The implementation of the revised SI in IEC standards

Luca Mari
IEC/TC 1 Chair

lmari@liuc.it
research.liuc.it/luca.mari

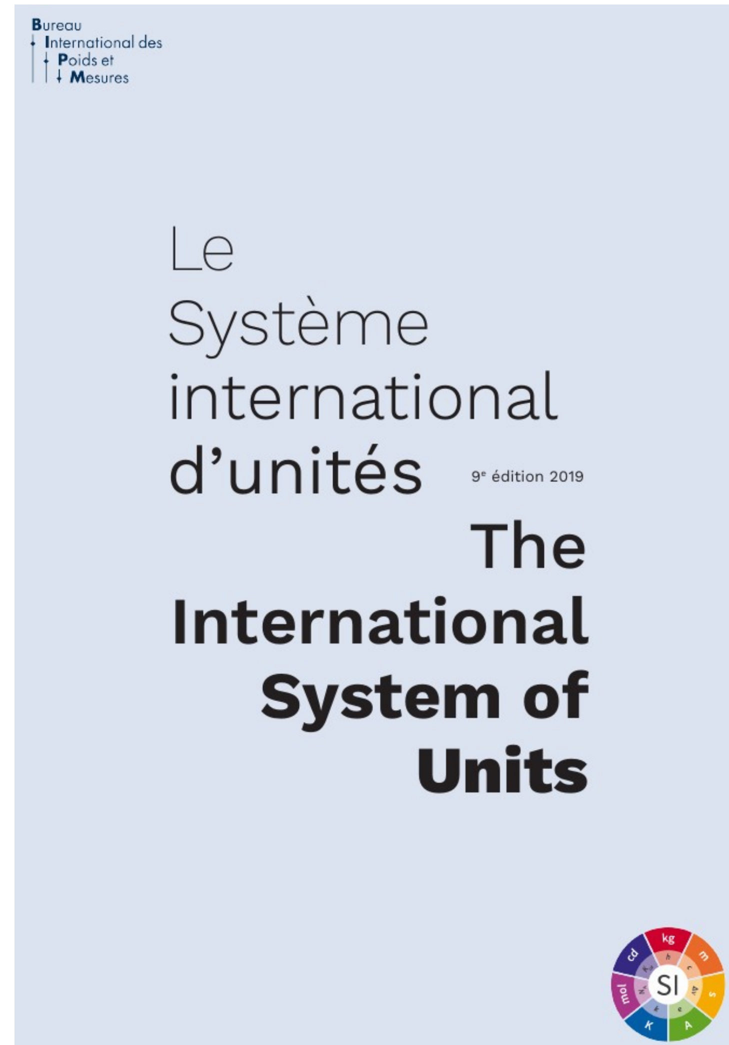
IEC General Meeting, Shanghai, 20 October 2019

The SI, standardization, and terminology

The SI provides **definitions**
of units of physical quantities

Definitions aim at **standardization**

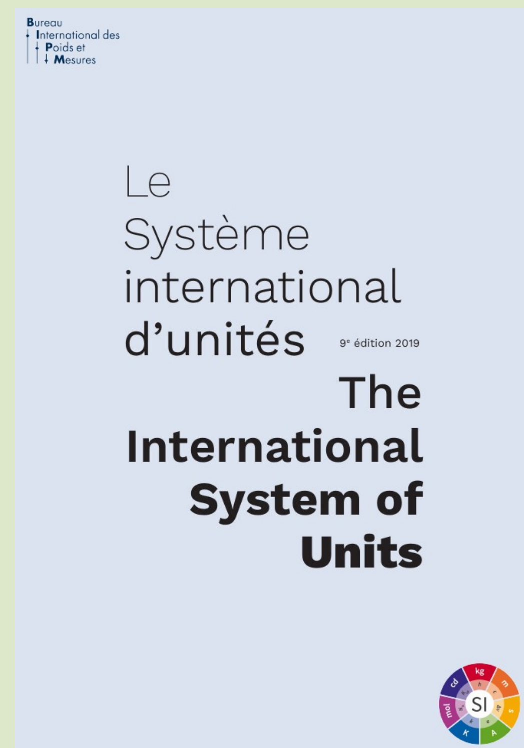
Standardization is based on
standardized language,
as provided by **terminology**



Checkpoint 1

Do you know these two documents?

1. I have read most or all of them
2. I scrolled them, but nothing more
3. I only know that they exist
4. I was not aware of them



The revised SI is a significant change...

An example: the kilogram

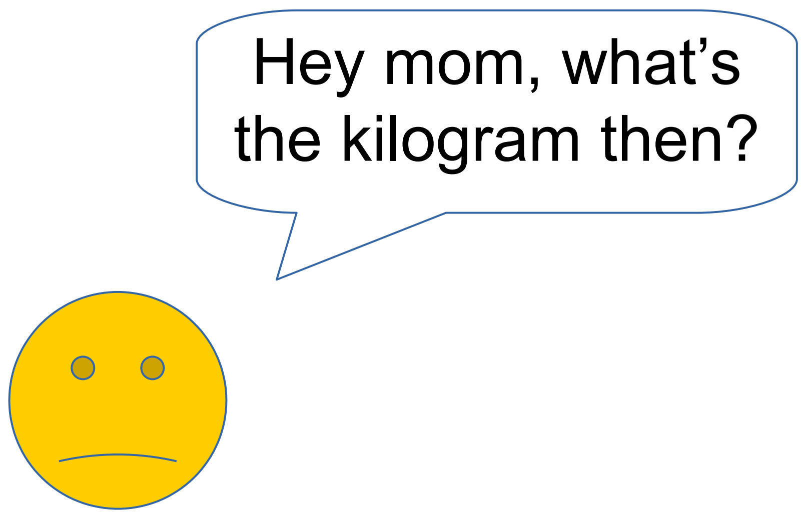
Before May 2019 (8th SI Brochure):

> "The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram."

Today (revised SI, 9th SI Brochure)

> "The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be 6.626 070 15 × 10^{-34} when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$."

"The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be 6.626 070 15 × 10^{-34} when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$."



Checkpoint 2

Do you understand this definition?

1. Yes, as I have been already extensively thought about it
2. I have already met it, and I think I understand it
3. It is the first time I see it, but I suppose I grasped the point
4. It is the first time I see it, and I find it hard to understand

"The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be $6.626\,070\,15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg $m^2\ s^{-1}$, where the metre and the second are defined in terms of c and $\Delta \nu_{Cs}$."

Our position: premises

0: We take the metrological correctness of the SI for granted

1: The metrological system is a key enabler for our society

2: The metrological system, including the SI, should be as understandable as it is possible

3. Technical standards play an important role in connecting the metrological system with our society

4. The definitions of the units in the revised SI are complex, and hard to understand by non-physicists, and phrased in terminologically peculiar way

Our position: consequence

IEC standards need to include definitions of the SI units that are

(α) in conformity with the 2018 CGPM Resolution

(β) terminologically correct

(γ) as understandable as possible to standards writers and users, translators, textbook writers, and the general public

and this is not a trivial outcome to achieve

Let us work together for this...

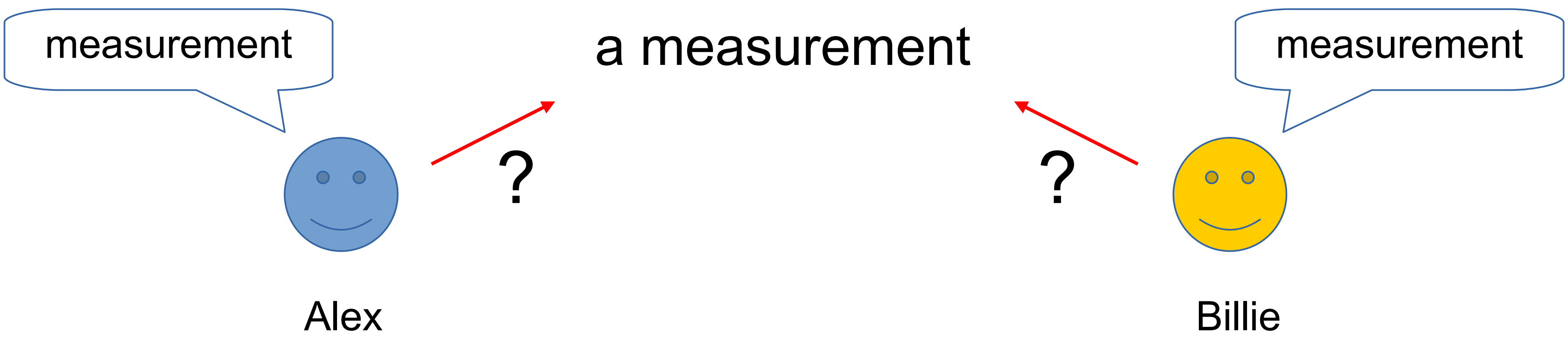
The role of language in standardization

Standardization is a **social endeavor**
and therefore an important task for it is **communication**,
as enabled by **language**

In a language **terms** refer to **objects**
(object: “anything perceivable or conceivable”)

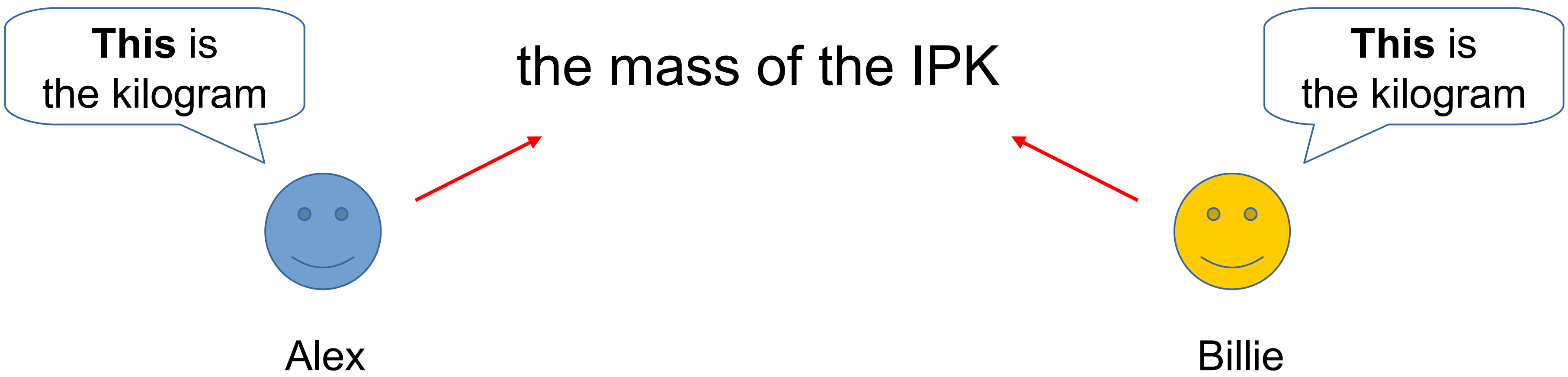
the English term: m-e-a-s-u-r-e-m-e-n-t — *refers to* → the object: measurement

The problem



How can we guarantee that with **the same term** different persons refer to **the same object**?

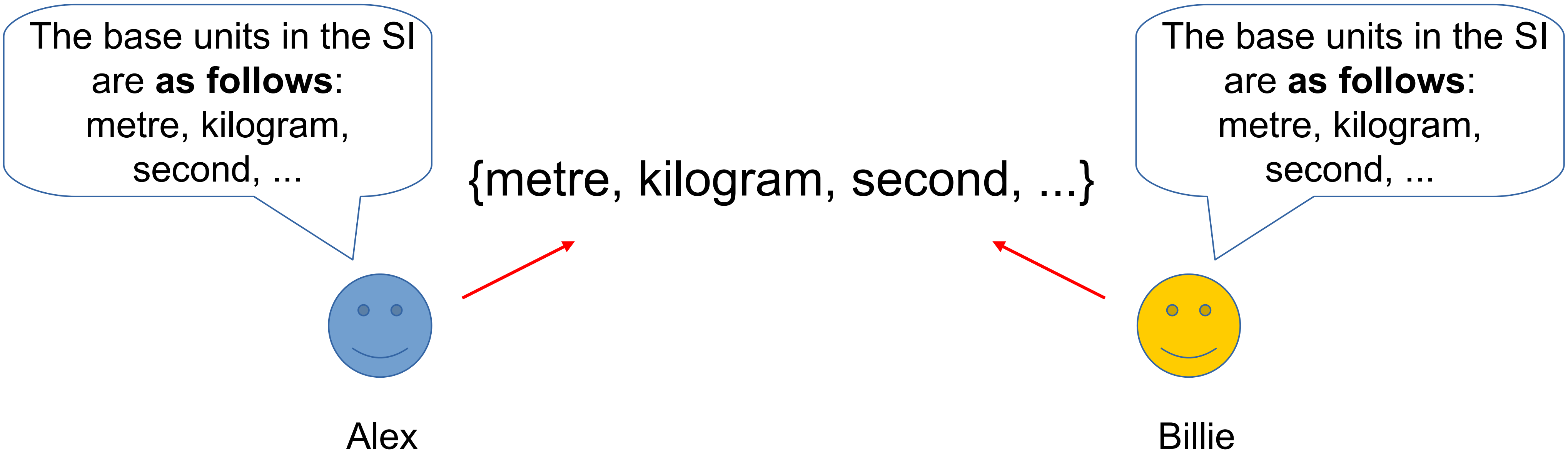
One simple solution



Reference by indication

(*it works only in some cases*)

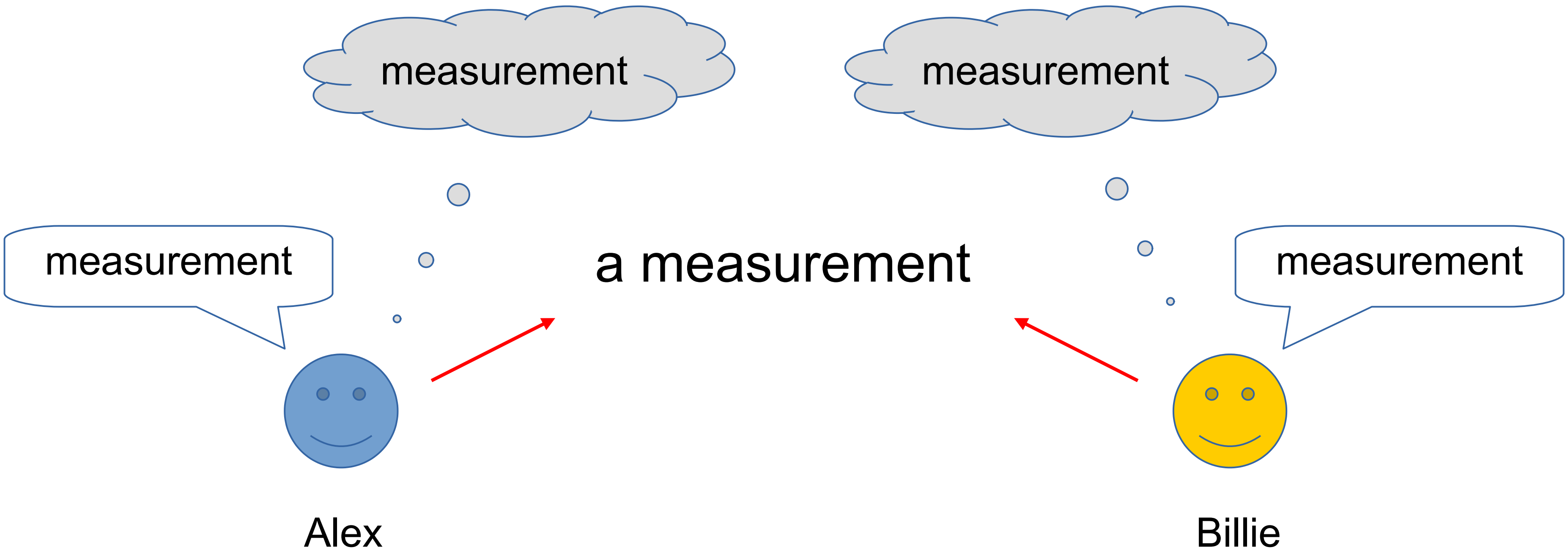
Another simple solution



Reference **by listing**

(*it works only in some cases*)

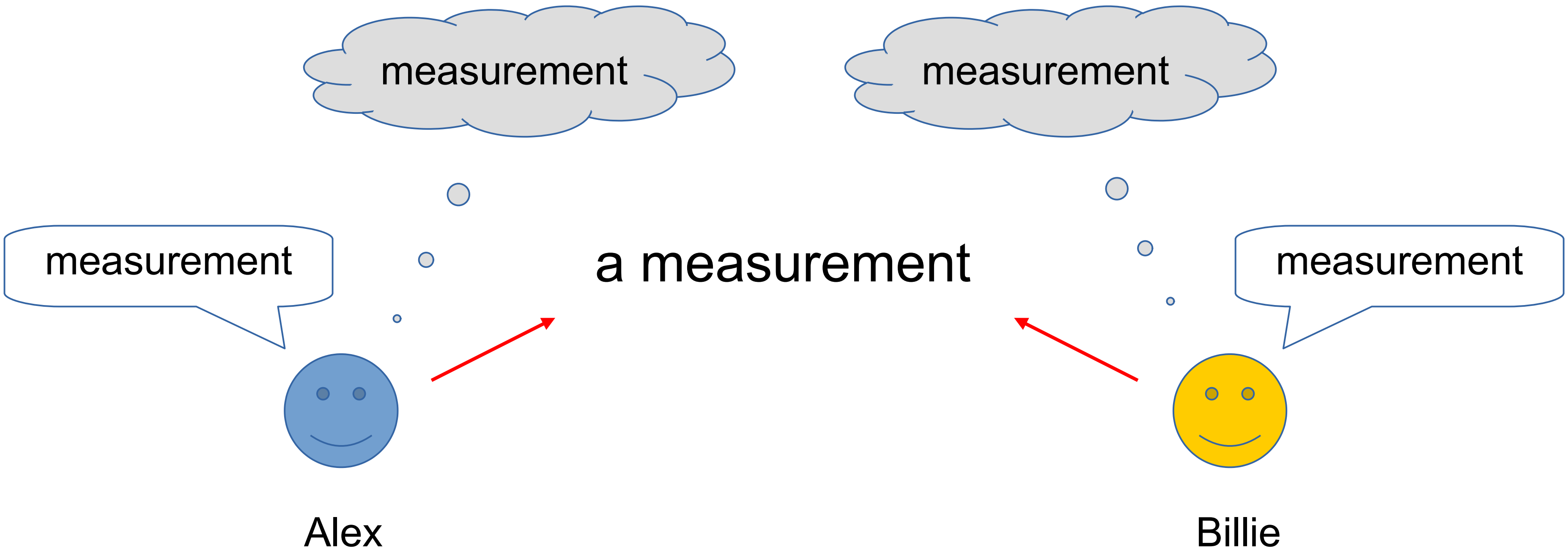
The usual, general solution



Reference **via conceptualization**

(*together with terms and objects,*
it requires introducing a third entity)

The problem



How can we guarantee that different persons

use the same term "measurement"

with the same meaning "measurement" ???

Checkpoint 3

Are you knowledgeable about this kind of problem?

1. Yes, I have extensive knowledge of terminology
2. I have some background information about this
3. I have never seen it as such, but I have some ideas about it
4. It is the first time I see it, and I find it hard to understand it

How can we guarantee that different persons

use the same term — measurement

with the same meaning — measurement ???

A solution:
defining the meaning of the term

The meaning of the <u>term</u> measurement

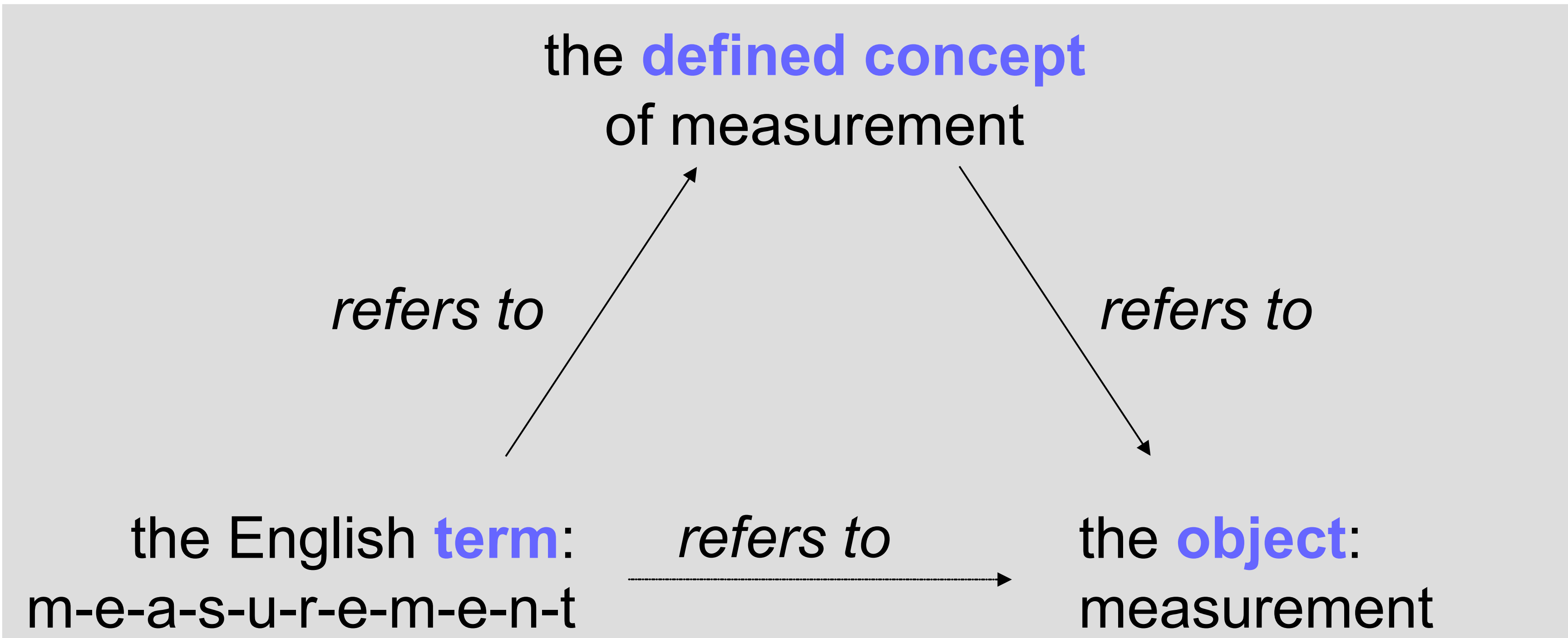
is defined as bla bla ...

so that when we say or write measurement

we mean the <u>concept</u> bla bla ...

and, most importantly,
we refer to the <u>object</u> measurement

The “triangle of reference”



A **term** refers to an **object**...

… because the **term** refers to a **concept** that is defined...

... and the definition of the **concept** refers to the **object**

Summary, so far

Premise: we use **terms** for referring to **objects**

Problem: how can we guarantee that that with the same term different persons refer to the same object?

Solution: by agreeing upon the meaning of the term

Problem: how can we agree upon the meaning of a term?

Solution: by means of a **definition**

The **formal** structure of a definition

preferred term

(optional)
admitted terms

definition

entry

Quantities and units / Basic concepts

112-01-14

unit of measurement
measurement unit
unit

real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the second quantity to the first one as a number

Note 1 – Units of measurement are designated by conventionally assigned names and symbols.

Note 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 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 generally not considered to be quantities of the same kind. Another example is the

(optional)
notes and examples

(source: www.electropedia.org/iev/iev.nsf/display?openform&ievref=112-01-14)

A vocabulary is a set of such entries

The **conceptual** structure of a definition

unit of measurement

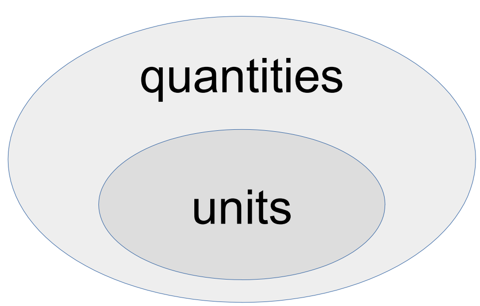
real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the second quantity to the first one as a number

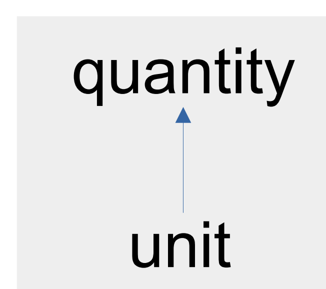
It is an example of an **intensional definition**, whose structure is
‘unit of measurement’ is defined as “real scalar quantity such that …”

so that

- a unit **is a** quantity (*a relation between objects*)
- ‘unit’ **is subordinate of** ‘quantity’ (*a relation between concepts*)

set diagram





concept diagram

Let’s do it with the definitions
of the base units of the revised SI

Three terminological conditions (A)

Let us consider the (simplest) example of the second:

> “The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency Δv_{Cs}, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1}.”

Condition A (***terms outside definitions***): “a definition is a statement that does not form a complete sentence. It must be combined with an entry term (designating the concept being defined) placed at the beginning of the entry in order to be read as a sentence” (ISO 704:2009: 6.3.2)

Easily done (shortened text)*:*

> second, s
> SI unit of time, defined by taking the fixed numerical value of the caesium frequency Δv_{Cs} to be *n* when expressed in s^{-1}

Three terminological conditions (B)

Condition B (***intensional definitions***): "a definition begins with a predicate noun stating the broader generic (superordinate) concept associated with the concept being defined, together with delimiters indicating the characteristics that delimit the concept being defined from coordinate concepts" (ISO 704:2009: 6.3.2)

Rather easily done:

> second, s
> duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta \nu_{Cs}$ is n when expressed in s^{-1}

Three terminological conditions (C)

Condition C (***non-circular definitions***): “If one concept is defined using a second concept, and that second concept is defined using the term or elements of the term designating the first concept, the resulting definitions are said to be circular (…) circular definitions make it impossible to fully understand the concept and shall be avoided” (ISO 704:2009: 6.5.2)

A definition must refer only to previously defined concepts

The definitions of the revised SI are phrased in a circular way!

For example, the second is defined in reference to the second

second, s
duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta \nu_{Cs}$ is n when expressed in s^{-1}

Checkpoint 4

What do you think about the condition of non-circularity?

1. I just agree: it is necessary to fulfill it
2. I suppose it is somehow important
3. I do not see why it is so important
4. I do not really understand it

A definition must refer only to previously defined concepts, and therefore be non-circular

Back to our starting point

IEC standards need to include definitions of the SI units that are

(α) in conformity with the 2018 CGPM Resolution
→ **???**

(β) terminologically correct
→ **???**

(γ) as understandable as possible to standards writers and users, translators, textbook writers, and the general public
→ **???**

Let us explore some options...

Option 0

Maintain the original, circular formulation,
by only fulfilling the easy (A & B) conditions:

> second, s
> duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$ is n when expressed in s^{-1}

(α) in conformity with CGPM	yes
(β) terminologically correct	no
(γ) as understandable as possible	???

Option –1

Set the numerical value of the defining constant,
and leave the unit undefined

> the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$ is *n* when expressed in s^{-1}

(α) in conformity with CGPM	yes
(β) terminologically correct	???
(γ) as understandable as possible	???

Option 1

Maintain the original formulation, but remove the circularity:

second, s
duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta\nu_{\mathrm{Cs}}$ is *n* when expressed in the inverse of this unit

(α) in conformity with CGPM	???
(β) terminologically correct	yes
(γ) as understandable as possible	???

Option 2

Recover the previous (explicit unit) definition:

second, s
duration of *n* periods of the caesium

(α) in conformity with CGPM	???
(β) terminologically correct	yes
(γ) as understandable as possible	yes

Checking these options with the metre

Option 0 (explicit constant, circular)

metre, m
length chosen as the SI unit of length, such that the fixed numerical value of the speed of light in vacuum *c* is *n* when expressed in $m\ s^{-1}$

Option –1 (no definition)

the fixed numerical value of the speed of light in vacuum *c* is *n* when expressed in $m\ s^{-1}$

Option 1 (explicit constant, non-circular)

metre, m
length chosen as the SI unit of length, such that the fixed numerical value of the speed of light in vacuum *c* is *n* when expressed in this unit times s^{-1}

Option 2 (explicit unit)

metre, m
length of the path travelled by light in vacuum in a duration of $1/n$ s

Checking these options with the kilogram

Option 0 (explicit constant, circular)

kilogram, kg
mass chosen as the SI unit of mass, such that the fixed numerical value of the Planck constant *h* is *n* when expressed in kg m^2 s^{-1}

Option –1 (no definition)

the fixed numerical value of the Planck constant *h* is *n* when expressed in kg m^2 s^{-1}

Option 1 (explicit constant, non-circular)

kilogram, kg
mass chosen as the SI unit of mass, such that the fixed numerical value of the Planck constant *h* is *n* when expressed in this unit times m^2 s^{-1}

Option 2 (explicit unit)

kilogram, kg
???

In summary...

		(α) in conformity with CGPM	(β) terminologically correct	(γ) as understandable as possible
0	second: duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$ is *n* when expressed in s^{-1}	yes	no	???
–1	the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$ is *n* when expressed in s^{-1}	yes	???	???
1	second: duration chosen as the SI unit of time, such that the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$ is *n* when expressed in the inverse of this unit	???	yes	???
2	second: duration of *n* periods of the caesium	???	yes	yes (but not always possible)

Do you agree with these judgments?

What do you think? What would you opt for?

Some references

ISO 704:2009, Terminology work – Principles and methods

ISO 1087-1:2000, Terminology work – Vocabulary – Part 1: Theory and application

ISO 860:2007, Terminology work – Harmonization of concepts and terms

L.Mari, J.Goodwin, Role of terminology in scientific and technical communication (https://www.iec.ch/standardsdev/resources/terminology)

L.Mari, J.Goodwin, E.Jacobson, L.Pendrill, The definitions of the base units in the revised SI: a terminological analysis, Measurement, 2020 (https://authors.elsevier.com/a/1ZsVJxsQa8B29 – free download before 27 November 2019)