Electricity and Magnetism

The Consultative Committee for Electricity and Magnetism (CCEM)

CCEM/19-03_a

The Revised SI: Bringing the quantum electrical standards into the SI

Definition of the kilogram

h = 6.626 070 15 × 10^{-34} Js

Planck constant

Definition of the ampere

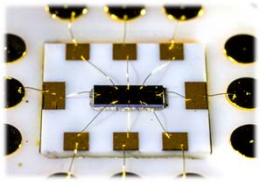
e = 1.602 176 634 × 10^{-19} C

Charge of the electron

Quantum Hall standard for resistance

$$R = \frac{1}{n}\frac{h}{e^2}$$

(*n*: quantum number)

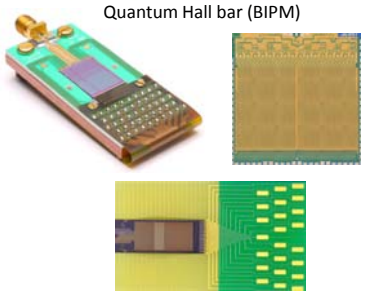


Quantum Hall bar (BIPM)

Josephson quantum standard for voltage

$$U = n f \frac{h}{2e}$$

(*n*: quantum number, *f*: frequency)



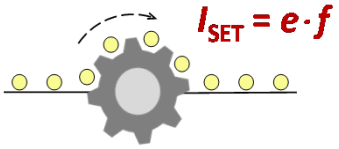
programmable Josephson arrays (NIST, NMIJ, PTB)

Global forum for progressing the state of the art

Scientific presentations at CCEM meetings (2013, 2015, 2017) and **workshop on future measurement challenges** (2017), covering:

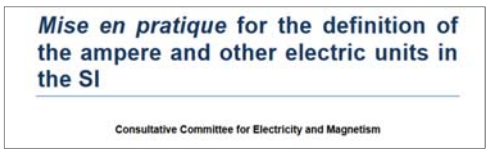
Renewable energy sources

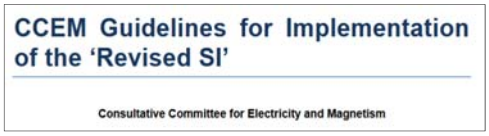
- Watt/Kibble balances, paving the way to the revised SI
- Graphene for wider uptake of quantum Hall resistance standards
- Josephson standards for arbitrary waveform generation
- Metrology for smart electrical grids to integrate renewables into electricity systems
- Single-electron tunneling for quantum standard for electrical current
- High-frequency metrology for communications
- Nanomagnetism and spintronics for future electronic devices



Schematic of single electron tunneling as a quantum standard for current

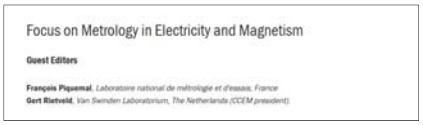
Facilitating dialogue between NMIs and stakeholders





https://www.bipm.org/en/measurement-units/rev-si/

NCSLI Measure Vol. 9, 2014



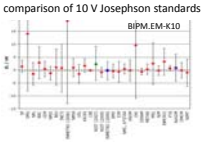
Metrologia Focus Issue

Supporting the CCRI in the development of a technique for measuring ultra-low ionization currents

Global comparability of measurements

- Quantum standards have greatly increased comparability of EM measurements world-wide
- BIPM runs on-site comparisons of quantum standards at Member State NMIs
- CCEM covers many quantities: not all 198 calibration service categories can be covered by a comparison, so comparisons are strategically planned
- CCEM developed a CMC review process with improved efficiency

BIPM comparison of 10 V Josephson standards



CCEM comparison of 10 pF capacitance calibrations