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The electrical Connection

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Watt and volt are probably more important in everyday electrical life than ampere: when replacing a lamp, you need the correct wattage, and when changing a battery, voltage is what you check. A quick explanation of the 'amp' is that a current of 1 A generates a power of 1 W in a conducting element to which a voltage of 1 V is applied.

This definition is the same as the one adopted at the first International Exposition of Electricity in Paris in 1881: an ampere is the current produced by one volt in one ohm. To avoid confusion, the name ampere was chosen after André-Marie Ampère, the founder of electrodynamics (pictured): at the time, a unit called weber (after Wilhelm Weber) was used to quantify electrical current.

Formulating electromagnetic measurements in terms of mechanical quantities (length, mass and time) was pioneered by Carl Friedrich Gauss, who in 1832 expressed his result for the intensity of the Earth's magnetic force using the millimetre, the milligramme and the second2 - the starting point for the centimetre-gram-second (CGS) system, later replaced by the metre- kilogram-second (MKS) system.

By the early twentieth century, there was a need to express electrical units in terms of physical standards, and a new system of international units was introduced for practical use. The international ampere was defined as the current that deposits 0.001118 grammes of silver per second on the cathode of a silver nitrate electrolyzer (ref. 3). It was hoped that such standards would be implemented.

The inability to express electrical quantities in a limited 3D system of (mechanical) units quickly became a critical issue. Giovanni Giorgi demonstrated the possibility of designing a single coherent 4D system in 1901 by connecting the MKS units to the practical electrical system via a single base electrical unit from which all others could be derived. After some deliberation, the ampere was chosen as the preferred unit.

Because of the low achievable accuracy (parts in 106 at best) when carrying out such a thought experiment, ampere realisations are derived in practise from the ohm and the volt, or, for currents less than 100 pA, from the farad, the volt, and the second.

The discovery of two condensed-matter quantum phenomena, the Josephson effect in 1962 and the quantum Hall effect in 1980, heralded a new era in metrology. These effects allow for precise measurements of the Josephson constant, KJ = 2e/h, and the von Klitzing constant, RK = h/e2, and thus calculations of the elementary charge, e, and the Planck constant, h. Predictions that are highly reproducible

History appears to be repeating itself. The conventional (quantum-standard) ohm and volt - in use since 1990 and based on defined values of KJ and RK (ref. 5) - are not embedded in the SI, as was the previous schism between the practical international electrical units and the CGS system.

Fortunately, progress is being made in metrology, and a revision of the SI to address this and other issues is scheduled for 2018. (ref. 6). The ampere will be defined in the new SI as the electric current corresponding to the flow of 1/(1.602176xyz 10?19) elementary charges per second, with the elementary charge fixed at 1.602176xyz 10?19 C. The last three significant digits, xyz, are not settled.

Unlike the 1948 definition, the new definition of the ampere is 'future-proof' in that it does not imply a method for realising the ampere. A simple method is to use quantum realisations of the volt and the ohm. A still difficult method is based on the definition of current itself: measuring the quantized flow of charges in a nanodevice over a specific time interval in a controlled manner. Interaction

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