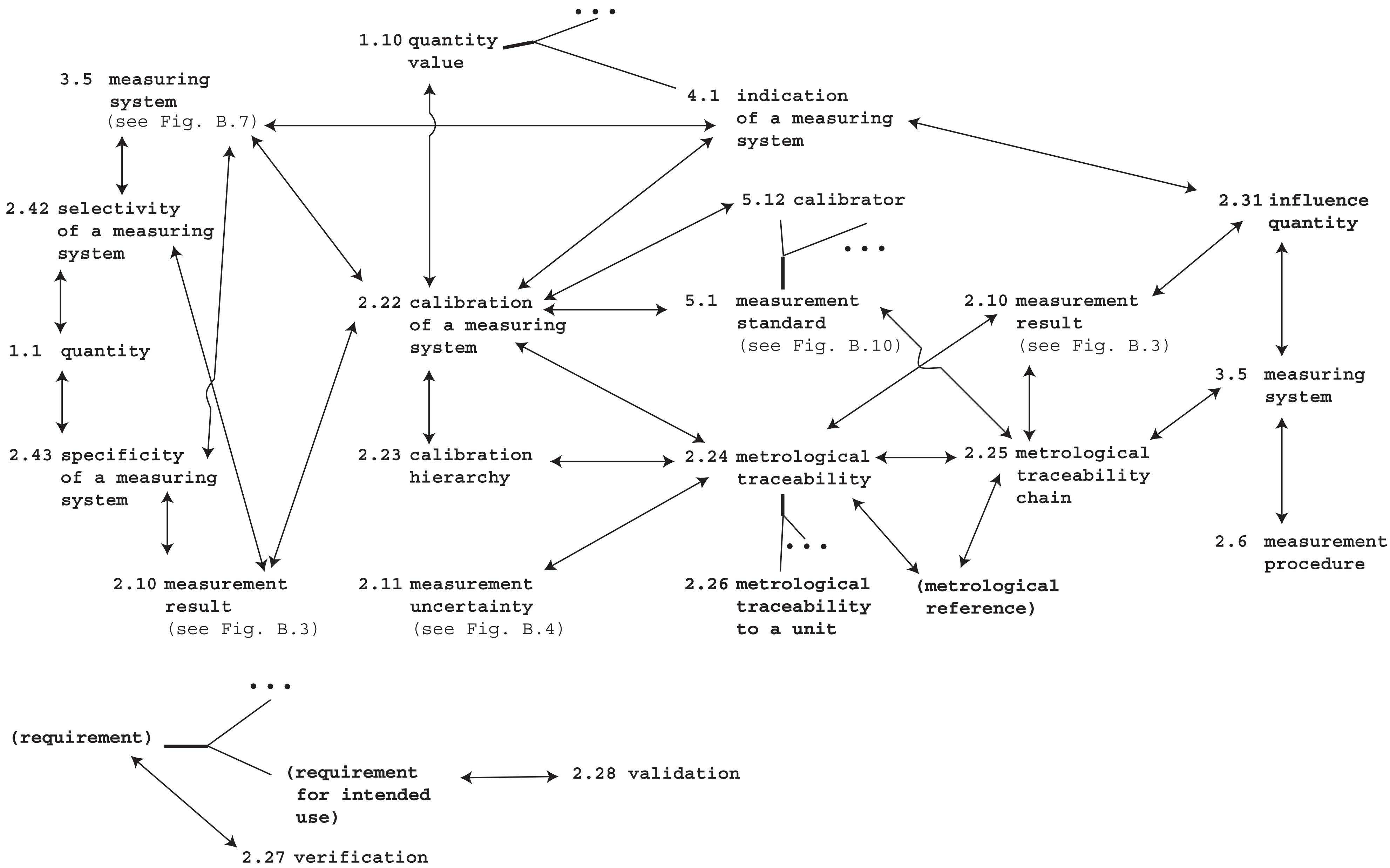


Figure B.5 Concept diagrams for part of Chapter 2, centred on "calibration of a measuring system"

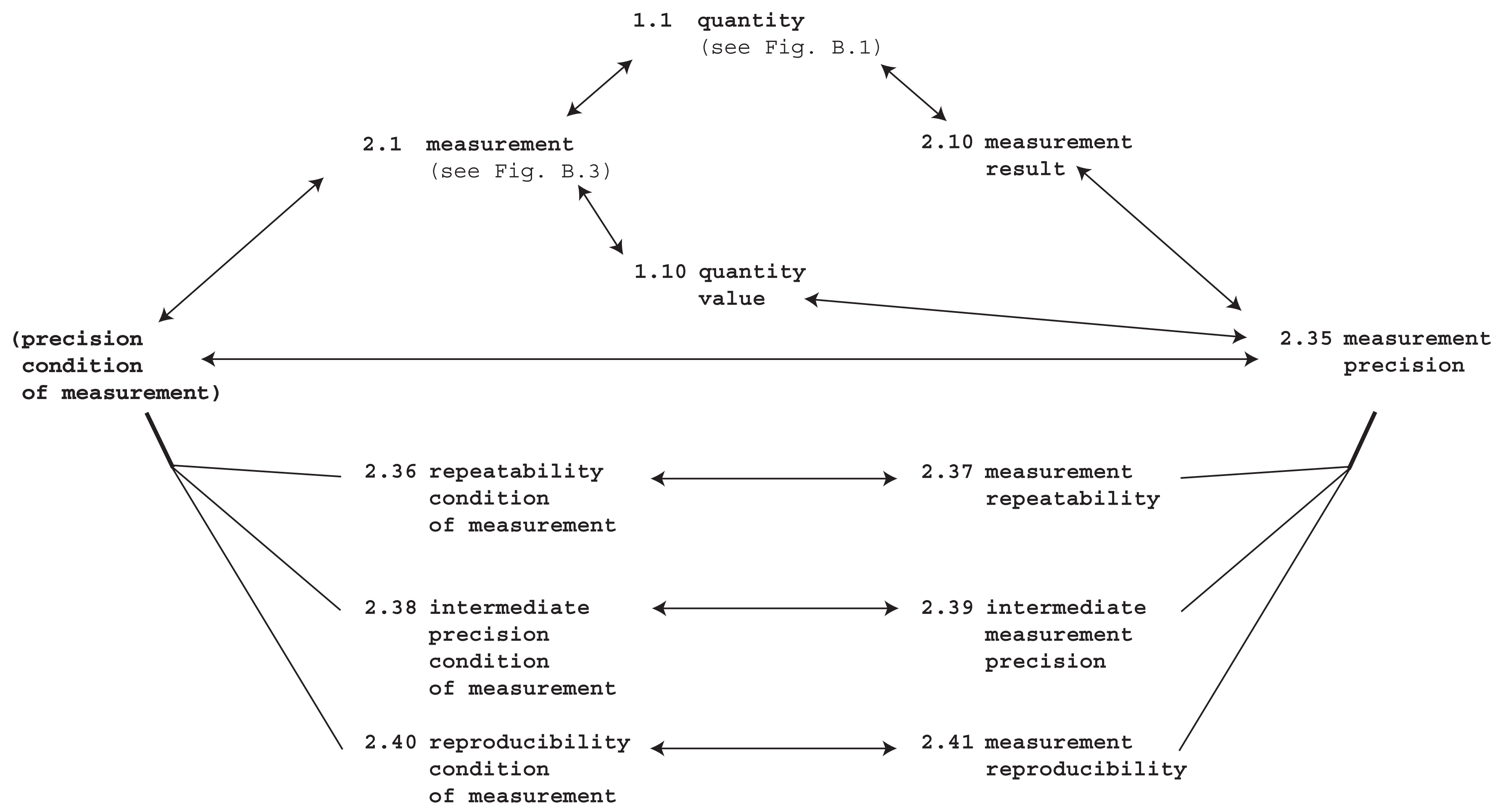


Figure B.6 Concept diagram for part of Chapter 2, centred on "measurement precision"

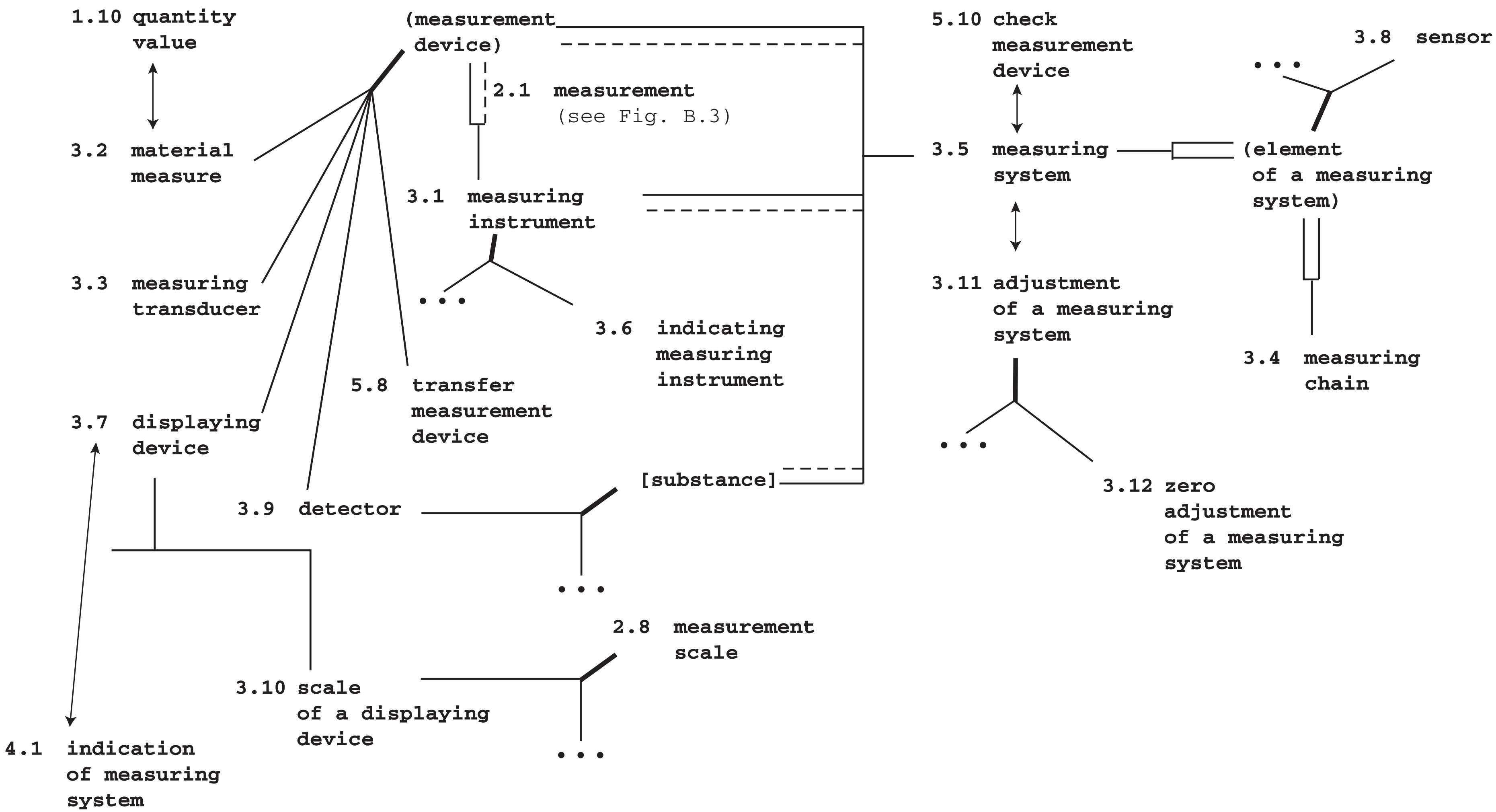


Figure B.7 Concept diagram for Chapter 3,'Devices for measurement'

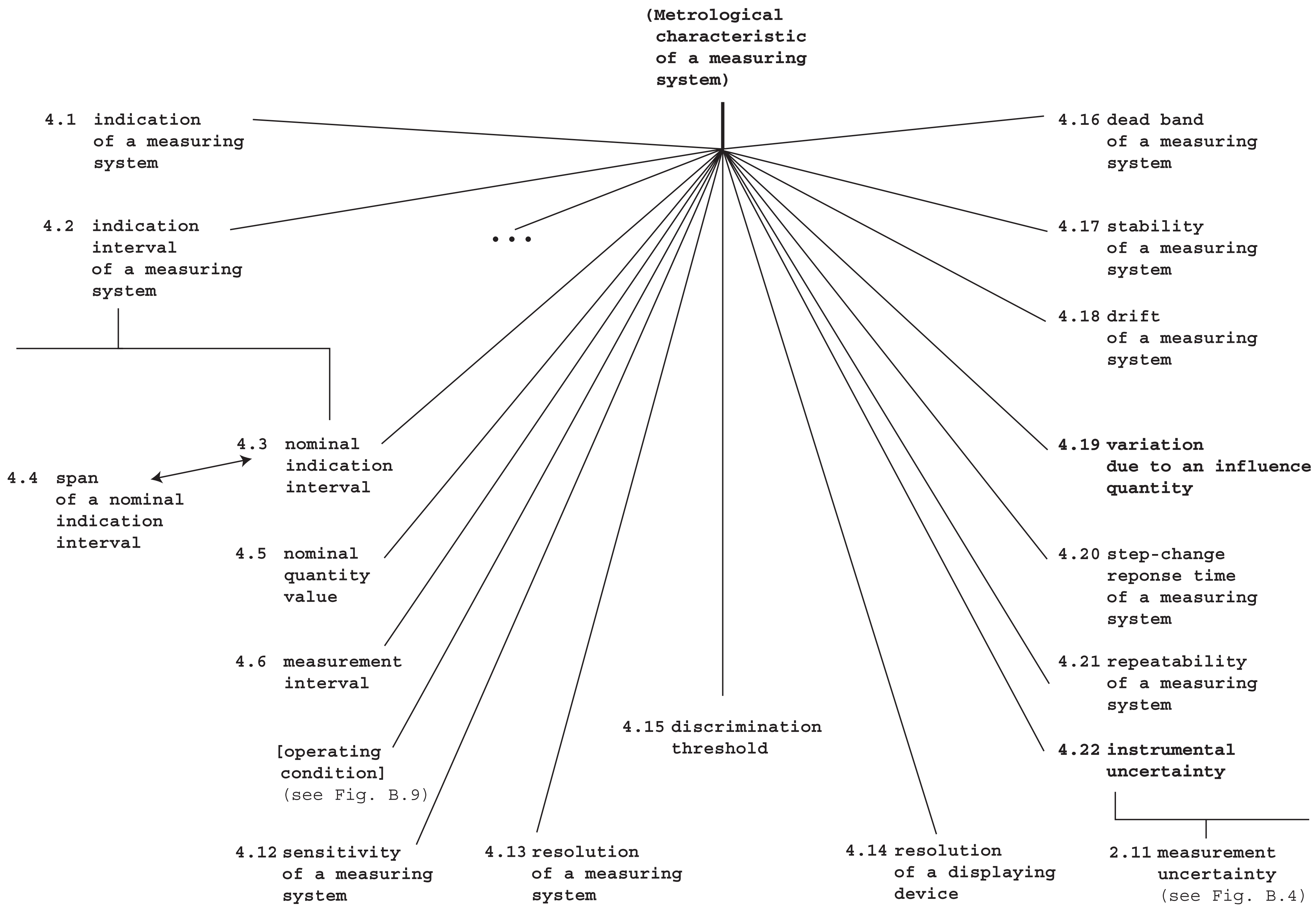


Figure B.8 Concept diagram for part of Chapter 4, centred on (metrological characteristic of a measuring system)

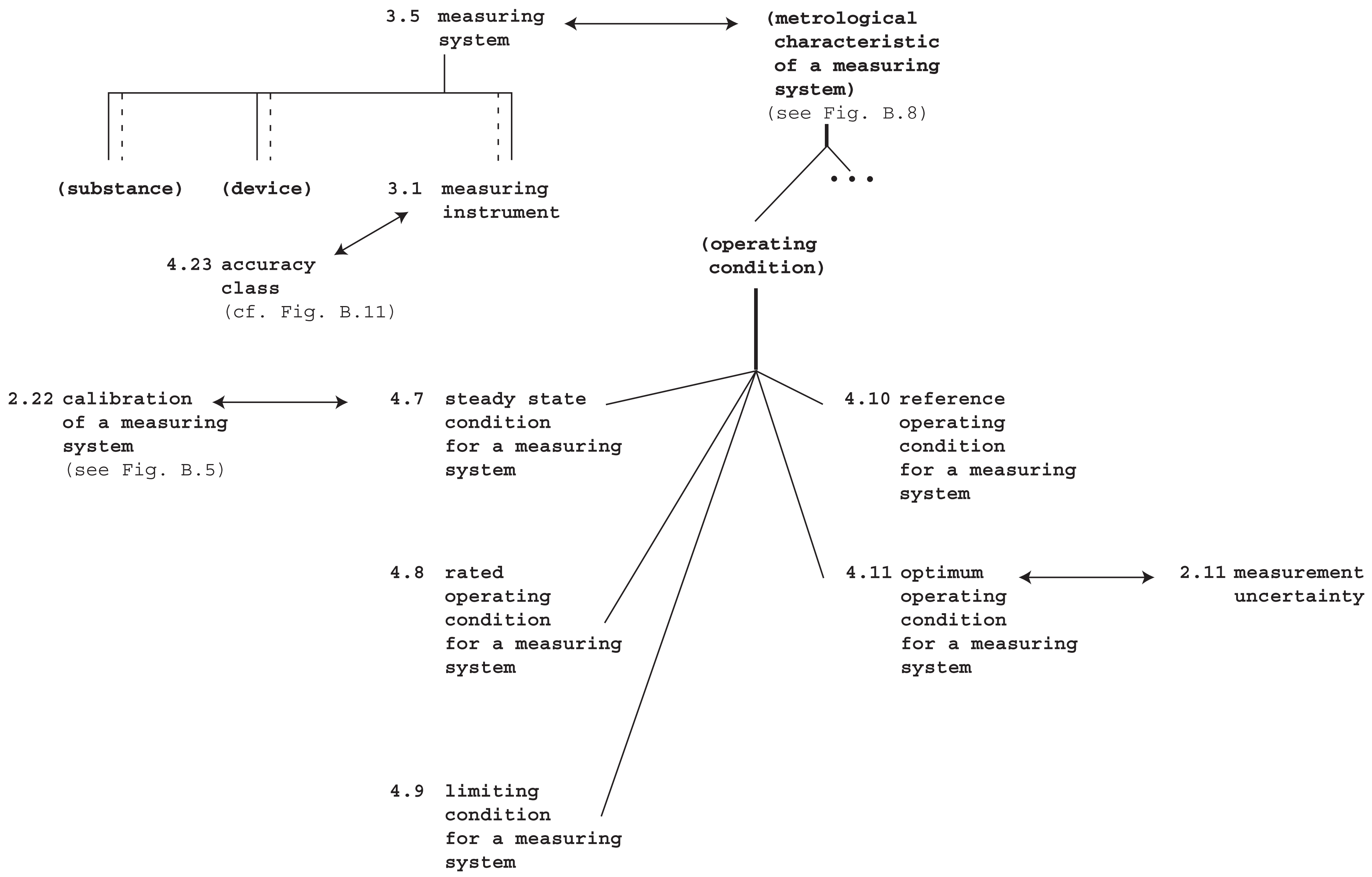


Figure B.9 Concept diagram for Chapter 4, centred on (operating condition)

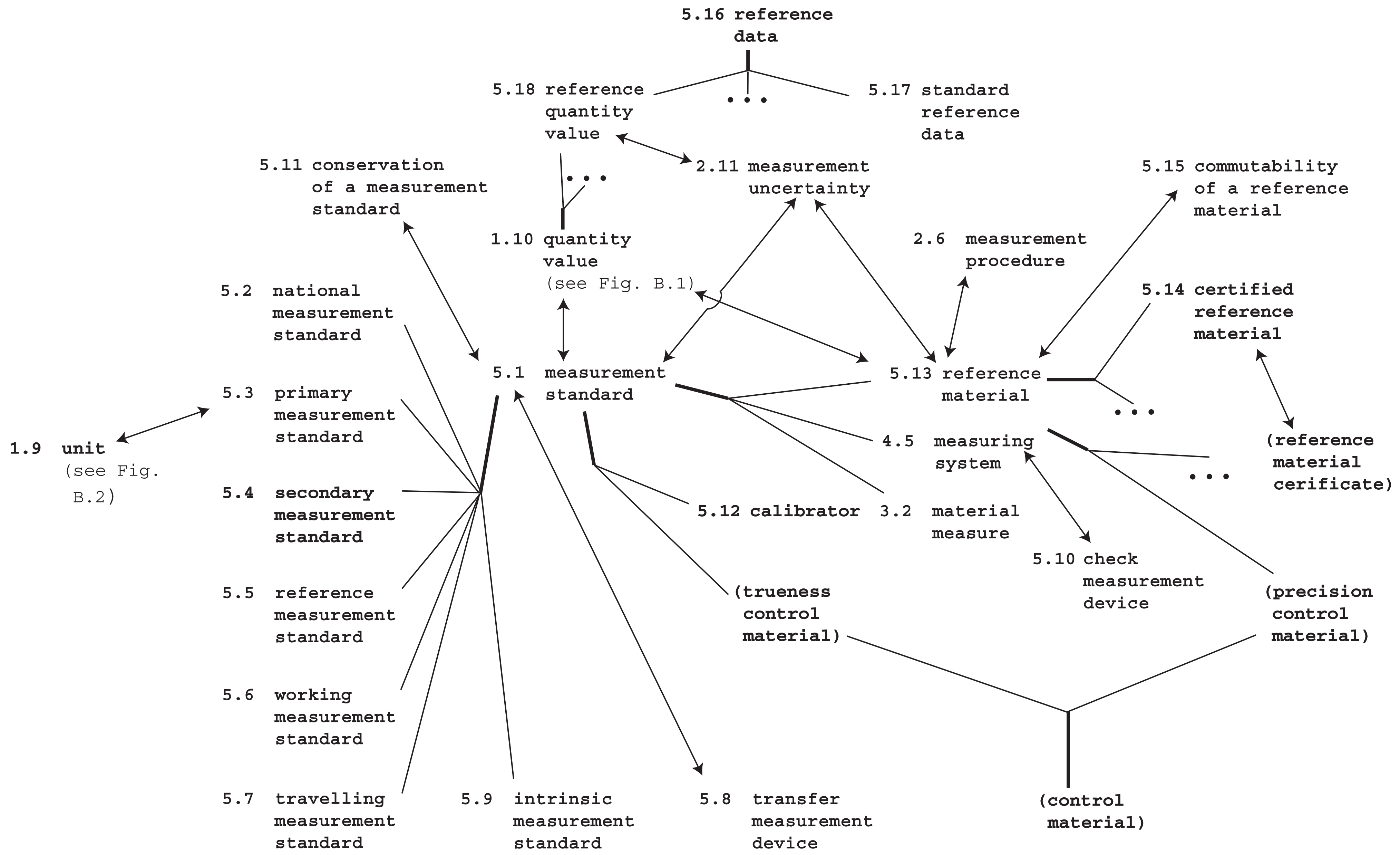


Figure B.10 Concept diagram for Chapter 5, "Measurement standards; etalons"

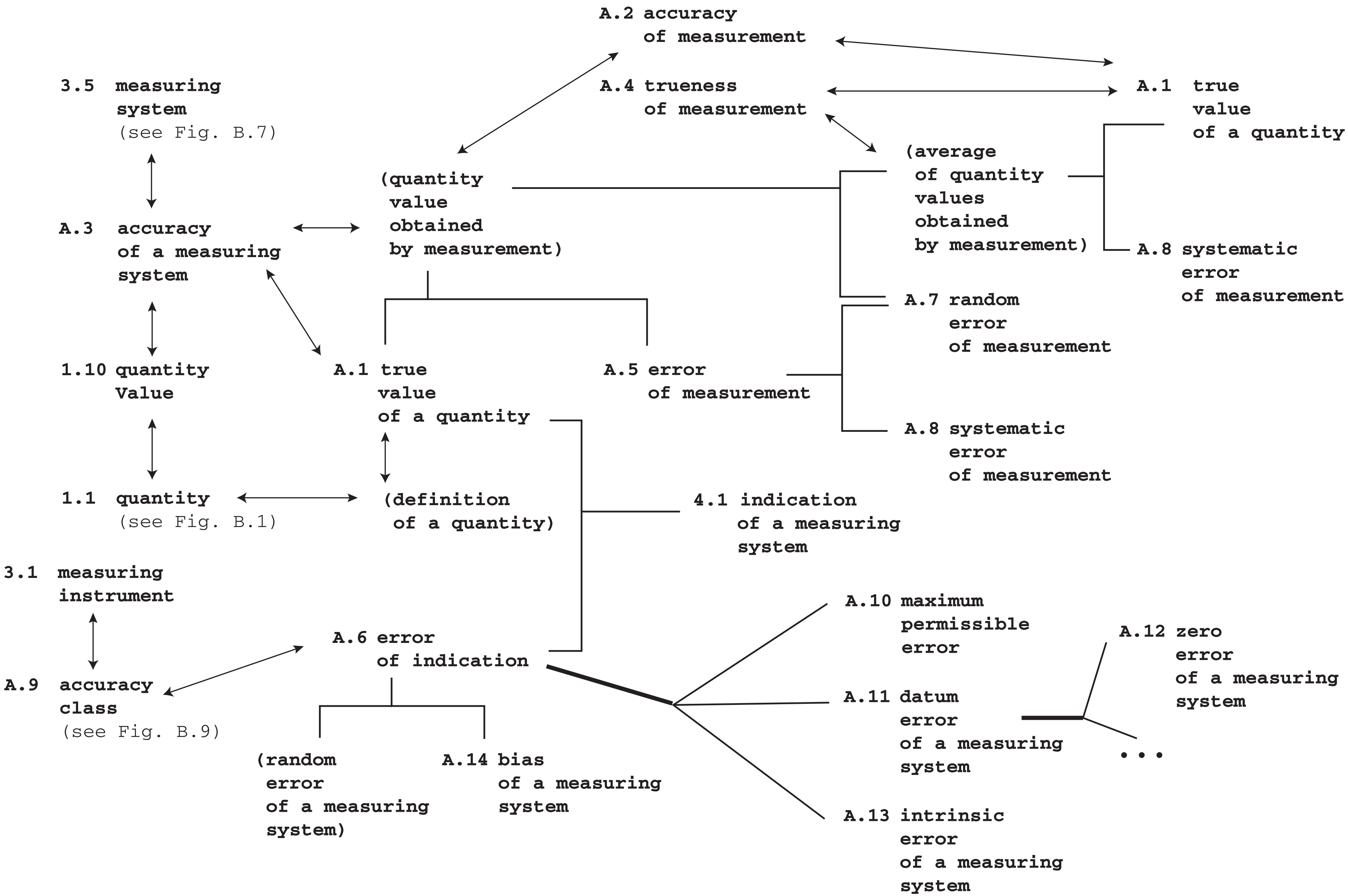


Figure B.11 Concept diagram for Annexe A, 'Concepts used in the Classical Approach (CA) to measurement'

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LIST OF ACRONYMS

CCQM	Consultative Committee for Amount of Substance/Comité Consultatif pour la Quantité de Matière
CGPM	General Conference on Weights and Measures/ Conférence Générale des Poids et Mesures
CODATA	Committee on Data for Science and Technology
GUM	Guide to the Expression of Uncertainty in Measurement
IEC	International Electrotechnical Commission
IUPAP	International Union of Pure and Applied Physics
IFCC	International Federation of Clinical Chemistry
ISO	International Organization for Standardization
IUPAC	International Union of Pure and Applied Chemistry
JCGM	Joint Committee for Guides in Metrology
JCGM-WG2	Working Group 2 of Joint Committee for Guides in Metrology
OIML	International Organization for Legal Metrology
VIM	International Vocabulary of Basic and General Terms in metrology

ALPHABETIC INDEX

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