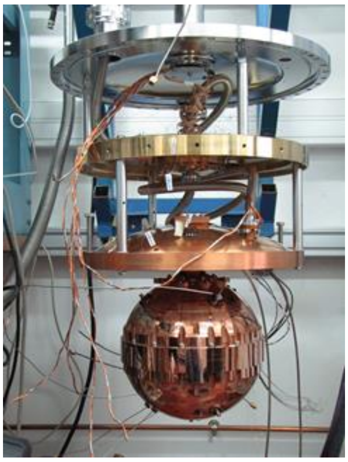
COMMUNIQUE DE PRESSE

Le 17 juillet 2017

LNE announces outstanding results on the eve of redefining the kelvin and kilogram units

In 2018, at the time of the 26th General Conference on Weights and Measures, four of the units comprising the International System (i.e. kilogram, ampere, Kelvin, and mole) are expected to be redefined. These newly-defined units shall be based on fundamental constants from physics. This endeavor has necessitated determining the values of such constants as precisely as possible: LNE researchers have recently obtained excellent results for the values of both Boltzmann's constant (used in redefining the Kelvin unit) and Planck's constant (applicable to the kilogram).

The new kelvin defined by Boltzmann's constant, as determined by means of an acoustic thermometer



A definition awaiting revision

Since 1968, the International System of Units has defined the Kelvin as a fraction equal to 1/273.16 of the thermodynamic temperature of the triple water point, which corresponds to 0.01°C, expressed as 273.16°K. The triple water point however is an artifact that, as it undergoes increased scrutiny, has revealed its flaws (e.g. isotopic composition, impurities).

The Kelvin unit therefore should soon be defined on the basis of a fundamental constant, namely Boltzmann's constant, whose numerical value will be fixed, as was the case for the speed of light in 1983 when defining the meter. The Kelvin will rely on Boltzmann's constant (k) applied to the quantum of thermal agitation energy kT, where T is the thermodynamic temperature. At present, Boltzmann's constant is estimated at a value of approximately 1.38064852 x 10-23 joules per Kelvin, with a relative uncertainty of 0.57 x 10-6, as established by the Committee on Data for Science and Technology (CODATA), which has issued a list of values for all fundamental physical constants. Yet the value of this particular constant still requires further refinements.

The acoustic thermometer

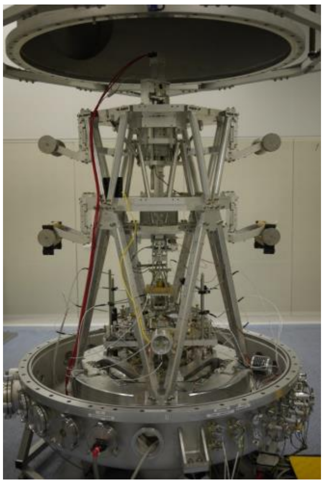
The joint LNE-CNAM / LCM team has developed an original method for deducing the value of Boltzmann's constant, namely by means of measuring the speed of sound within a rare gas inside a closed cavity. Researchers proceeded by placing helium-4 in a 3-liter, quasi-spherical resonator. This acoustic thermometer design is based on an accurate determination of both acoustic and microwave resonances in order to measure sound at various pressures. Such an experiment is highly demanding since all its parameters (gas purity, acoustic signal measurements) must be controlled with great precision.

A record outcome

The team succeeded in determining Boltzmann's constant with an uncertainty of 0.60 x 10-6, which to this day represents the best level recorded in the world! An article on this research was accepted for publication in the June 2017 issue of the review *Metrologia*.

The kilogram defined by Planck's constant, as determined using the Kibble balance

Current definition



The unit standard of mass is a platinum-iridium cylinder, held since 1889 at the International Bureau of Weights and Measures in Sèvres outside of Paris. The "big K", as the device has been nicknamed, is kept in complete security within a vault underneath three glass bell jars: by definition, its mass is exactly equal to 1 kg. This material artifact however now reveals its limitations, given that it is solely available in a single place and furthermore unstable over time. In fact, during the four comparisons drawn spanning a century and a half, inconsistencies were detected between the mass of the "big K" and that of copies of this cylinder, meaning that the device no longer allows measuring masses with certainty. To overcome these limitations, the kilogram will soon be defined on the basis of Planck's constant (h). A determination of the most accurate possible value of this universal constant still however needs to be performed.

The Kibble balance

The method employed by LNE teams to determine Planck's constant relies on the Kibble balance (formerly called the watt balance). This experiment consists of comparing a mechanical power with a pre-established virtual electrical power by means of referring to both the Josephson effect and the quantum Hall effect. Such a comparison is then used to correlate the mass unit, i.e. the kilogram, with Planck's constant. The electromechanical experiment, which requires considerable fine-tuning, also presumes simultaneous control over the mass magnitudes, acceleration due to gravity, time, length, electrical voltage and resistance while maintaining uncertainties at close to state-of-the-art values.

LNE's Kibble balance, first developed in 2002, has recently yielded a Planck's constant value of: h = 6.62607041 × 10-34 Js, with a relative uncertainty equal to 5.7 × 10-8. These results were published in the June 2017 issue of Metrologia and should serve to help choose a fixed value of Planck's constant in redefining the kilogram.

Once the kilogram has been reset in 2018 through selection of a fixed Planck's constant value, LNE's Kibble balance will be applied to generating the mass unit in a way that circumvents reference the "big K": the value of the kilogram will thus be made independent of a device reading, instead solely based on constants from physics.

Thomas Grenon, LNE's Managing Director

"Research lies at the heart of LNE's public service mission and constitutes a pillar among our activities, whether the research be fundamental, in the aim of redefining units within the International System (SI) that occupies so much of our efforts, or applied. After creating a quantum standard for the ampere last year, LNE has now confirmed, thanks to these two results, its position as France's reference laboratory in the field of measurement."

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