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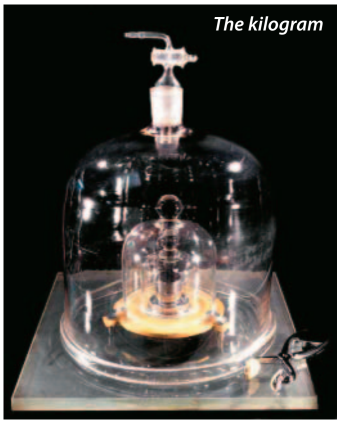
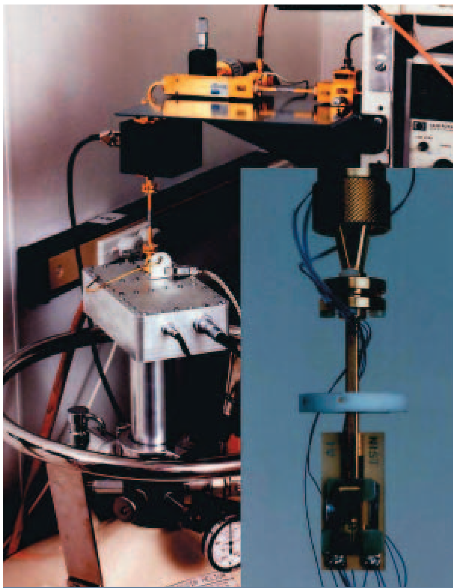


Changing the SI



A Josephson Voltage standard that one day may play a part in the definition of the kilogram

The International System of Units (SI) has been an outstanding success since its introduction in 1960, meeting well the needs of science and commerce.

By relating all our measurements to this shared set of standard units, such as the metre, kilogram and second, it is possible to trade and communicate throughout the world without misunderstanding.

The SI is based on the very best scientific knowledge, and it is extremely rare for measurement difficulties to be traced to the SI system itself. Yet there is a misconception that the SI measurement system is cast in stone. In reality, thanks to an international community of metrologists, it is constantly being improved (admittedly over a relatively long time scale – a useful rule of thumb for many quantities is a factor-of-ten improvement about every 15 years).

Such steady improvement is necessary to keep up with enhanced measurement techniques and technological advances. The next decade could see the most significant overhaul of the system since the signing of the Metric Treaty in 1875.

The main driving force for the proposed changes is that the unit of mass, the kilogram, is defined by a single artefact held in a vault in Paris. This presents both a risk and an impediment to improvement. “The kilogram” is a metallic lump whose mass is simply defined to be 1 kg. It is now the only unit that is based on a physical artefact, the 1 m length bar having been discarded in 1960 in favour of a definition based on the properties of light.

The main risk is that the artefact could change with time and there is no way of knowing by how much. The evidence from copies of the 1 kg artefact is that a change of 50 micrograms over 100 years is likely to have occurred, but the actual change may be as much as 20 times greater.

The major impediment is that the single artefact becomes extremely valuable and cannot be used frequently because of the risk of damage. This leads to long calibration chains and corresponding losses of accuracy with increasing numbers of comparisons. It is better to have standards based on fundamental physics that enable many equivalent standards of high accuracy to be developed by any sufficiently competent laboratory.

The development of quantum physics is another driver for the change in the SI. Thanks to some amazingly exact quantum effects (the Josephson effect and the quantum Hall effect), voltage and resistance can be consistently reproduced around the world to very high precision. This has enabled the manufacture of electrical instrumentation that has lower measurement uncertainty than the present SI units.

The quantum electrical effects have enabled mass to be measured in terms of electrical quantities through the comparison of electrical power (current × voltage) with mechanical power (force × velocity). We are now on the threshold of obtaining sufficient accuracy in these measurements to consider replacing the artefact mass with a definition based on electrical standards.

Historically, the SI has evolved from a collection of artefact standards to definitions based on invariant properties of nature. For example, in 1983 the metre was defined by fixing the speed of light to an exact value. The use of other fundamental constants of physics, such as the Planck constant, *h*, and the charge of the electron, *e*, is now being considered to define the electrical quantities (these would then also define the kilogram).

And while we are at it, the Boltzmann and Avogadro constants are natural ways to define the units of temperature (kelvin) and the quantity of matter (mole).

The international metrology community doesn’t make these changes lightly. There are several technical issues to be resolved and the changes will be unlikely to be put in place before 2015. The staff of MSL will work through this transition, so you can be assured that practical measurements will be improved as a result of any changes.

Errata: The October/November Measurement Matters article, Under Pressure, contained several errors due to the loss of formatting during the publishing process. The pressure definitions and conversion factors in the article should read as follows: 1 pascal = 1 Pa = 1 newton/metre^2, 1 bar = 100,000 Pa and the very small absolute pressure in the last paragraph is 10^{-6} Pa.