Workshop on the determination of the Fundamental Constants

Eltville, Germany

2 February 2015

Fundamental Constants and the New SI

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NIST National Institute of Standards and Technology • U.S. Department of Commerce

Introduction

A comprehensive evaluation of fundamental constants was first done by R. Birge in 1929.

Values of the fundamental constants are currently recommended every 4 years by CODATA.

The values are obtained by a least-squares adjustment.

The constants are expressed in terms of units of the International System of Units (SI).

The SI is likely to be redefined in 2018.

The uncertainties of many fundamental constants will change significantly as a result.

Outline

Fundamental constants

International System of Units (SI)

Redefinition of the SI

Effects on fundamental constants

Some of the Fundamental Constants

- Newtonian constant of gravitation:
  $$G = 6.673\,84(80) \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}} \qquad [1.2 \times 10^{-4}]$$
- Avogadro constant:
  $$N_{\mathrm{A}} = 6.022\,141\,29(27) \times 10^{23}\ \mathrm{mol^{-1}} \qquad [4.4 \times 10^{-8}]$$
- electron mass:
  $$m_{\mathrm{e}} = 9.109\,382\,91(40) \times 10^{-31}\ \mathrm{kg} \qquad [4.4 \times 10^{-8}]$$
- Planck constant:
  $$h = 6.626\,069\,57(29) \times 10^{-34}\ \mathrm{J\,s} \qquad [4.4 \times 10^{-8}]$$
- electron mass (in u):
  $$m_{\mathrm{e}} = 5.485\,799\,0946(22) \times 10^{-4}\ \mathrm{u} \qquad [4.0 \times 10^{-10}]$$
- fine-structure constant:
  $$\alpha = 1/137.035\,999\,074(44) \qquad [3.2 \times 10^{-10}]$$
- Rydberg constant:
  $$R_\infty = 10\,973\,731.568\,539(55)\ \mathrm{m^{-1}} \qquad [5.0 \times 10^{-12}]$$

Electron mass in various units

- solar mass unit:

  $$m_\mathrm{e} = 4.580\,92(55) \times 10^{-61}\ \mathrm{M}_\circ \qquad [1.2 \times 10^{-4}]$$

- kilogram (SI):

  $$m_\mathrm{e} = 9.109\,382\,91(40) \times 10^{-31}\ \mathrm{kg} \qquad [4.4 \times 10^{-8}]$$

- relative atomic mass unit:

  $$m_\mathrm{e} = 5.485\,799\,0946(22) \times 10^{-4}\ \mathrm{u} \qquad [4.0 \times 10^{-10}]$$

- natural unit:

  $$m_\mathrm{e} = 1\ \mathrm{nu} \qquad [0]$$

The NIST Reference on Constants, Units, and Uncertainty

Information at the foundation of modern science and technology from the Physical Measurement Laboratory of NIST

CODATA Internationally recommended 2010 values of the Fundamental Physical Constants

Constants Topics:
- Values
- Energy Equivalents
- Searchable Bibliography
- Background

Constants Bibliography

Constants, Units & Uncertainty home page

Version history and disclaimer

(e.g., **electron mass**, most misspellings okay)

Search by name [ ] Search

Display ◉ alphabetical list, ○ table (image), or ○ table (pdf)

by clicking a category below

Universal | Adopted values | Frequently used constants
Electromagnetic | Non-SI units | Extensive listings
Atomic and nuclear | Conversion factors for energy equivalents | All values (ascii)
Physico-chemical | X-ray values

physics.nist.gov/constants

Find the correlation coefficient between any pair of constants
Data from the least-squares adjustment of the values of the constants

See also

Article on the 2010 adjustment of the values of the constants
Searchable bibliography on the constants
Background information related to the constants
Links to selected scientific data
Previous Values (2006) (2002) (1998) (1986) (1973) (1969)
The CODATA 2014 values of the constants will be posted in Spring of 2015.

DEADLINE NOTICES!

There will be an adjustment of the constants to provide the values for a revision of the International System of Units (SI) expected to take place in 2018. To be considered for use in this adjustment, new results must be **accepted for publication by 1 July 2017**.

The 2018 CODATA adjustment of the fundamental constants will be based on the revised SI, which will significantly affect the uncertainties of many constants. For data to be considered for use in this adjustment, they must be **discussed in a publication preprint or a publication by 1 July 2018**.

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2010

~~2006~~ CODATA RECOMMENDED VALUES OF THE FUNDAMENTAL CONSTANTS OF PHYSICS AND CHEMISTRY

NIST SP 959 ~~(Aug/2008)~~ UPDATE PUBS

Values from: P. J. Mohr, B. N. Taylor, and D. B. Newell, *Rev. Mod. Phys.* ~~80, 633 (2008)~~ and *J. Phys. Chem. Ref. Data* ~~37, 1187 (2008).~~ The number in parentheses is the one-sigma ($1\ \sigma$) uncertainty in the last two digits of the given value.

Quantity	Symbol	Numerical value	Unit
speed of light in vacuum	c, c_0	299 792 458 (exact)	$\mathrm{m\ s^{-1}}$
magnetic constant	μ_0	$4\pi \times 10^{-7}$ (exact)	$\mathrm{N\ A^{-2}}$
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817... \times 10^{-12}$	$\mathrm{F\ m^{-1}}$
Newtonian constant of gravitation	G	6.674 ~~28(67)~~ $\times 10^{-11}$ [384(80)]	$\mathrm{m^3\ kg^{-1}\ s^{-2}}$
Planck constant	h	6.626 06~~8 96(33)~~ $\times 10^{-34}$ [957(29)]	J s
$h/2\pi$	$\hbar$	1.054 571 ~~628(53)~~ $\times 10^{-34}$ [726(47)]	J s
elementary charge	e	1.602 176 ~~487(40)~~ $\times 10^{-19}$ [565(35)]	C
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	7.297 352 5~~376(50)~~ $\times 10^{-3}$ [698(24)]	
inverse fine-structure constant	α^{-1}	137.035 999 ~~679(94)~~ [074(44)]	
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 5~~27(73)~~ [39(55)]	$\mathrm{m^{-1}}$
Bohr radius $\alpha/4\pi R_\infty$	a_0	0.529 177 2~~08 59(36)~~ $\times 10^{-10}$ [1092(17)]	m
Bohr magneton $e\hbar/2m_e$	μ_B	927.400 9~~15(23)~~ $\times 10^{-26}$ [68(20)]	$\mathrm{J\ T^{-1}}$

REVIEWS OF MODERN PHYSICS, VOLUME 84, OCTOBER–DECEMBER 2012

CODATA recommended values of the fundamental physical constants: 2010*

Peter J. Mohr,† Barry N. Taylor,‡ and David B. Newell§

National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8420, USA

(published 13 November 2012)

This paper gives the 2010 self-consistent set of values of the basic constants and conversion factors of physics and chemistry recommended by the Committee on Data for Science and Technology (CODATA) for international use. The 2010 adjustment takes into account the data considered in the 2006 adjustment as well as the data that became available from 1 January 2007, after the closing date of that adjustment, until 31 December 2010, the closing date of the new adjustment. Further, it describes in detail the adjustment of the values of the constants, including the selection of the final set of input data based on the results of least-squares analyses. The 2010 set replaces the previously recommended 2006 CODATA set and may also be found on the World Wide Web at physics.nist.gov/constants.

DOI: 10.1103/RevModPhys.84.1527 PACS numbers: 06.20.Jr, 12.20.−m

Formation of CODATA

- **1966 –ICSU establishes the Committee on Data for Science and Technology (CODATA)**
  - To strengthen international science for the benefit of society by promoting improved scientific and technical data management and use

icsu.org

codata.org

- **1969 CODATA establishes the Task Group on Fundamental Constants**
  - To periodically provide the scientific and technological communities with a self-consistent set of internationally recommended values of the basic constants and conversion factors of physics and chemistry based on all of the relevant data available at a given point in time.

Task Group Members for the 2014 Adjustment

F. Cabiati, Istituto Nazionale di Ricerca Metrologica, Italy
J. Fischer, Physikalisch-Technische Bundesanstalt, Germany
J. Flowers (deceased), National Physical Laboratory, UK
K. Fujii, National Metrology Institute of Japan, Japan
S. G. Karshenboim, Pulkovo Observatory, Russia
E. de Mirandés, Bureau international des poids et mesures
P. J. Mohr, National Institute of Standard and Technology, USA
D. B. Newell, National Institute of Standard and Technology, USA
F. Nez, Laboratoire Kastler-Brossel, France
K. Pachucki, University of Warsaw, Poland
T. J. Quinn, Bureau international des poids et mesures
C. Thomas, Bureau international des poids et mesures
B. N. Taylor, National Institute of Standard and Technology, USA
B. M. Wood, National Research Council, Canada
Z. Zhang, National Institute of Metrology, China

Fundamental constants and the New SI

The fundamental constants are given in SI units.

Changes in the SI units will result in changes in the constants.

It is expected that the SI will be redefined in 2018 in terms of fundamental constants.

The change in the SI is motivated in part by problems with maintaining the kilogram mass standard.

Barney & Clyde

BY GENE WEINGARTEN, DAN WEINGARTEN AND DAVID CLARK

January 25, 2015

GO

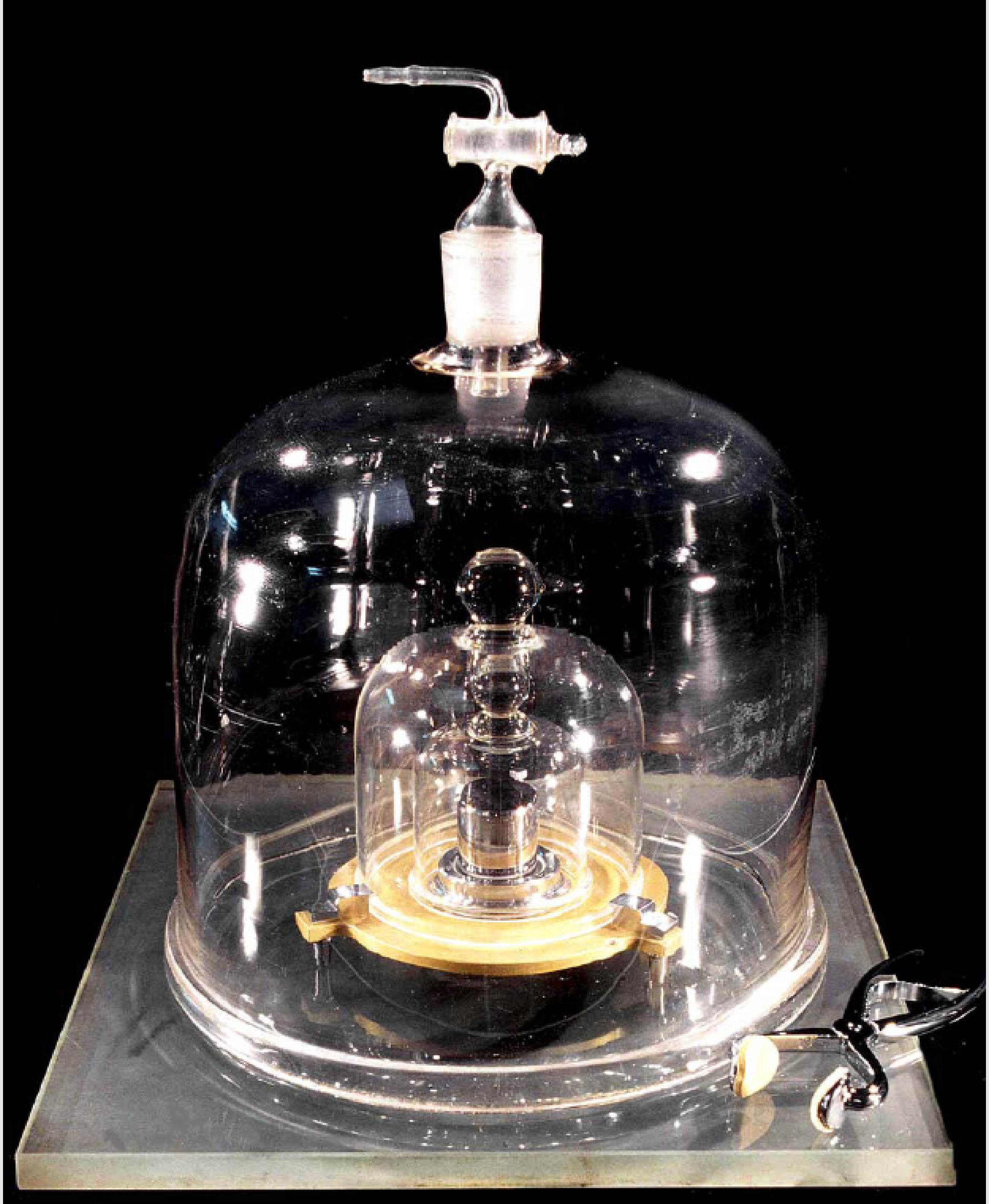
Limitations of the current kilogram prototype definition

The prototype definition is not linked to an unchanging property of nature.

The mass of the international prototype appears to be changing relative to the mass of its copies.

The prototype and its copies appear to gain mass over time and lose mass when washed for use in comparisons.

The kilogram mass definition cannot be realized independently of the international prototype.

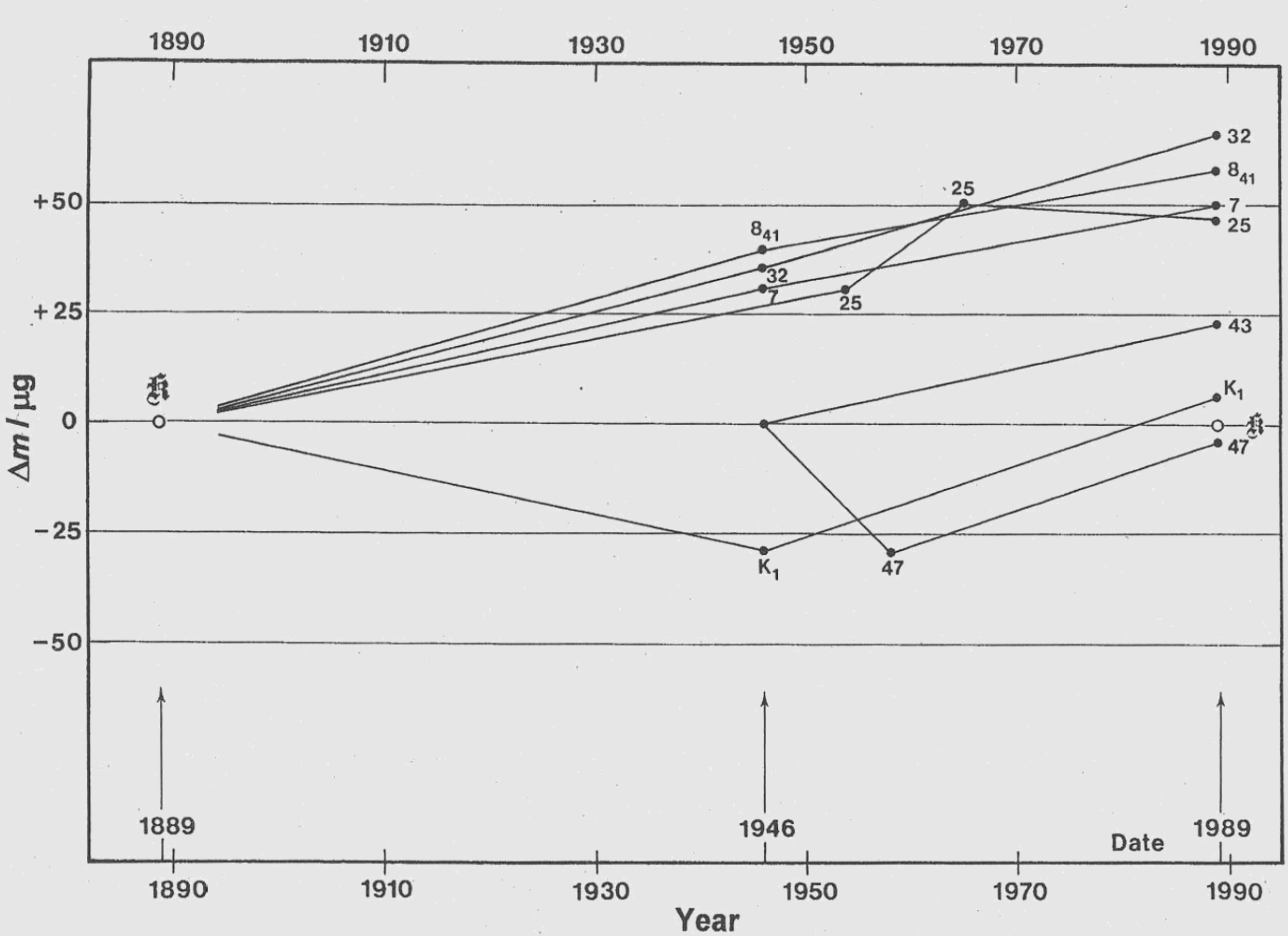


official copies (3 of 6)

international prototype

official copies (3 of 6)

La Troisième Vérification Périodique des Prototypes Nationaux du Kilogramme (1988-1992)



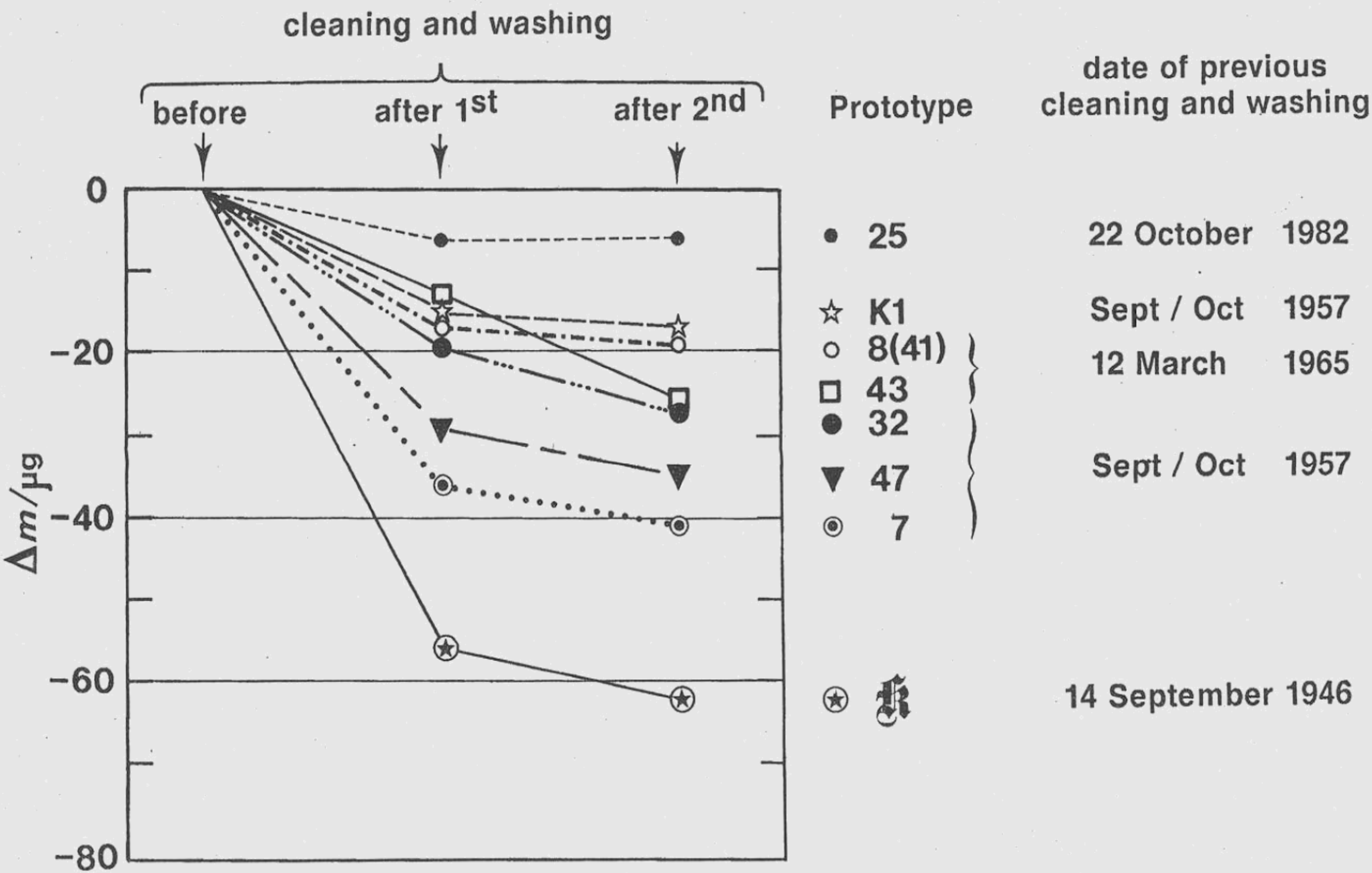


Fig. 2. — Change in mass Δm observed after each cleaning and washing of the international prototype 𝔎, its six official copies and prototype No. 25.

International System of Units (SI)

SI base units and symbols

- meter m (length)
- kilogram kg (mass)
- second s (time)
- ampere A (electric current)
- kelvin K (thermodynamic temperature)
- mole mol (amount of substance)
- candela cd (luminous intensity)

Some SI derived units and symbols

- hertz Hz (frequency)
- newton N (force)
- joule J (energy)
- coulomb C (electric charge)
- volt V (electric potential difference)

Non-SI units and symbols

- electron volt eV (energy)
- unified atomic mass unit u (mass)

New SI

In the New SI, the fundamental constants, c, h, e, k, N_A, ν_{Cs}, ... are given fixed numerical values.

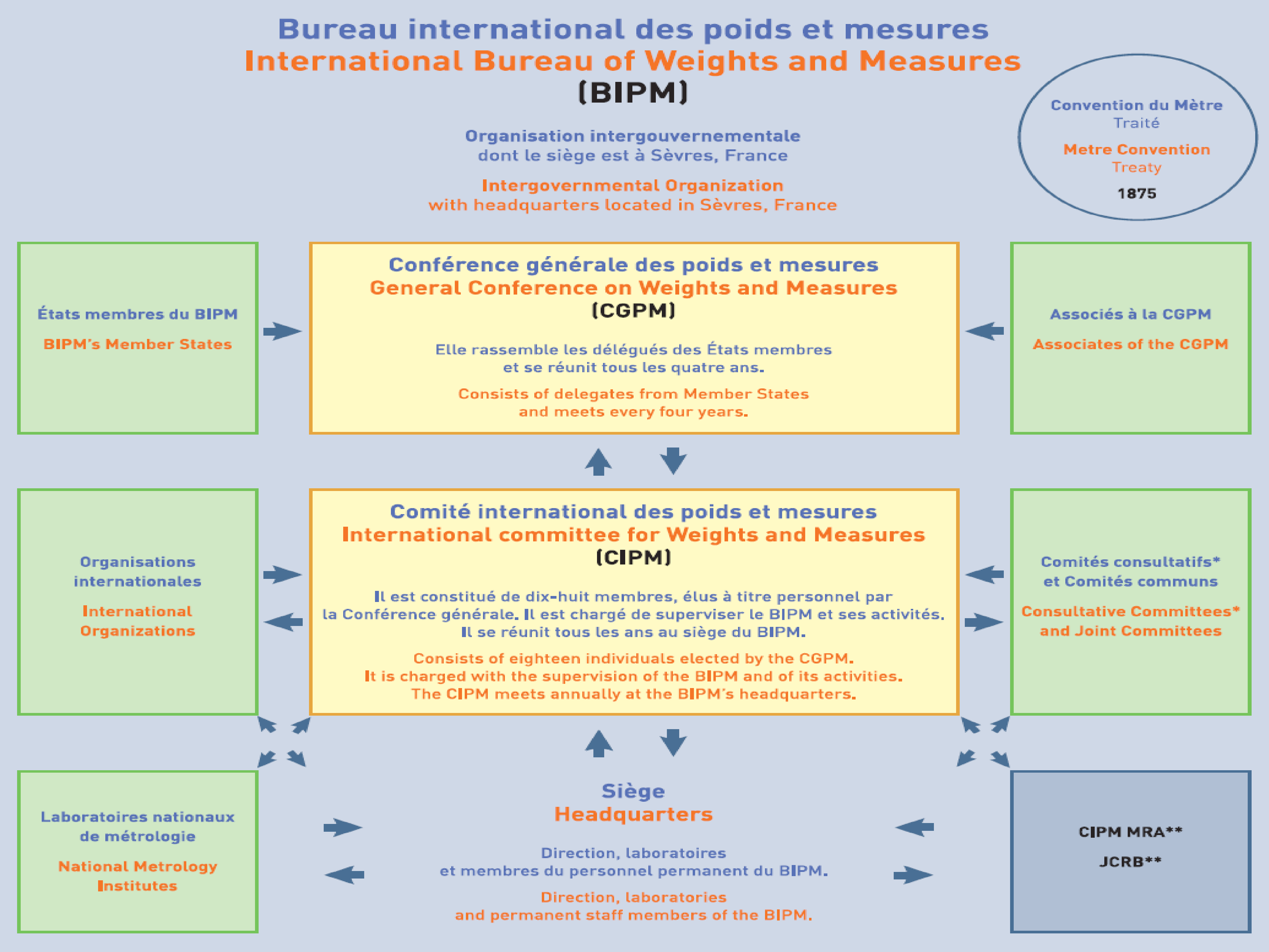
Based on this definition, measurements can be made in terms of SI units.

The quantities represented by the traditional base units can all be determined from this definition, even though there is not a one-to-one correspondence between the constants and the base units.

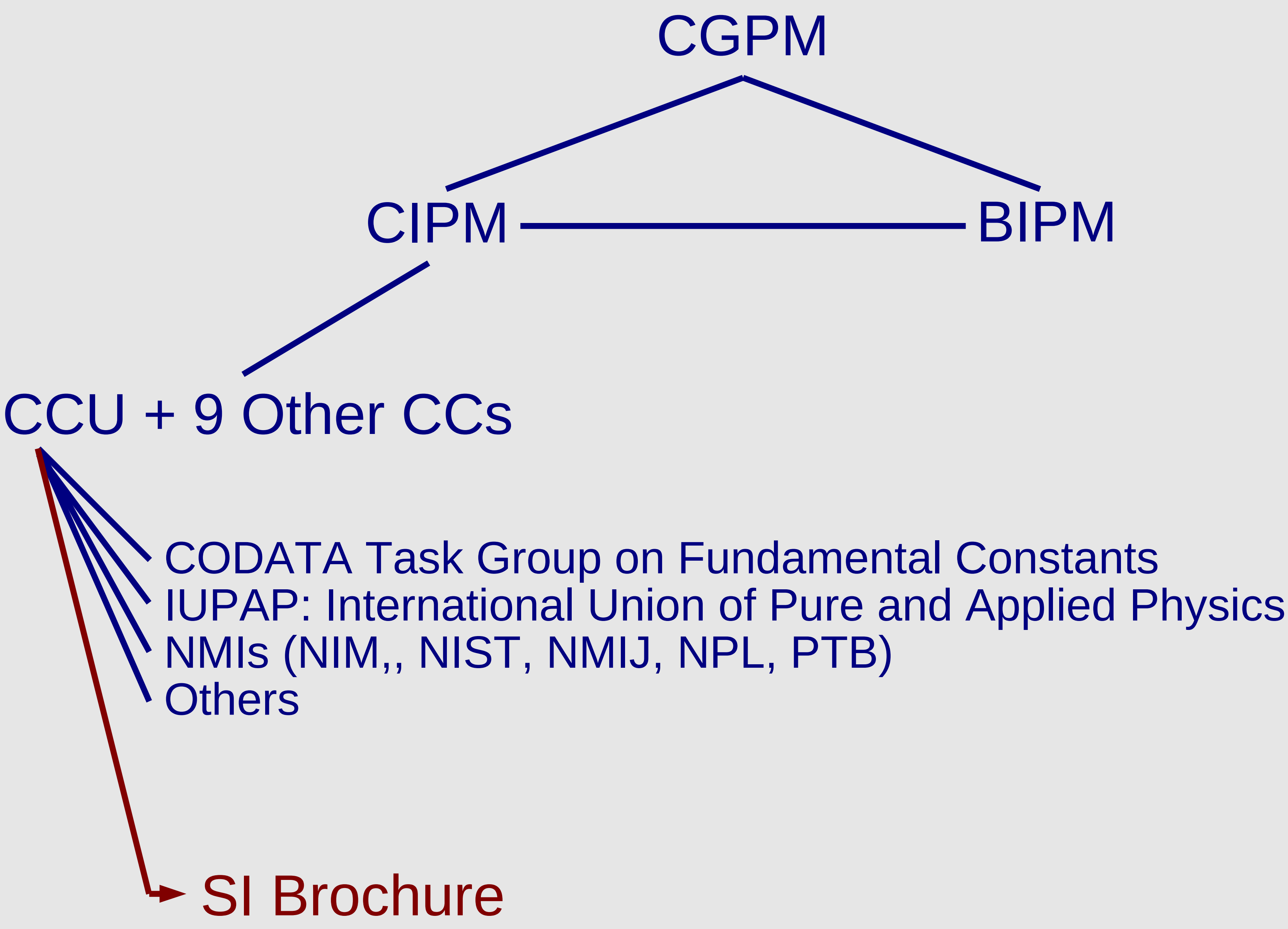
The traditional set of base units determines all the units in the SI.

So assigning fixed values to the fundamental constants c, h, e, k, N_A, ν_{Cs}, ... determines all the units in the SI.

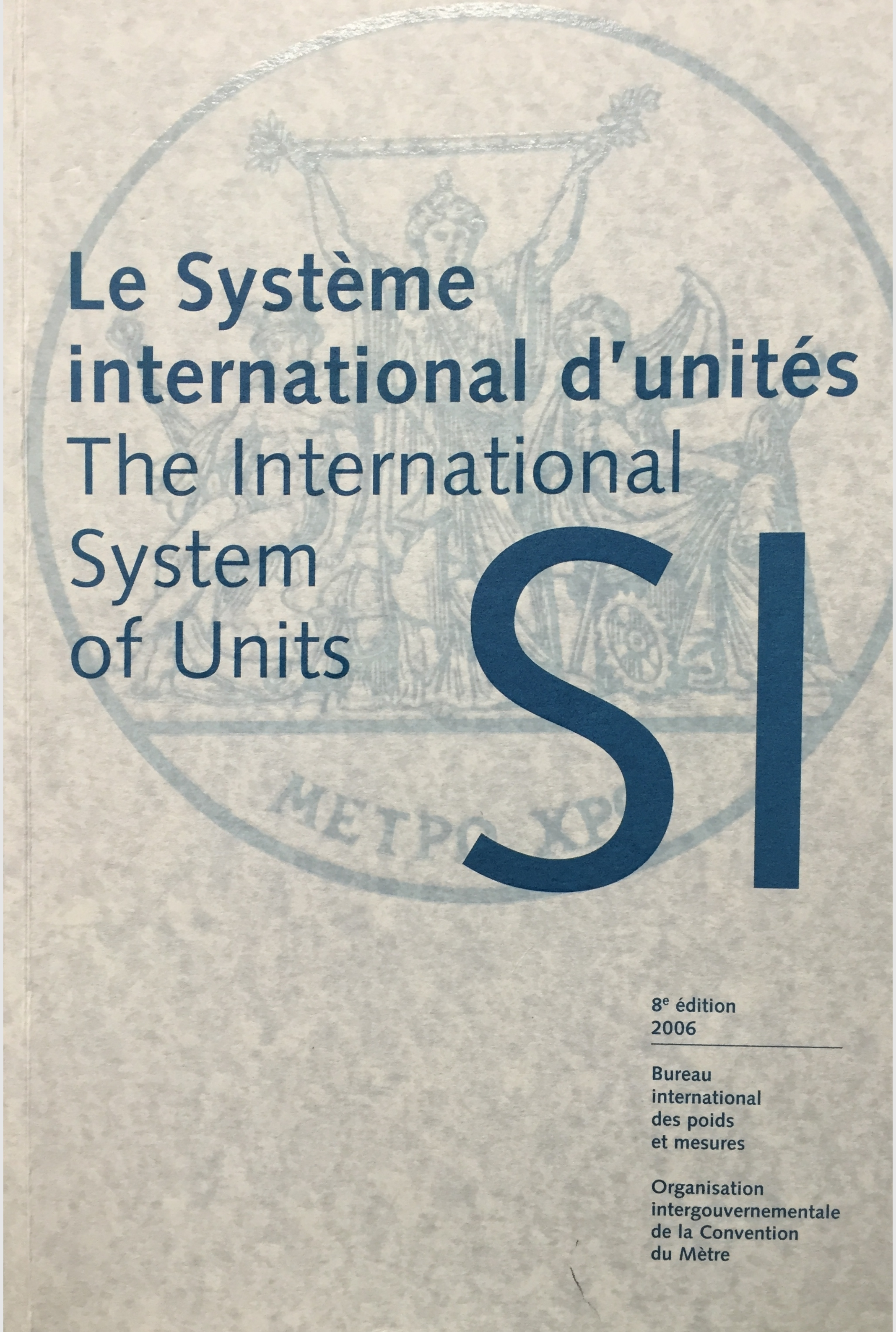
The distinction between base units and other units is unnecessary.


Bureau international des poids et mesures
International Bureau of Weights and Measures
(BIPM)
Organisation intergouvernementale
dont le siège est à Sèvres, France
Intergovernmental Organization
with headquarters located in Sèvres, France
Convention du Mètre
Traité
Metre Convention
Treaty
1875
États membres du BIPM
BIPM's Member States
Conférence générale des poids et mesures
General Conference on Weights and Measures
(CGPM)
Elle rassemble les délégués des États membres
et se réunit tous les quatre ans.
Consists of delegates from Member States
and meets every four years.
Associés à la CGPM
Associates of the CGPM
Organisations internationales
International Organizations
Comité international des poids et mesures
International committee for Weights and Measures
(CIPM)
Il est constitué de dix-huit membres, élus à titre personnel par
la Conférence générale. Il est chargé de superviser le BIPM et ses activités.
Il se réunit tous les ans au siège du BIPM.
Consists of eighteen individuals elected by the CGPM.
It is charged with the supervision of the BIPM and of its activities.
The CIPM meets annually at the BIPM's headquarters.
Comités consultatifs*
et Comités communs
Consultative Committees*
and Joint Committees
Laboratoires nationaux
de métrologie
National Metrology
Institutes
Siège
Headquarters
Direction, laboratoires
et membres du personnel permanent du BIPM.
Direction, laboratories
and permanent staff members of the BIPM.
CIPM MRA**
JCRB**

Organization Chart



SI Brochure


Le Système international d'unités
The International System of Units
SI
ΜΕΤΡΟ ΧΡ
8e édition
2006
Bureau international des poids et mesures
Organisation intergouvernementale de la Convention du Mètre

2.2 The SI in terms of seven defining constants

The international system of units, the SI, is the system of units in which

- **the unperturbed ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ is exactly 9 192 631 770 hertz,**
- **the speed of light in vacuum c is exactly 299 792 458 metre per second,**
- **the Planck constant h is exactly $6.626\ 069\ 57 \times 10^{-34}$ joule second,**
- **the elementary charge e is exactly $1.602\ 176\ 565 \times 10^{-19}$ coulomb,**
- **the Boltzmann constant k is exactly $1.380\ 648\ 8 \times 10^{-23}$ joule per kelvin,**
- **the Avogadro constant N_{A} is exactly $6.022\ 141\ 29 \times 10^{23}$ reciprocal mole,**
- **the luminous efficacy K_{cd} of monochromatic radiation of frequency 540×10^{12} hertz is exactly 683 lumen per watt,**

where the hertz, joule, coulomb, lumen, and watt, with unit symbols Hz, J, C, lm, and W, respectively, are related to the units second, metre, kilogram, ampere, kelvin, mole, and candela, with unit symbols s, m, kg, A, K, mol, and cd, respectively, according to the relations $\mathrm{Hz} = \mathrm{s}^{-1}$ (for periodic phenomena), $\mathrm{J} = \mathrm{kg\ m^2\ s^{-2}}$, $\mathrm{C} = \mathrm{A\ s}$, $\mathrm{lm} = \mathrm{cd\ sr}$, and $\mathrm{W} = \mathrm{kg\ m^2\ s^{-3}}$. The steradian, symbol sr, is the SI unit of solid angle and is a special name and symbol for the number 1, so that $\mathrm{sr} = \mathrm{m^2\ m^{-2}} = 1$.

Electrical measurements in the New SI

- Voltage: Josephson effect

$$V \propto \frac{1}{K_{\mathrm{J}}} \qquad K_{\mathrm{J}} = \frac{2e}{h}$$

- Resistance: Quantum Hall effect

$$R \propto R_{\mathrm{K}} \qquad R_{\mathrm{K}} = \frac{h}{e^2}$$

- Current:

$$I = \frac{V'}{R} \propto e$$

- Power: $P = IV = \frac{V'V}{R} \propto \frac{1}{K_{\mathrm{J}}^2 R_{\mathrm{K}}} = \frac{h}{4}$

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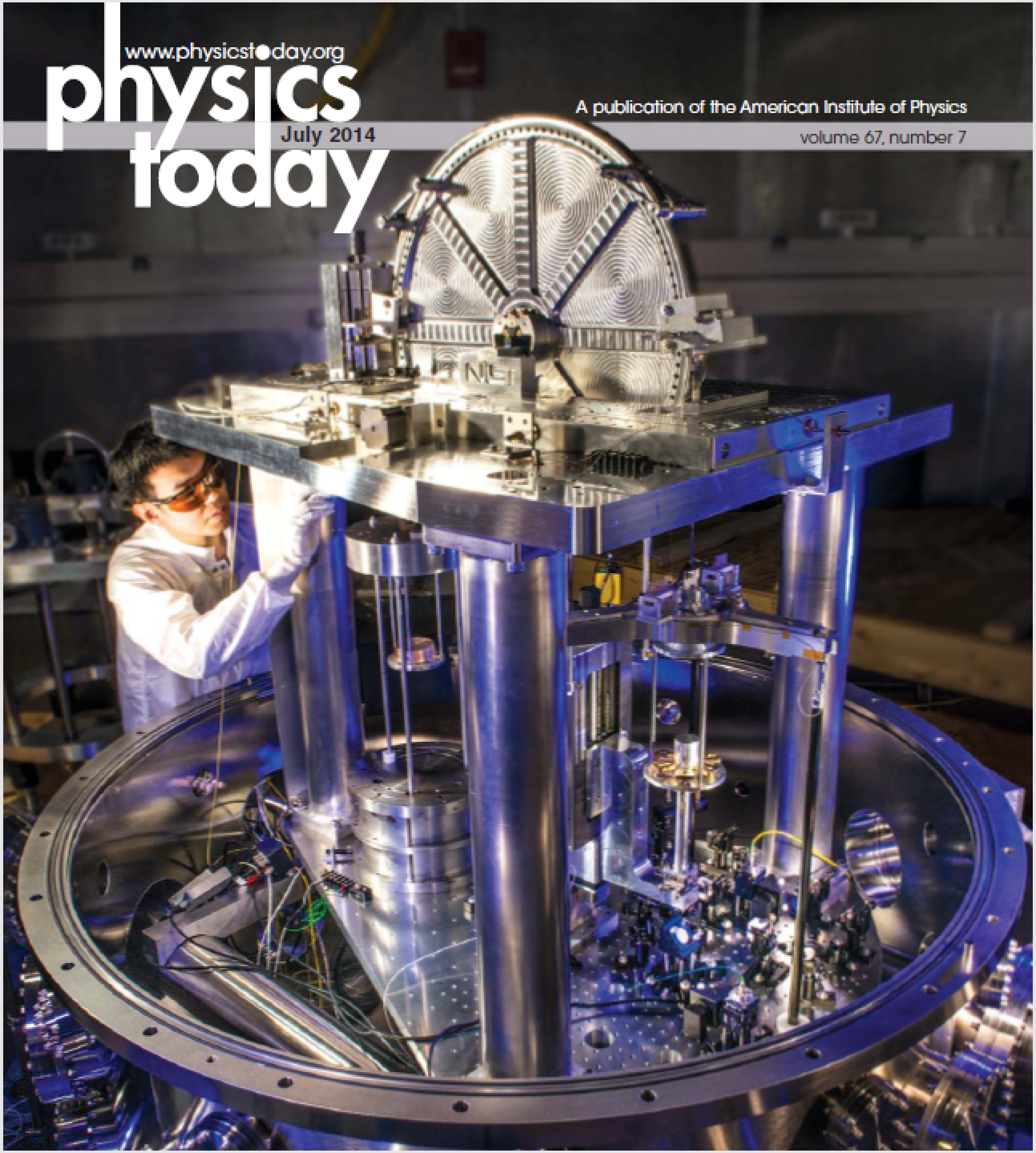

Relation between the Avogadro constant N_A and the Planck constant h

- **Rydberg constant definition:**

$$R_\infty = \frac{\alpha^2 m_e c}{2h} \quad \Rightarrow \quad \frac{1}{m_e} = \frac{\alpha^2 c}{2hR_\infty}$$

- **unified atomic mass unit u:**

$$m_e = A_r(e)\,\mathrm{u} \quad \Rightarrow \quad \frac{1}{\mathrm{u}} = \frac{A_r(e)}{m_e}$$

- **Avagadro constant:**

$$N_A = \frac{10^{-3}\ \mathrm{kg/mol}}{1\ \mathrm{u}} = A_r(e)\left(\frac{\alpha^2 c}{2hR_\infty}\right)\ 10^{-3}\ \mathrm{kg/mol}$$

"Silicon sphere for Avogadro project" by The Commonwealth Scientific and Industrial Research Organisation of Australia - CSIRO.

Thermodynamic temperatures

Ideal gas thermometry

- Constant-volume gas thermometry (< 900 K)

$$PV = nN_A kT$$

- Acoustic gas thermometry (< 900 K)

$$kT = \left(\frac{m}{\gamma}\right)v^2$$

Noise thermometry (< 1300 K)

$$\overline{U^2} = 4kTR\Delta f$$

Detector-based radiometry

- Total radiation thermometry (60 K to 400 K)

$$M(T) = n^2\sigma T^4, \sigma = \frac{2}{12}\frac{\pi^5 k^4}{h^3 c^2}$$

- Spectral radiation thermometry (900 K to > 3000 K)

$$L(\lambda, T) = \frac{\mathrm{c}_{1\mathrm{L}}}{n^2\lambda^5\left(\exp\left(\frac{\mathrm{h}}{n\lambda\, c\, kT}\right) - 1\right)}$$

The Boltzmann constant, *k*, is determined at the triple point of water.

Quantity	Symbol	Present SI $u_r \times 10^9$	New SI $u_r \times 10^9$
International prototype of the kilogram	$m(K)$	0	44
Permeability of free space	μ_0	0	0.32
Permittivity of free space	ε_0	0	0.32
Triple point of water	T_{TPW}	0	910
Molar mass of carbon-12	$M(^{12}C)$	0	0.70
Planck constant	h	44	0
Elementary charge	e	22	0
Boltzmann constant	k	910	0
Avogadro constant	N_A	44	0
Molar gas constant	R	910	0
Faraday constant	F	22	0
Stefan–Boltzmann constant	σ	3600	0
Electron mass	m_e	44	0.64
Atomic mass unit	m_u	44	0.70
Mass of carbon-12	$m(^{12}C)$	44	0.70
Josephson constant	K_J	22	0
von Klitzing constant	R_K	0.32	0
Fine-structure constant	α	0.32	0.32
$E = mc^2$ energy equivalent	J↔kg	0	0
$E = hc/\lambda$ energy equivalent	J↔m^{-1}	44	0
$E = h\nu$ energy equivalent	J↔Hz	44	0
$E = kT$ energy equivalent	J↔K	910	0
1 J = 1 (C/e) eV energy equivalent	J↔eV	22	0

From D.Newell (2014)

Unit Democracy

Base Units

Derived Units → SI Units

Dimensionless Units

OPEN ACCESS
IOP Publishing

Metrologia

Metrologia **52** (2015) 40–47

doi:10.1088/0026-1394/52/1/40

Dimensionless units in the SI

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Abstract

The International System of Units (SI) is supposed to be coherent. That is, when a combination of units is replaced by an equivalent unit, there is no additional numerical factor. Here we consider dimensionless units as defined in the SI, e.g. angular units like radians or steradians and counting units like radioactive decays or molecules. We show that an incoherence may arise when different units of this type are replaced by a single dimensionless unit, the unit 'one', and suggest how to properly include such units into the SI in order to remove the incoherence. In particular, we argue that the radian is the appropriate coherent unit for angles and that hertz is not a coherent unit in the SI. We also discuss how including angular and counting units affects the fundamental constants.

Coherent units in the SI

$$E = \frac{1}{2} m v^2 = \frac{1}{2} (2\ \mathrm{kg})\,(3\ \mathrm{m/s})^2 = \frac{2 \cdot 3^2}{2}\ \mathrm{kg\ m^2\ s^{-2}} = 9\ \mathrm{J}$$

$$\mathrm{kg\ m^2\ s^{-2}} = \mathrm{J}$$ (coherent)

Coherent units in the SI

$$E = \frac{1}{2} m v^2 = \frac{1}{2} (2\ \mathrm{kg})\,(3\ \mathrm{m/s})^2 = \frac{2 \cdot 3^2}{2}\ \mathrm{kg\ m^2\ s^{-2}} = 9\ \mathrm{J}$$

$$\mathrm{kg\ m^2\ s^{-2}} = \mathrm{J}$$ (coherent)

$$1\ \mathrm{Hz} = 2\pi\ \mathrm{rad\ s^{-1}}$$

Table 3. Coherent derived units in the SI with special names and symbols

	SI coherent derived unit [a]			
Derived quantity	Name	Symbol	Expressed in terms of other SI units	Expressed in terms of SI base units
plane angle	radian [b]	rad	1 [b]	m/m
solid angle	steradian [b]	sr [c]	1 [b]	m^2/m^2
frequency	hertz [d]	Hz		s^{-1}
force	newton	N		$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1}\ kg\ s^{-2}$
energy, work, amount of heat	joule	J	N m	$m^2\ kg\ s^{-2}$
power, radiant flux	watt	W	J/s	$m^2\ kg\ s^{-3}$
electric charge, amount of electricity	coulomb	C		s A
electric potential difference, electromotive force	volt	V	W/A	$m^2\ kg\ s^{-3}\ A^{-1}$
capacitance	farad	F	C/V	$m^{-2}\ kg^{-1}\ s^4\ A^2$
electric resistance	ohm	Ω	V/A	$m^2\ kg\ s^{-3}\ A^{-2}$

Coherent units in the SI

$$E = \frac{1}{2}mv^2 = \frac{1}{2}(2\ \mathrm{kg})\,(3\ \mathrm{m/s})^2 = \frac{2 \cdot 3^2}{2}\ \mathrm{kg\ m^2\ s^{-2}} = 9\ \mathrm{J}$$

$$\mathrm{kg\ m^2\ s^{-2}} = \mathrm{J}$$ (coherent)

$$1\ \mathrm{Hz} = 2\pi\ \mathrm{rad\ s^{-1}}$$

Coherent units in the SI

$$E = \frac{1}{2} m v^2 = \frac{1}{2} (2\ \mathrm{kg})\,(3\ \mathrm{m/s})^2 = \frac{2 \cdot 3^2}{2}\ \mathrm{kg\ m^2\ s^{-2}} = 9\ \mathrm{J}$$

$$\mathrm{kg\ m^2\ s^{-2} = J}$$ (coherent)

$$1\ \mathrm{Hz}\ =\ 2\pi\ \mathrm{rad\ s^{-1}}$$

$$1\ \mathrm{s^{-1}}\ =\ 2\pi\ \mathrm{s^{-1}}$$

Coherent units in the SI

$$E = \frac{1}{2} m v^2 = \frac{1}{2} (2\ \mathrm{kg})\, (3\ \mathrm{m/s})^2 = \frac{2 \cdot 3^2}{2}\ \mathrm{kg\ m^2\ s^{-2}} = 9\ \mathrm{J}$$

$$\mathrm{kg\ m^2\ s^{-2} = J}$$ (coherent)

$$1\ \mathrm{Hz}\ =\ 2\pi\ \mathrm{rad\ s^{-1}}$$

$$1\ \mathrm{s^{-1}}\ =\ 2\pi\ \mathrm{s^{-1}}$$

$$1\ =\ 2\pi$$ (?)

cycles vs radians

cycles ⟶ 1 vs radians ⟶ 1

$$\mathrm{e}^{x} = 1 + x + \frac{x^2}{2} + \ldots$$

$$\mathrm{e}^{\mathrm{i}y} = \cos y + \mathrm{i}\sin y$$

$$\mathrm{e}^{\mathrm{i}\theta} \implies \mathrm{e}^{\mathrm{i}y} \quad \text{where} \quad \theta = y \text{ rad}$$

"rad" so that for one complete revolution, we have

$$\theta = y \text{ rad} \to (y + 2\pi) \text{ rad} = y \text{ rad} \implies \mathrm{e}^{\mathrm{i}y} \to \mathrm{e}^{\mathrm{i}(y+2\pi)} = \mathrm{e}^{\mathrm{i}y}$$

$$\mathrm{e}^{\mathrm{i}\theta/\mathrm{rad}} \to \mathrm{e}^{\mathrm{i}\theta}$$

$$\mathrm{e}^{\mathrm{i}(kx-\omega t)/\mathrm{rad}} \to \mathrm{e}^{\mathrm{i}(kx-\omega t)}$$

Consequences for fundamental constants

$$\mathrm{Hz} = \mathrm{cycles\ s^{-1}} \neq \mathrm{s^{-1}}$$

$$\boldsymbol{E} = h\nu \implies h = \frac{\boldsymbol{E}}{\nu} = 6.626\ldots\ \mathrm{J\ Hz^{-1}} \neq 6.626..\ \mathrm{J\ s}$$

$$\boldsymbol{E} = \hbar\omega \implies \hbar = \frac{\boldsymbol{E}}{\omega} = 1.054\ldots\ \mathrm{J/(rad\ s^{-1})} \ = \ 1.054\ldots\ \mathrm{J\ s\ rad^{-1}}$$

$$\rightarrow\ 1.054\ldots\ \mathrm{J\ s}$$

On the future revision of the SI

→ At its 25th meeting (November 2014) the CGPM adopted a Resolution on the future revision of the International System of Units. This Resolution built on the CGPM's previous Resolution (2011), which took note of the CIPM's intention to propose a revision of the SI and set out a detailed road-map towards the future changes.

> In the "New SI" four of the SI base units – namely the kilogram, the ampere, the kelvin and the mole – will be redefined in terms of constants; the new definitions will be based on fixed numerical values of the Planck constant (h), the elementary charge (e), the Boltzmann constant (k_B), and the Avogadro constant (N_A), respectively. Further, the definitions of all seven base units of the SI will also be uniformly expressed using the explicit-constant formulation, and specific *mises en pratique* will be drawn up to explain the realization of the definitions of each of the base units in a practical way.

- SI road-map (updated 2014)
- Resolution 1 of the CGPM (2014): On the future revision of the International System of Units, the SI
- Resolution 1 of the CGPM (2011): On the possible future revision of the International System of Units, the SI

The NIST Reference on Constants, Units, and Uncertainty

Information at the foundation of modern science and technology from the Physical Measurement Laboratory of NIST

CODATA Internationally recommended 2010 values of the Fundamental Physical Constants

Constants Topics:
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Energy Equivalents
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Version history and disclaimer

(e.g., **electron mass**, most misspellings okay)

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Universal	Adopted values	Frequently used constants
Electromagnetic	Non-SI units	Extensive listings
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Physico-chemical	X-ray values	

Find the correlation coefficient between any pair of constants
Data from the least-squares adjustment of the values of the constants

See also

Article on the 2010 adjustment of the values of the constants
Searchable bibliography on the constants
Background information related to the constants
Links to selected scientific data
Previous Values (2006) (2002) (1998) (1986) (1973) (1969)
The CODATA 2014 values of the constants will be posted in Spring of 2015.

DEADLINE NOTICES!

There will be an adjustment of the constants to provide the values for a revision of the International System of Units (SI) expected to take place in 2018. To be considered for use in this adjustment, new results must be **accepted for publication by 1 July 2017**.

The 2018 CODATA adjustment of the fundamental constants will be based on the revised SI, which will significantly affect the uncertainties of many constants. For data to be considered for use in this adjustment, they must be **discussed in a publication preprint or a publication by 1 July 2018**.

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Conclusion

The redefinition of the SI will result in many fundamental constants being either exact or having significantly smaller uncertainties.

A consistent treatment of coherent units in the SI will lead to modified units for some of the fundamental constants.

Related Publications

Redefinition of the kilogram: a decision whose time has come Metrologia **42,** 71 (2005).

IM Mills, PJ Mohr, T Quinn, BN Taylor, M Williams

Redefinition of the kilogram, ampere, kelvin and mole: a proposed approach to implementing CIPM recommendation 1 (CI-2005), Metrologia **43**, 227 (2006).

IM Mills, PJ Mohr, T Quinn, BN Taylor, M Williams

Defining units in the quantum based SI
Metrologia **45**, 129 (2008).

PJ Mohr

Resource Letter FC-1: The physics of fundamental constants
American Journal of Physics **78**, 338 (2010).

PJ Mohr and DB Newell