

Determination of the fundamental electrical constants

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One of the major issues of the modern metrology is to revise the International System of units (SI) with the ultimate goal of defining all units in terms of constants of Nature. Giving up the present definition of the mass unit defined by means of a unique material artefact, the international kilogram prototype, the trend is to define the mass unit by fixing the value of the Planck constant h . In the same way, the ampere, the kelvin and the mole would be redefined by fixing the elementary charge e , the Boltzmann constant k_B and the Avogadro constant N_A respectively. This present context arises partly from the metrological applications of the quantum Hall effect (QHE) and the ac Josephson effect (JE). These phenomena link the electrical quantities directly to h and e , through the von Klitzing constant R_K and the Josephson constant K_J , which are presumably equal to h/e^2 and $2e/h$, respectively. They insure a high level of reproducibility and a unique representation of the electrical units worldwide. Moreover, through the development of highly accurate electromechanical systems such as the calculable capacitor or the watt balance, the use of the Josephson array voltage standards (JAVS) and the quantum Hall resistance standards (QHRS) allows the determination of the fine structure constant α and h .

With the great progress of nanofabrication, a new class of quantum electrical devices has emerged, the so-called Single Electron Tunnelling (SET) devices based on the Coulomb blockade. Similar to JAVS and QHRS, the SET devices could be the basis for a quantum current standard whose amplitude is equal to the product of the elementary charge and a frequency. The Coulomb blockade of the SET provides the third leg of the quantum metrological triangle (QMT). Its closure by applying Ohm's law to the quantities observed in JAVS, QHRS and SET devices, or by means of an electron counting capacitance standard (ECCS) is a great challenge. In addition, by combining the results from the watt balance, the calculable capacitor and a single-electron tunnelling experiment, the elementary charge e can be determined directly. Until now, the evaluation of e is derived from a complex calculation and is no more related to a single experiment.

Starting by a description of the present context around the modernization of the SI, the talk will deal with the quantum electrical metrology and the determination of α , h and e . The general principles of the Thompson-Lampard calculable capacitor and the watt balance will be given along with their main features. Then the QMT experiments will be described, mainly the experimental set-up which involves the use of cryogenic current comparators.

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