Magnetic disunity

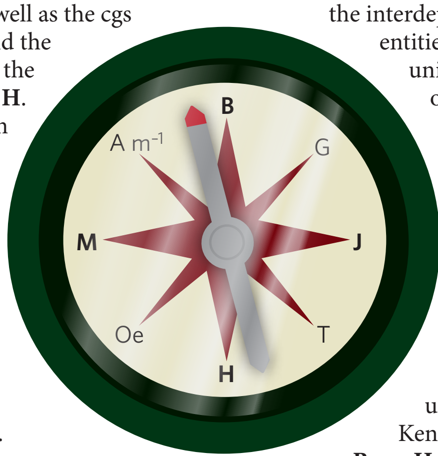
The path to consistent cgs magnetic units has been long and winding, as is the process of universally adopting SI units. **Andreas Trabesinger** peeks into the history of the field.

When, in 1820, the Danish physicist and chemist Hans Christian Ørsted observed that a wire carrying electrical current can deflect a compass needle, the significance of that discovery was quite evident to him. He penned down his findings in Latin, had them printed at his own expense, and sent copies to peers all over Europe. His strategy proved successful: others quickly took up exploring electromagnetism, and Ørsted's text was promptly translated into French, English, German, Italian and Danish[1].

Elsewhere in Europe, Carl Friedrich Gauss ventured into new territory of his own. In 1833 he (later jointly with Wilhelm Weber) started developing a system to relate measurements of terrestrial magnetism to mechanical units, providing a powerful framework for quantifying magnetic moments and magnetic fields. Gauss and Weber went on to found the *Magnetische Verein* (Magnetic Club) in Göttingen, to promote the systematic study of spatial and temporal variations of the Earth's magnetic field across the world.

It is somewhat ironic then that the history of magnetic units bearing the names of Gauss and Ørsted is one characterized by confusion rather than clarity. With the flurry of activity in the field of electromagnetism by engineers and scientists alike, a slew of conventions and notations sprang into existence. "Since 1890 incipiently, and since 1900 definitely, there has been widespread ambiguity in the world's magnetic literature, over the definitions, names and symbols of certain magnetic-circuit units, and especially in regard to the gauss", observed the Irish electrical engineer Arthur Kennelly in 1933 (ref. 2).

On the electrical side, a set of units based on the centimetre–gram–second (cgs) system had been internationally adopted by 1893, agreed in a series of International Electrical Congresses. For magnetic units, however, the situation remained unclear. Some progress came with the 1900 International Electrical Congress, held in Paris, where at least two magnetic units were assigned, the maxwell as the cgs unit of magnetic flux and the gauss for the cgs unit of the magnetic-field strength **H**.



The recommendation of the Paris meeting notwithstanding, the gauss kept being merrily used for either **H** or the magnetic flux density **B** — or both — as consensus on whether **B** and **H** are distinct physical fields was yet to emerge. The decision-making process dragged on, involving the creation of ever-new international bodies and meetings across Europe and in the US. At long last, a committee of the International Electrotechnical Commission voted in 1930 that **B** and **H** were to be considered physically distinct quantities. This implied, importantly, that the constant relating **B** to **H**, the permeability of free space μ_0, is not just a number, but has physical dimensions.

The unit name gauss was then assigned to **B**, reversing the decision made in Paris in 1900, whereas for **H** the unit oersted was recommended. But further-reaching changes were needed, and in 1935 the decision was taken to adopt a system with four basic units: metre, kilogram, second (MKS) "and a fourth fundamental unit to be chosen later"[3] — eventually, the ampere took that place.

In the International System of Units (SI), **B** is now expressed in tesla, and **H** in amperes per metre. Many issues related to the early developments, however, still linger in today's 'magnetic literature'. The long discussion regarding the physical nature of **B** and **H** has been summarized[3] in terms of the differences in how experimentalists, interested primarily in the physical manifestation of a phenomenon, and theoreticians, driven by the interest in the interdependence of the basic entities, set up a system of units. The consequences of 'rationalizing' the units — making them coherent with one another — has left us with slightly awkward values such as $4\pi \times 10^{-7}$ N A^{-2} for μ_0 in SI units. And two conventions of how to relate **B** to **H** remain in use: according to the Kennelly convention, $\mathbf{B} = \mu_0\mathbf{H} + \mathbf{J}$ (**J** being the magnetic polarization), and according to the convention introduced by Arnold Sommerfeld, $\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M})$, with **M** the magnetization per unit volume.

Magnetism fundamentally pervades our understanding and use of physical phenomena. Its history is intertwined with that of geology, physics, engineering and numerous other fields. It might therefore be of little surprise that this is one of the few remaining areas where SI units are still not universally accepted. Calls for unity are yet to be heard[4]. But one lesson to be learned should be that at the very least units, notations and conventions should be used consistently and declared clearly. Ørsted and Gauss deserve no less. ❐

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