Bureau International des Poids et Mesures

Press kit

26th General Conference on Weights and Measures (CGPM)

Towards a historic revision of the International System of Units (SI)

Open Session 16th November 2018

Key contacts for press enquires during the conference:

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Statement from Director of BIPM

A historic milestone. World Metrology Day held on 20 May 2018 was the first step towards the historic revision of the International System of Units (SI); a change that is eagerly awaited by the entire international metrology community and which represents one of the most significant changes to the SI since its creation. This landmark decision is expected be taken on the final day of the 26th meeting of the General Conference on Weights and Measures (CGPM), which will be held at the Palais des Congrès in Versailles from 13 to 16 November 2018, when the BIPM Member States will be asked to vote for the adoption of a Resolution that will redefine four of the seven base units of the SI.

The revision of the SI will also mark the end of the link between the SI and artefacts. The International System of Units (SI), which has been under the responsibility of the International Bureau of Weights and Measures (BIPM) since its adoptions by the 11th CGPM in 1960, superseded over the Metric System, which was one of the most important legacies of the French Revolution.

Today, the SI is the legal system of units in use in almost all countries around the world. This revision of the SI is the culmination of many years of intensive scientific cooperation between the National Metrology Institutes and the BIPM.

The BIPM, an international future-oriented organization. The BIPM, located in Sèvres near Paris, was created on 20 May 1875 by a treaty, the Metre convention, and is mostly known to the general public as the custodian of the international prototypes of both the metre and the kilogram. It is one of the oldest international organizations. Funded to address the growing needs for reliable and uniform measurements in society, trade and industry, the BIPM was, in the late 19th century, at the heart of the first international cooperation in the field of metrology that has been successfully expanding ever since. Today, the BIPM has 60 Member States and 42 Associates of the CGPM. The BIPM activities are at the heart of the big challenges faced by today's world, including climate change, health and energy sustainability. The BIPM carries out high-level scientific activities in the field of metrology and acts as a forum for its Member States.

In November 2018, it is expected that the definitions of four units (the kilogram, the ampere, the kelvin and the mole) will be revised. The definitions of all the units of the revised SI will be linked to physical constants, which will guarantee their stability and universality. The kilogram, the last unit to be defined from an artefact (the famous international prototype of the kilogram, sanctioned by the first CGPM in 1889 and kept at the Pavillon de Breteuil), will henceforth be linked to the Planck constant.

The new definitions will use 'the rules of nature to create the rules of measurement' linking measurements at the atomic and quantum scales to those at the macroscopic level. As science and technology progress, the demands for measurements to underpin new products and services will increase. Metrology is a dynamic branch of science and the steps taken by the BIPM and the wider metrology community to advance the SI in 2018 will underpin these requirements ensuring that scientists can study it and engineers can improve it. And, since science and engineering play an important role in our lives, measurement matters for everyone.

Dr Martin J T Milton

Open Session to consider the redefinition of the SI base units

Press must register at: https://form.jotform.com/BIPM/CGPM-MEDIA-open-session

Registration opens from 7.30 am.

The pressroom is located on the second floor of the conference venue, open from 7.30 am.

Power, Wi-Fi and quiet interview spaces are also available.

Space in the balcony has been allocated for the press including excellent views of the stage and delegations for camera or photography crews. Live feeds to audio recording are also provided.

Agenda

8.30 – Call to opening session (expect to begin by 8.45)

Opening of the session – Sébastien Candel (Président de l'Académie des Sciences)

Four short reports from the key committees who have been working towards the redefinition:

> Progress towards a redefinition of the SI and report from the Consultative Committee for Units (CCU) – Joachim Ullrich (CIPM Vice-President)
>
> Achievements in the measurement of *k* and report from the Consultative Committee for Thermometry (CCT) – Yuning Duan (CIPM Member)
>
> Achievements with the quantum electrical effects and report from the Consultative Committee for Electricity and Magnetism (CCEM) – Gert Rietveld (CIPM Member)
>
> Achievements in the measurement of *h* and report from the Consultative Committee for Mass and Related Quantities (CCM) – Philippe Richard (CIPM Member)

Questions

Copies of these slides will be available at: LINK

10.20 – Coffee Break

This is an alternative time for cameras to be set up if required.

10:50 – Reconvene the meeting

11.00 – Start of the live webcast

Video – NAME – available from: LINK

Welcome to the session and the webcast – Sébastien Candel (Président de l'Académie des Sciences)

Four short keynote talks from our guest speakers:

> "The quantum Hall effect and the revised SI" – Klaus von Klitzing (Nobel laureate, Max Planck Institute, Stuttgart)
>
> "The role of the Planck constant in physics" – Jean-Philippe Uzan (Centre national de la recherche scientifique (CNRS), Paris)

"Optical atomic clocks – opening new perspectives on the quantum world" – Jun Ye (JILA, Boulder)

"Measuring with fundamental constants; how the revised SI will work" – Bill Phillips (Nobel laureate, NIST, Gaithersburg)

Biographies provided: LINK

Introduction to the Resolution "On the revision of the International System of Units (SI)" – Dr Martin Milton, Director BIPM

Voting process

Final vote and closing remarks – Barry Inglis, CIPM Chair

13:25 – End of session

13.45 – Press Q&A – Press Room Floor 2

Martin Milton, Director BIPM and Barry Inglis, Chair CIPM – in English

14.00 onwards – Press one to one interviews and briefings

Please request these in advance so time can be booked:

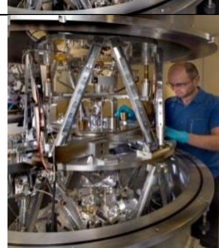
- Spokespeople from BIPM
- Individual NMI Directors, delegates or voting delegates
- Guest speakers

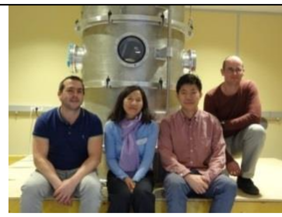
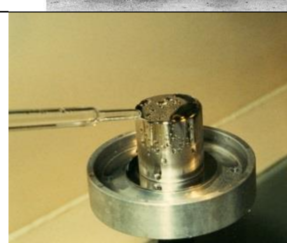
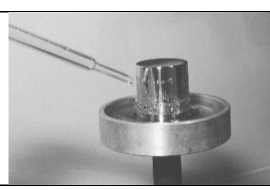
We have a full list of press contacts for the National Measurement Institutes around the world – available upon request.

Resources

The following photos are available from fiona,auty@npl.co.uk

Images

File name	*Picture*	*Caption*	*Taken in*
Observatoire le pool 35		Detail of a container for storage of a mass standard under vacuum	2017
Observatoire le pool 36		Detail of a container for storage of a mass standard under vacuum	2017
balance de kibble-4		Scientist preparing the BIPM Kibble balance for a measurement	2018
balance de kibble-12		Scientist preparing the BIPM Kibble balance for a measurement	2018
balance de kibble-13		Scientist preparing the BIPM Kibble balance for a measurement	2018
2018-04-kb-vacuum		BIPM Kibble balance with its vacuum chamber closed	2018

DSC04281		BIPM Kibble balance team Adrien Kiss (France) Hao Fang (China) Shisong Li (China) Franck Bielsa (France)	2017
jardin 19-04-2018-2		Pavillon de Breteuil, the iconic headquarters of the BIPM near Paris	2018
jardin 19-04-2018-8		Pavillon de Breteuil, the iconic headquarters of the BIPM near Paris	2018
BIPM grille 2		The entrance to the BIPM in the 1950s	50's
Cleaning		Washing the base of a prototype	Before 1990
Cleaning2		Cleaning the cylindrical surface of a prototype using a chamois leather moistened with a mixture of equal parts ethanol and ether	Before 1990
Cleaning B&W		Washing the cylindrical surface of a prototype	Before 1990

Cleaning

R. Davis: The three photos related to cleaning are taken from this monograph (https://www.bipm.org/utils/common/pdf/monographies-misc/Monographie1990-1-FR.pdf / https://www.bipm.org/utils/common/pdf/monographies-misc/Monographie1990-1-EN.pdf), written by Georges Girard. His hands are shown in one of the photos. The photos are not of the International Protype Kilogram (IPK) but Prototype no. 43, one of the six official copies of the IPK.

kilogramme etalon		International prototype of the kilogram	-
caveau prototypes		The international prototype and its six official copies in the safe	2001
2003_1215kilogram0028		The IPK being placed in the safe, completing a project to reorganize the kilogram prototypes (or simply: The IPK being returned to the safe)	2003
CIPM1894		Members of the CIPM in 1894 (10th meeting)	1894

CIPM 1894
https://www.bipm.org/en/committees/cipm/cipm-1894.html

Members of the CIPM at its 10th meeting (September 1894) pictured on the steps outside the *Grande Salle* of the Pavillon de Breteuil
From left to right:
B.-A. Gould, H.-J. Chaney, A. Arndtsen, R. Thalén (back row), H. Wild (front row), W. Foerster (President), A. Hirsch (Secretary), J.-R. Benoît (Director of the BIPM, back row), J. Bertrand, L. de Bodola, H. de Macedo, St.-C. Hepites

Engraving		Casting of the platinum-iridium alloy used to manufacture national prototypes of the metre at the Conservatoire des Arts et Métiers in 1874	-

Film

The Associated Press news agency has filmed an interview with Martin Milton the Director of BIPM and footage of the Kibble Balance available for press use.

The following video from the BBC shows the opening of the Kilogram safe at BIPM.

The Measure of All Things - www.bbc.co.uk/programmes/p01b8sj5

News broadcasters can get in touch with Getty directly to seek the footage at: service.ukibroadcast@gettyimages.com

Illustrations

A range of illustrations have been developed to helpd explain the SI.

These are available from via links below.

SI Logo		**JPG format**	**PNG format**	**EPS format**
Basic	Colour	SI-1-jpg.zip	SI-1-png.zip	SI-1-eps.zip
	Black	SI-2-jpg.zip	SI-2-png.zip	SI-2-eps.zip
	White		SI-3-png.zip	SI-3-eps.zip
With defining constants	Colour	SI-4-jpg.zip	SI-4-png.zip	SI-4-eps.zip
	Black	SI-5.jpg	SI-5.png	SI-5.eps
	White		SI-6.png	SI-6.eps
Defining constants only	Colour	SI-7.jpg	SI-7.png	
	Black	SI-8.jpg	SI-8.png	
	White		SI-9.png	

Please note the guide to their use.

Chronology - Key steps in the history of the International System of Units (SI)

17 April 1795	The law of 18 Germinal Year III (Republican calendar) established the Metric System in France.
22 June 1799	Two platinum standards representing the metre and the kilogram were deposited in the French National Archives.
1832	Carl Friedrich Gauss introduced a system of "absolute" units based on the millimetre, the milligram and the second.
1st Sept 1869	Emperor Napoleon III approved the creation of an international scientific commission to propagate the use of metric measurement to facilitate trade, the comparison of measurement between states and the creation of an international metre prototype.
16th Nov 1869	The French government invited counties to join the International Scientific Commission.
1870	The first meeting of the newly formed International Metre Commission.
1872	The decision was taken, by the International Metre Commission committee of preparatory research, to make porotype copies of the original standards deposited at the Archives de la Republique which took another 16 years.
1874	The British Association for the Advancement of Science introduced the CGS (centimetre, gram and second) System.
20 May 1875	The signing of the Meter Conversion on 20th May, by 17 countries established The General Conference on Weights and Measures (CGPM) to discuss and endorse proposed changes to the system of units and The International Committee for Weights and Measures (CIPM), to oversee the discussion and recommendations on the system of units and the establishment of The International Bureau of Weights and Measures (BIPM) to provide the administration of the entire system and to house the international prototypes standards. The system of units agreed was similar to the CGS but called MKS with base units of the Metre, kilogram and time. The meter and Kilogram were represented by physical artefacts and time but the astrological second.
1889	The first CGPM sanctioned the new international prototypes of the metre and the kilogram.
1901	Giovanni Giorgi proposed to the Associazione Elettrotecnica Italiana a new system enabling the combination of the fundamental units, the kilogram, the metre and the second, with a fourth unit of an electrical nature.
1921	Revision of the Metre Convention extending the activities of the BIPM to new fields of metrology.
1927	The Consultative Committee for Electricity (CCE now the Consultative Committee for Electricity and Magnetism CEPM) was created by the CIPM. It was the first such committee.

1935	The International Electrotechnical Commission (IEC) adopted the Giorgi System known as the MKS System.
1939	The CCE recommended the adoption of the MKS System based on the metre, the kilogram and the second (following discussion within IEC and IUPAP).
1946	As a first step that had already been planned in 1933, the CIPM approved the MKS (Mass, Kilogram and Second) System to replace the former system of electrical units called the “international System”.
1948	The 9th CGPM requested the CIPM to launch an international survey, the outcome of which was to be used to formulate recommendations for a single practical system of measurement units, suitable for adoption by all countries.
1954	The CGPM approved the introduction of the ampere, the kelvin and the candela as base units for electric current, thermodynamic temperature and luminous intensity respectively.
1960	The 11th CGPM adopted the name of the International System of Units (SI) for the system based on six base units: the metre, the kilogram, the second, the ampere, the kelvin and the candela. The 11th CGPM also adopted a new definition of the metre.
1967	The second was redefined as an “atomic second”. The new definition depended henceforth on the properties of a caesium atom.
1971	The 14th CGPM added a new unit to the SI: the mole as the unit for amount of substance.
1979	The candela was redefined in terms of a monochromatic radiation.
1983	For the first time a definition of a base unit of the SI was based on a fundamental constant: the speed of light. The metre was henceforth the length of the path travelled by light in vacuum during a specific fraction of a second.
1990	New practical conventions based on quantum phenomena were adopted for the ohm and the volt.
16 Nov 2018	Four base units of the SI will be redefined: each definition will be linked to a constant of physics. The 1990 conventions will no longer be needed and will be abolished.
20 May 2019	World Metrology Day on 20 May 2019 will mark the official entry into force of the revised SI if agreed at the 26th CGPM.

Key Papers in Metrologia leading up to the 2018 revision of the International System of Units (SI)

D B Newell *et al* 2018 *Metrologia* **55** L13
The CODATA 2017 values of *h*, *e*, *k*, and N_A for the revision of the SI
https://doi.org/10.1088/1681-7575/aa950a

Peter J Mohr *et al* 2018 *Metrologia* **55** 125
Data and analysis for the CODATA 2017 special fundamental constants adjustment*
https://doi.org/10.1088/1681-7575/aa99bc

Martin J T Milton *et al* 2014 *Metrologia* **51** R21
Towards a new SI: a review of progress made since 2011
https://doi.org/10.1088/0026-1394/51/3/R21

The kilogram (kg)

Philippe Richard *et al* 2016 *Metrologia* **53** A6
Foundation for the redefinition of the kilogram
https://doi.org/10.1088/0026-1394/53/5/A6

H Bettin and S Schlamminger 2016 *Metrologia* **53** A1
Realization, maintenance and dissemination of the kilogram in the revised SI
https://doi.org/10.1088/0026-1394/53/5/A1

Richard S Davis *et al* 2016 *Metrologia* **53** A12
A brief history of the unit of mass: continuity of successive definitions of the kilogram
https://doi.org/10.1088/0026-1394/53/5/A12

M Stock *et al* 2017 *Metrologia* **54** S99
Maintaining and disseminating the kilogram following its redefinition
https://doi.org/10.1088/1681-7575/aa8d2d

B M Wood *et al* 2017 *Metrologia* **54** 399
A summary of the Planck constant determinations using the NRC Kibble balance
https://doi.org/10.1088/1681-7575/aa70bf

D Haddad *et al* 2017 *Metrologia* **54** 633
Measurement of the Planck constant at the National Institute of Standards and Technology from 2015 to 2017
https://doi.org/10.1088/1681-7575/aa7bf2

G Bartl *et al* 2017 *Metrologia* **54** 693
A new ^{28}Si single crystal: counting the atoms for the new kilogram definition
https://doi.org/10.1088/1681-7575/aa7820

K Fujii *et al* 2018 *Metrologia* **55** L1
Avogadro constant measurements using enriched ^{28}Si monocrystals
https://doi.org/10.1088/1681-7575/aa9abd

Kenichi Fujii *et al* 2016 *Metrologia* **53** A19
Realization of the kilogram by the XRCD method
https://doi.org/10.1088/0026-1394/53/5/A19

Ian A Robinson and Stephan Schlamminger 2016 *Metrologia* **53** A46
The watt or Kibble balance: a technique for implementing the new SI definition of the unit of mass
https://doi.org/10.1088/0026-1394/53/5/A46

Michael Stock *et al* 2015 *Metrologia* **52** 310
Calibration campaign against the international prototype of the kilogram in anticipation of the redefinition of the kilogram part I: comparison of the international prototype with its official copies
https://doi.org/10.1088/0026-1394/52/2/310

Estefanía de Mirandés *et al* 2016 *Metrologia* **53** 1204
Calibration campaign against the international prototype of the kilogram in anticipation of the redefinition of the kilogram, part II: evolution of the BIPM as-maintained mass unit from the 3rd periodic verification to 2014
https://doi.org/10.1088/0026-1394/53/5/1204

The kelvin (K)

J Fischer *et al* 2018 *Metrologia* **55** R1
The Boltzmann project
https://doi.org/10.1088/1681-7575/aaa790

L Pitre *et al* 2017 *Metrologia* **54** 856
New measurement of the Boltzmann constant *k* by acoustic thermometry of helium-4 gas
https://doi.org/10.1088/1681-7575/aa7bf5

Christof Gaiser *et al* 2017 *Metrologia* **54** 280
Final determination of the Boltzmann constant by dielectric-constant gas thermometry
https://doi.org/10.1088/1681-7575/aa62e3

Jifeng Qu *et al* 2017 *Metrologia* **54** 549
An improved electronic determination of the Boltzmann constant by Johnson noise thermometry
https://doi.org/10.1088/1681-7575/aa781e

M R Moldover *et al* 2014 *Metrologia* **51** R1
Acoustic gas thermometry
https://doi.org/10.1088/0026-1394/51/1/R1

The ampere (A)

F Stein *et al* 2017 *Metrologia* **54** S1
Robustness of single-electron pumps at sub-ppm current accuracy level
https://doi.org/10.1088/1681-7575/54/1/S1

The mole (mol)

Richard J C Brown 2018 *Metrologia* **55** L25
The evolution of chemical metrology: distinguishing between amount of substance and counting quantities, now and in the future
https://doi.org/10.1088/1681-7575/aaace8

Richard S Davis and Martin J T Milton 2014 *Metrologia* **51** 169
The assumption of the conservation of mass and its implications for present and future definitions of the kilogram and the mole
https://doi.org/10.1088/0026-1394/51/3/169

Martin J T Milton 2013 *Metrologia* **50** 158
The mole, amount of substance and primary methods
https://doi.org/10.1088/0026-1394/50/2/158

The candela (cd)

Joanne C Zwinkels *et al* 2010 *Metrologia* **47** R15
Photometry, radiometry and 'the candela': evolution in the classical and quantum world
https://doi.org/10.1088/0026-1394/47/5/R01

General

Peter J Mohr 2008 *Metrologia* **45** 129
Defining units in the quantum based SI
https://doi.org/10.1088/0026-1394/45/2/001

Ian M Mills *et al* 2006 *Metrologia* **43** 227

Redefinition of the kilogram, ampere, kelvin and mole: a proposed approach to implementing CIPM recommendation 1 (CI-2005)

https://doi.org/10.1088/0026-1394/43/3/006

Ian M Mills *et al* 2005 *Metrologia* **42** 71
Redefinition of the kilogram: a decision whose time has come
https://doi.org/10.1088/0026-1394/42/2/001

Frequently Asked Questions

Why is measurement important?

Measurement affects our daily lives…

- When our medical care depends critically on measurements – of concentrations of chemicals in blood, or the intensity of X-rays
- When a satellite navigation system guides us along a road, and it depends on time measured by ultra-precision clocks on satellites
- When we buy a part that 'just fits': a nut fits a bolt, or a Lego® brick sticks perfectly to another brick

In all these situations, and thousands more, we are enjoying the benefits of a global system of measurement.

Measurement is the quantitative comparison of something against a reference. A measurement result is expressed as a value (a number), together with one or more units of measurement, for example:

… a car travelling at a speed of 10.4 metres per second (m/s).

When a measured value is given along with its one or more units, this tells us the dimension (such as mass, length or time) and the scale of the measured value.

What is the SI?

The International System of Units (SI) is a globally-agreed system of measurements. The SI has seven base units and a number of derived units defined in terms of the base units. The SI units express measurements of any quantity, like physical size, temperature or time.

This International System of Units is necessary to ensure that our everyday units of measurement, whether of a metre or a second, remain comparable and consistent worldwide. Being inaccurate by a fraction of a second might not matter for cooking pasta, but it becomes very important for determining who won the 100 metres at the Olympics or in high-frequency stock market trading.

Standardising such measurements not only helps to keep them consistent and accurate, but also helps society to build confidence. For instance, the kilogram is used every day, and defining this unit helps to outline how much food a shop is selling, and means that consumers can trust that the shop is really providing the amount they say they are. This consistency is also relied on to ensure the correct dosage of medicine is taken, even when measurements are very small.

When did the SI start?

The creation of the decimal metric system, the ancestor to the SI, was considered to be on 22 June 1799, when two platinum standards representing the metre and the kilogram were deposited in the Archives de la République in Paris.

In 1869, Emperor Napoleon III approved the creation of an international scientific commission to propagate the new metric measurement to facilitate trade. On 16 November, the French government invited counties to join the International Meter Commission – around 30 countries joined and in 1870 they held their first meeting.

It was this community that eventually led to the signing of the Metre Convention on 20 May 1875, by 17 countries. Although it was called the 'Metre Convention', they actually agreed on three units: the metre and the kilogram – defined by the physical artefacts that had been created; and the second which would be based upon astrological time.

In 1889, the international prototypes for the metre and the kilogram, together with the astronomical second as the unit of time, were units constituted as the base units metre, kilogram, and second, the original measurement system. In 1946, the scope of this was extended to adopt the ampere, giving the four-dimensional system based on the metre, kilogram, second and ampere.

The name International System of Units, with the abbreviation SI, was given to the system in 1960.

Why is the SI important?

The SI units form a foundation for measurement across the world to ensure consistency and reliability. They are the basis of trading, manufacturing, innovation and scientific discovery around the world.

SI units can provide new opportunities for innovation. Some examples where greater accuracy is supporting better methods and understanding with a positive impact on society include:

- The accurate measurement of temperature: This will support the ability to identify and measure reliably very small changes across large time periods with greater accuracy. Therefore, it will allow for more precise monitoring and better predictions for climate change.
- The more accurate administration of drugs: The pharmaceutical industry needs to use a standard for very small amounts of mass in order to make dosages of medication even more appropriate for patients.

SI units can help us support innovation into the future. As our ability to measure properties improves, the standards we have for measurement will need to keep up. The accuracy of services like the Global Positioning System (GPS) are limited by our ability to use standard units, in this case the second to measure time. We can track our locations effectively because we can establish time using the SI definition of a second, which can be realised by an atomic clock. This advancement was made possible because society had defined the second more accurately well before we had even discovered what it could be used for. The atomic clock was made before computing really took off. Now, accurate timing is a fundamental part of the industry; without it, the internet, mobile phones and other technologies could not work reliably.

How are the units of measurement defined?

Originally, measurement units were defined by physical objects or properties of materials. For example, the metre was originally defined by a metal bar exactly one metre in length.

However, these physical representations can change over time or in different environments, and are no longer accurate enough for today’s research and technological applications. Over the last century, scientists measured natural constants of nature, such as the speed of light and the Planck constant, with increasing accuracy. They discovered that these are more stable than physical objects, and fixed numerical values to the constants. These natural constants do not vary, so are at least one million more times more stable.

It has been the aspiration of the measurement community to move to a complete measurement system redefined without physical artefacts. This definition marks the end of the process and an historic moment as the last artefact, the Internal Prototype Kilogram, will be retired and the kilogram defined in terms of Planck's constant.

Why do we need more accurate definitions?

As science advances, ever more accurate measurements are both required and achievable. The standard and definition must reflect this increasing accuracy. The kilogram has been based on a physical object certified in 1889 using industrial revolution, consisting of a cylinder of platinum-iridium, and it is the last unit to be based on an actual object. Its stability has been a matter of significant concern, resulting in recent proposals to change the definition to one derived from constants of nature.

We are at the beginning of the quantum or digital revolution. By defining measurement units in terms of constants means that the definitions of the units are fit for purpose for this next generation of scientific discovery.

What are the seven base units?

The kilogram (kg) – the SI base unit of mass

The metre (m) – the SI base unit of length

The second (s) – the SI base unit of time

The ampere (A) – the SI base unit of electrical current

The kelvin (K) – the SI base unit of thermodynamic temperature

The mole (mol) – the SI base unit of amount of substance

The candela (cd) – the SI base unit of luminous intensity

Further information on how to use SI units: www.bipm.org/en/measurement-units/base-units.html

What is the SI redefinition?

The global metrology community anticipates that a revision to the SI units will be agreed in 2018, when the General Conference on Weights and Measures (CGPM) meets from 13–16 November.

This decision is expected to mean a more practical definition of the SI. All of the units would be expressed in terms of constants that can be observed in the natural world (for example, the speed of light, the Planck constant and the Avogadro constant). Using these unchanging standards as the basis for measurement will mean that the definitions of the units will remain reliable and unchanging into the future.

Information on the constants the SI units: www.bipm.org/en/measurement-units/rev-si/

Why do we need this change?

It has been the aspiration of the measurement community since the Age of Enlightenment to have a universally-accessible system. The use of physical artefacts for this has always been a practical approach, but one that the community wanted to move away from as soon as possible. Physical artefacts can be unstable, as they are vulnerable to both human and environmental damage.

This revision of the SI will, for the first time, see all base units in the SI defined by the constants of physical science that we use to describe nature. Using the constants we have found in nature as our universal basis for measurement allows not only scientists, but also industry and society, to have a measurement system that is more reliable, consistent, and scalable across quantities, from very large to very small.

There are two key ways the SI will change to create a more stable and future-proof basis for measurement:

- It will take physical artefacts out of the equation: The kilogram is still defined by a physical object equal to the mass of the International Prototype of the Kilogram (IPK), an artefact stored at the International Bureau of Weights and Measures (BIPM) in France. This revision will finally remove the need for this last artefact.
- For the first time, all the definitions will be separate from their realisations: Instead of definitions becoming outdated as we find better ways to realise units, definitions will remain constant and future-proof. For example, the ampere is currently defined as "the magnetic force between two wires at a certain distance apart", which means that it uses the realisation of a measurement to define it. However, advancements like the advent of the Josephson and quantum Hall effects, have revealed better ways of realising the ampere, making the original approach obsolete.

Will the seven units change as part of the Revised SI?

No. The seven base units (second, metre, kilogram, ampere, kelvin, mole and candela) and their corresponding base constants (time, length, mass, electric current, thermodynamic temperature, amount of substance and luminous intensity) remain unchanged.

Which are changing?

The kilogram (kg), ampere (A), kelvin (K), and mole (mol) will have new definitions.

The new definitions affect four of the base units:

The kilogram	in terms of the Planck constant (h)
The ampere	in terms of the elementary charge (e)
The kelvin	in terms of the Boltzmann constant (k)
The mole	in terms of the Avogadro constant (N_A)

Defining the kilogram in terms of fundamental physical constants will ensure its long-term stability, and hence its reliability, which is at present in doubt.

What about the definitions of the other units?

The definitions of the second (s), metre (m), and candela (cd), will not change, but the way the definitions are written will be revised to make them consistent in form with the new definitions for the kilogram (kg), ampere (A), kelvin (K) and mole (mol). These new wordings are also expected to be approved at the 26th CGPM in November 2018 and to come into force on 20 May 2019.

What about the 22 coherent derived units with special names and symbols?

These will remain unchanged in the Revised SI.

When will the proposed change come into effect?

Redefinition, if agreed, will come into practice on World Metrology Day, 20 May 2019.

What does this mean in practice?

On the surface, it will appear that not much has changed. In the same way that if you replaced the decaying foundations of a house with robust new ones, it may not be possible to identify the difference from the surface, but some substantial changes would have taken place to ensure the longevity of the property.

These changes will ensure that the SI definitions will stand the test of time, despite advancements in technology, but will continue to remain robust.

Information for users of the SI: www.bipm.org/utils/common/pdf/SI-statement.pdf

What and when is World Metrology Day?

World Metrology Day is an annual event on 20 May during which more than 80 countries celebrate the impact measurement has on our daily lives.

On this day, the international metrology community, which works to ensure that accurate measurements can be made across the world, raises awareness of the impact and importance of having reliable measurements. The theme for World Metrology Day 2018 was 'Constant Evolution of the International System of Units (SI)'.

The date marks the beginning of a formal international collaboration in metrology in 1875, when the first international measurement treaty, the Metre Convention, was signed by representatives from 17 nations to agree on the coordination of measurement.

This treaty saw the creation of organisations to oversee the running of the BIPM including the General Conference on Weights and Measures (CGPM).

Information on World Metrology Day: www.worldmetrologyday.org/

Who agrees on the SI and any proposed changes?

The signing of the Metre Convention in 1875 saw the creation of the International Bureau of Weights and Measures (BIPM). It operates under the supervision of the International Committee for Weights and Measures (CIPM), which is itself set under the authority of the General Conference on Weights and Measures (CGPM).

The CGPM meets every three to six years. With delegates from all of the 60 member states, this body discusses and chooses to endorse changes to the SI, after taking on board advice from the CIPM.

The CIPM is a committee made up of 18 individuals, each of a different nationality, nominated by the CGPM for their high level of understanding in the field. The CIPM is still to this day responsible for decisions about the SI, with the goal of creating a reliable basis for measurement that can be used now and into the future. The international community now includes 60 Member States, and 42 Associate States and Economies.

The BIPM is based in Sèvres where it has laboratories that provide metrology services for the Member States. It also carries out coordination and liaison activities and houses the secretariat for the CIPM and its consultative committees. The BIPM's original purpose was to create and house the international prototypes defining units of what is now known as the SI, and as such it is where the international prototype of the kilogram resides.

What is the proposal for the change?

The full resolution: www.bipm.org/utils/en/pdf/CGPM/Convocation-2018.pdf#page=30

In short, the CGPM, at its 26th meeting, will be asked to vote to accept the Resolution 1 adopted unanimously by the CGPM at its 24th meeting (2011). This resolution laid out, in detail, a new way of defining the SI based on a set of seven defining constants, drawn from the fundamental constants of physics and other constants of nature, from which the definitions of the seven base units are deduced.

What impact does the redefinition have on the realization of the kilogram?

kilogram will be defined in terms of the Planck constant, guaranteeing long-term stability of the SI mass scale. The kilogram can then be realized by any suitable method, (for example the Kibble (watt) balance or the Avogadro (X-ray crystal density) method). Users will be able to obtain traceability to the SI from the same sources used at present (the BIPM, national metrology institutes and accredited laboratories). International comparisons will ensure their consistency.

The value of the Planck constant will be chosen to ensure that there will be no change in the SI kilogram at the time of redefinition. The uncertainties offered by NMIs to their calibration customers will also be broadly unaffected.

What impact does the redefinition have on the realization of the ampere?

The ampere and other electrical units, as practically realized at the highest metrological level, will become fully consistent with the definitions of these units. The transition from the 1990 convention to the revised SI will result in small changes to all disseminated electrical units.

For the vast majority of measurement users, no action need be taken as the volt will change by about 0.1 parts per million and the ohm will change by even less. Practitioners working at the highest level of accuracy may need to adjust the values of their standards and review their measurement uncertainty budgets.

What impact does the redefinition have on the realization of the kelvin?

The kelvin will be redefined with no immediate effect on temperature measurement practice or on the traceability of temperature measurements, and for most users, it will pass unnoticed. The redefinition lays the foundation for future improvements. A definition free of material and technological constraints enables the development of new and more accurate techniques for making temperature measurements traceable to the SI, especially at extremes of temperature.

After the redefinition, the guidance on the practical realization of the kelvin will support its world-wide dissemination by describing primary methods for measurement of thermodynamic temperature and equally through the defined scales ITS-90 and PLTS-2000.

What impact does the redefinition have on the realization of the mole?

The mole will be redefined with respect to a specified number of entities (typically atoms or molecules) and will no longer depend on the unit of mass, the kilogram. Traceability to the mole can still be established via all previously employed approaches including, but not limited to, the use of mass measurements along with tables of atomic weights and the molar mass constant M_u.

Atomic weights will be unaffected by this change in definition and M_u will still be 1 g/mol, although now with a measurement uncertainty. This uncertainty will be so small that the revised definition of the mole will not require any change to common practice.

Will there be any change to the realization of the second, the metre and the candela.

No

The second will continue to be defined in terms of the hyperfine transition frequency of the caesium 133 atom. The traceability chain to the second will not be affected. Time and frequency metrology will not be impacted.

The metre in the revised SI will continue to be defined in terms of the speed of light, one of the fundamental constants of physics. Dimensional metrology practice will not need to be modified in any way and will benefit from the improved long-term stability of the system.

The candela will continue to be defined in terms of K_{cd}, a technical constant for photometry and will therefore continue to be linked to the watt. Traceability to the candela will still be established with the same measurement uncertainty via radiometric methods using absolutely-calibrated detectors.

Who will vote and how will the vote take place?

The vote will follow the reading of the proposal on 16th November ~ 13.00 UTC.

The 60 Members States will be invited to vote and the proposal needs a majority to be accepted. We are, however, expecting all 60 States to agree to this change as work has been truly international in nature and the potential for the change historic.

Follow the vote live on BIPM's YouTube channel at 10:50 UTC on 16 November 2018:
www.youtube.com/channel/UC9ROltu1--gjcrk5ZcWbHVQ

What will happen to the kilogram after the vote?

The International Prototype Kilogram (IPK) will remain where it is under the same conditions. It is an historic artefact that has been under study for 140 years and will retain a bit of metrological interest even though its mass will no longer define the kilogram.

All other nations holding kilograms will also keep theirs in the same way, as the use of physical kilogram artefacts will remain an important part of traceability to the new definition of the kilogram for some years to come – until such experiments to realise the kilogram are readily available by other means.

When has the International Prototype of the Kilogram (IPK) been used?

Starting in 1885, the kilogram has been used in three calibration campaigns, each lasting several years. The third of these ended in 1993. In preparation for the upcoming redefinition, the kilogram was used again in 2014 to supply traceable values to NMIs working on replacing it. This may seem strange but it helps ensure that the size of the redefined kilogram will be the same as the size of the present kilogram. Nevertheless, handling and environmental conditions are not conducive to the mass of an artefact remaining stable. The kilogram is held in a safe which requires the presence of three people who hold keys for access – The Director of the BIPM, The President of the International Committee of Weights and Measures (CIPM) and the Director of the French Archives. This procedure is overseen by the 18 members of the International Committee of Weights and Measures. This last happened in 2014.

Has the IPK changed?

It is difficult to quantify this as the kilogram, by definition, is a kilogram! The question could be: Has the mass of the kilogram been seen to change with respect to any constant of nature? The answer is "not yet". This is because until quite recently such comparisons were impossible to carry out with the necessary precision.

But comparisons with other kilograms held in the same conditions show us that over the past 30 years there have been no detectable changes.

However, from 1889 through 1993, the detected differences in mass between supposedly identical artefacts average out to be about 50 µg per century. The reason for the changes and the reasons the changes have stopped (or paused) are, and probably will remain, a mystery. These are questions that artefact definitions invite but do not exist for the redefined kilogram.

Will I get my standard of mass calibrated after the change?

After the redefinition of the kilogram, laboratories will continue sending mass standards to their National Metrology Institute (NMI) for calibration or to a secondary calibration laboratory, just as now. However, the traceability path that the NMI will use to link it to the SI kilogram will change and be a realisation of the new definition.

Information for users of the SI: www.bipm.org/utils/common/pdf/SI-statement.pdf

How can we be sure that laboratories' realisations of the kilogram are correct?

As with the inter-comparison mechanism that already exists and is widely used for all other units, all laboratories claiming to realise the kilogram will need to demonstrate traceability to the definition of the kilogram, by comparing results with their peers. This approach is set out in CIPM Mutual Recognition Arrangement established in 1999.