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Inside...

A new basis for the SI system of units:

occasion to reconsider the presentation and teaching of magnetism

Frank Stacey[1], Bruce Moskowitz[2], Mike Jackson[2], David Dunlop[3], Özden Özdemir[3], Subir Banerjee[2]

[1]CSIRO Energy and Resources, Brisbane, Australia. frank.stacey@csiro.au
[2] IRM
[3]Geophysics, Department of Physics, University of Toronto, Toronto, Ontario, Canada

The metric system of physical units, now formalised as the SI system (Système International d'Unités) began with the definition of the metre as one ten millionth of the distance from the pole to the equator along the meridian through Paris. Then, with the metre specified, the kilogram was defined as the mass of a cubic decimetre of pure water at 0ºC and, with the second established as a specific fraction of the assumed constant duration of the solar day, the MKS (metre-kilogram-second) system became the basis of an international agreement on units. There have been numerous revisions of the system and its definitions, driven by demands for reproducibility and accuracy, incorporation of units for electricity and magnetism and making use of improvements in measurement techniques. For some time there were platinum standards for both the metre and kilogram, but now there is only one remaining material artefact, the standard kilogram kept in Paris. The need to supersede it has been recognised for many years and a change is imminent. A forewarning was recently published by the chairman of the CODATA Task Force on Fundamental Constants (Newell, 2014). It will be more dramatic than the earlier redefinitions of standards. Four fundamental physical constants, Planck's constant, h, Boltzmann's constant, k, the elementary electric charge, e, and Avogadro's number, N_A, will no longer be parameters with measurement uncertainties, but will become constants with defined values. A consequence is that some presently defined constants will be treated as measured parameters with attendant uncertainties. One of them is the permeability of free space, μ_0, presently defined as $4\pi\times10^{-7}$ H m^{-1}, and we need to consider the implications of this for the magnetism community.

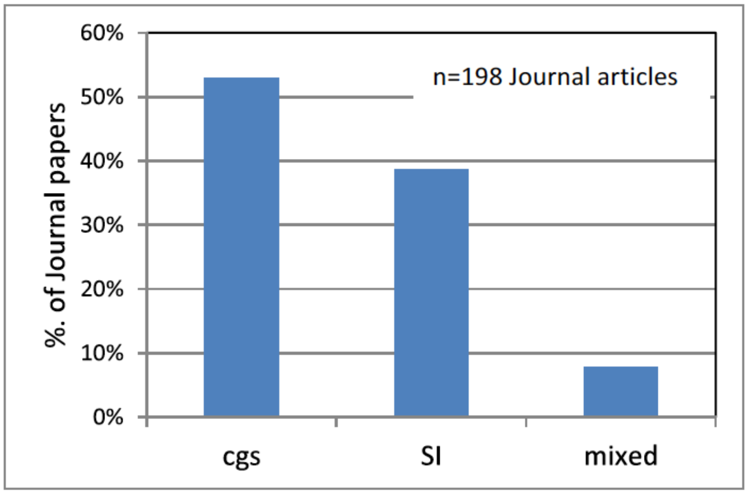

Figure 1. Magnetism units used in several recent Physics and Engineering Journals. Data collected from the following journals: J. Magnetism and Magnetic Materials (v 384, 15-June-2015; vol. 382, 15-May 2015); Phys. Rev. B (vol. 91, no. 2, 1 Jan 2015, no. 6, 1 Feb 2015), Phys. Rev. B Condensed Matter/material physics (91, No1 1 Jan 2015), J. Appl. Physics (vol. 117, Issue 17, 07 May 2015), and IEEE Transitions on Magnetics (Jan 2015).

μ_0 is the coefficient relating the magnetic intensity, or flux density B, to the field strength, H, in a vacuum: $B = \mu_0 H$. Historically, the Gaussian electromagnetic system of units was used, with $\mu_0 = 1$ by definition and the numerical values of B and H equal in a vacuum, although their units were recognised to be different, B in gauss and H in oersted. The difference becomes obvious when materials are involved and a value of permeability, μ, differing from μ_0 is required. The ratio, μ/μ_0, could be either slightly less than unity (for diamagnetic materials), slightly greater than unity (for paramagnetic materials) or, in the most interesting cases of ferromagnetic materials, much greater. A value for μ, or susceptibility $\chi = (\mu/\mu_0 - 1)$, was an immediately obvious indication of how strongly magnetic a material was. To retain that simple indication without the inconvenient and non-intuitive numerical values of μ in the SI system, some authors (e.g. Harnwell, 1938) wrote permeability as a product $(\mu\,\mu_0)$, with μ, the relative permeability, coinciding with the definition of permeability in the Gaussian system. But many practitioners of material magnetism avoid these problems altogether by continuing to use the Gaussian electromagnetic units, oersted and gauss, which remain the practical units of the subject, sometimes with conversion to SI units for political correctness in publication. A

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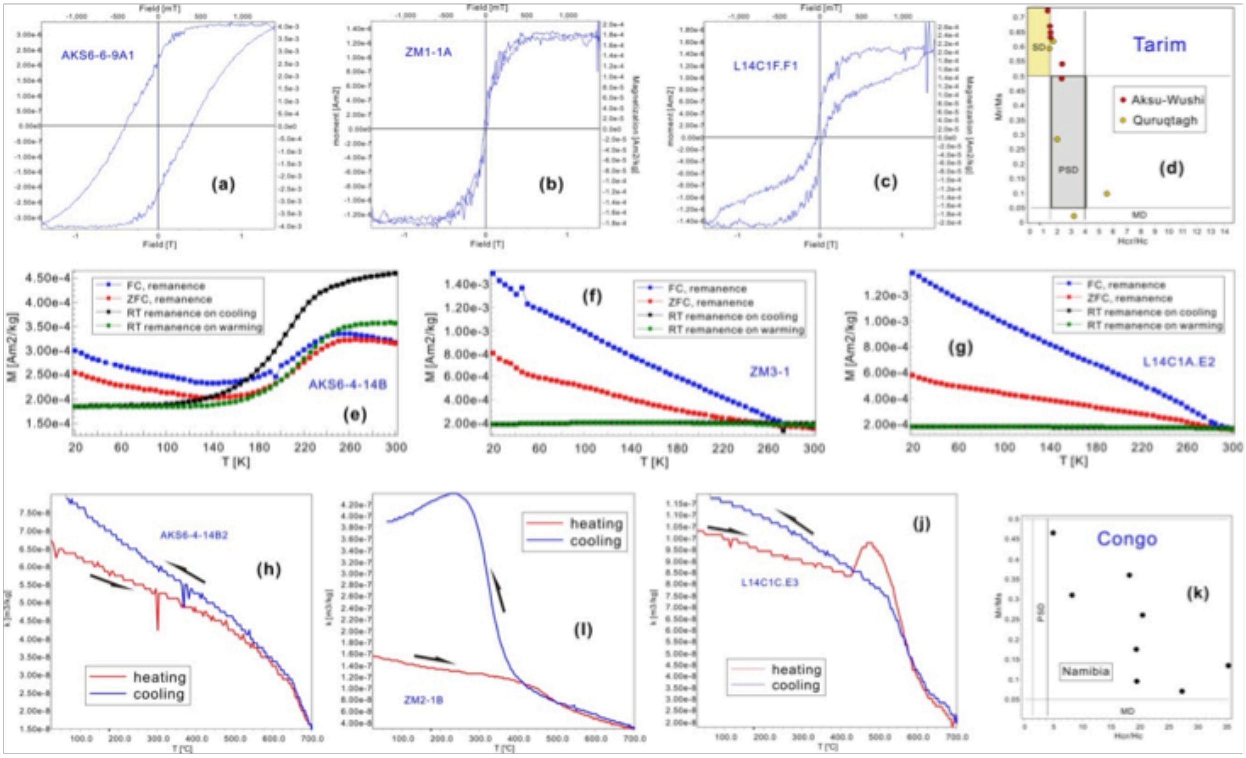
Visiting Fellows' Reports

Rock magnetic study of Neoproterozoic cap carbonates

Bin Wen
State Key Laboratory for Mineral Deposits Research, School of Earth Sciences and Engineering, Nanjing University, Nanjing 210046, China, and Department of Geology and Geophysics, Yale University, New Haven, CT 06520-8109, USA;
bin.wen@yale.edu

With the aim to constrain the paleolatitude of the late Neoproterozoic ice ages, we conducted a detailed paleomagnetic study of cap dolostones overlying diamictites in both Tarim (NW China) and Congo cratons (Northern Namibia). To identify the major remanence carriers and better understand the nature or property of the remanent magnetizations, a systematic rock magnetic study was performed at the Institute for Rock Magnetism (IRM, University of Minnesota). The rock magnetic experiments include: hysteresis parameters measurements; low-temperature experiments on Magnetic Properties Measurement System (MPMS); high-temperature susceptibility experiments; thermal demagnetizations of orthogonal isothermal remanent magnetizations (Lowrie, 1990); and anisotropy of magnetic susceptibility (AMS).

Samples from a newly discovered cap dolomite from the Aksu-Wushi section of northwestern Tarim show a slightly wasp-waisted shape of “fat” or “pot-bellied” hysteresis loops (Fig. 1a). They reach magnetic saturation at almost 1.4 T and have relatively high coercive force and coercivity of remanence suggesting the dominance of magnetically hard minerals with a very small amount of soft phase. On a Day diagram (Day et al., 1977; Dunlop, 2002), hysteresis parameters show that most samples are single and pseudo-single domains (SD, PSD, Fig. 1d). FC-ZFC and RTSIRM curves of low-temperature measurements (Fig. 1e), huge remanence decreases below about 260 K characterize the Morin transition of hematite (Morin, 1950), while the Verwey transition drop of magnetite at 120 K (Verwey, 1939) is very slight or invisible. This dominant presence of hematite with small amount of magnetite is further supported by both thermo-magnetic and the Lowrie (1990) experiments. Rapid and slight changes in slope of susceptibility curves upon heating and cooling (Fig. 1h) occur at about 680 °C (hematite) and 580 °C (magnetite). Lowrie tests show that the magnetization is mainly contributed by minerals with coercivity of 0.4 – 1.0 T (unblocking temperatures around 680 °C) and, only a small amount from low-coercivity (below 0.4 T) with Curie temperature around 600 °C corresponds to magnetite. AMS data for the representative samples shows low anisotropy degree Pj and oblate



Rock magnetic properties of representative samples. (a-d, k) Hysteresis loops and Day diagram (Day et al., 1977; Dunlop, 2002). (e-g) The FC-ZFC and RTSIRM curves of low-temperature measurements. (h-j) Thermal-magnetic experiments in the heating and cooling cycles.

bedding-parallel fabrics, indicating that the fabrics were acquired during deposition.

Samples from northeastern Tarim mainly exhibit “wasp-waisted” hysteresis loops (Fig. 1b), indicating a mixture of coercive/grain-size minerals (Roberts et al., 1995) and saturate at field in excess of 1.0 T (Fig. 1b). The parameters of Hcr/Hc vs Mr/Ms show a complicated distribution of grain size (Fig. 1d). On the curves of low-temperature measurements, FC and ZFC show a continuous increase with decreasing temperature from 300 to 20 K (Fig. 1f), reflecting the magnetic contribution of goethite (Dekkers, 1989). High temperature measurements are characterized by irreversible heating and cooling curves (Fig. 1i), suggesting alteration during heating. Most samples show the unblocking temperatures of magnetite (about 580 °C) and hematite (about 680 °C) on heating (Fig. 1i).

Cap carbonates from Namibia, Congo Craton have “wasp-waisted” hysteresis loops (Fig. 1c), which saturate around 1.4 T, suggesting the presence of hard minerals. They have anomalously high Hcr/Hc ratios with respect to Mr/Ms ratios which indicate a mixture of PSD and MD grains (Fig. 1k). FC and ZFC curves show a strong goethite contribution (Fig. 1g), and only a very weak Morin transition around 260 K. Thermal experiments (Fig. 1j) show a sharp increase in magnetic susceptibility on heating from 300 or 400 to 500 °C, indicating formation of new minerals (Fig. 4e and f), and two dramatic decreases at temperatures of ~ 600 °C and 700 °C, indicating the occurrences of magnetite and hematite within samples. The non-occurrence of the Verwey transition in the low-temperature curves, however, may indicate that the magnetite is secondary and produced during heating.

Based on the detailed rock magnetic study, the following conclusions can be reached:
Dominant hematite with a very small amount of magnetite is the major remanence carrier for the cap carbonates from Aksu-Wushi area, NW Tarim Craton. Most ferromagnetic minerals are SD and PSD, and the samples are characterized by primary sedimentary fabrics. All the magnetic properties suggest that the remanent magnetization probably records the magnetic field information from the time of deposition.

Unlike the samples from Aksu-Wushi area, the magnetic records of the cap carbonates from both Quruqtagh and Namibia are less reliable because of the very weak signals of stable magnetic carriers (both magnetite and hematite) and because the rocks from both areas posses a distribution of grain sizes, in particular, the occurrence of MD grains, which are not effective magnetic remanence carriers in rocks (Butler, 1992). As a result, more caution is needed when interpreting the paleomagnetic data of these samples.

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The next Visiting Fellowship application deadline is April 30th.

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Current Articles

A list of current research articles dealing with various topics in the physics and chemistry of magnetism is a regular feature of the IRM Quarterly. Articles published in familiar geology and geophysics journals are included; special emphasis is given to current articles from physics, chemistry, and materials-science journals. Most are taken from ISI Web of Knowledge, after which they are subjected to Procrustean culling for this newsletter. An extensive reference list of articles (primarily about rock magnetism, the physics and chemistry of magnetism, and some paleomagnetism) is continually updated at the IRM. This list, with more than 10,000 references, is available free of charge. Your contributions both to the list and to the Current Articles section of the IRM Quarterly are always welcome.

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Magnetic Fabrics and Anisotropy

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Table 1. Labeling of hysteresis loop axes from published figures in several recent Physics and Engineering Journals:

uo= permeability of free space;

ub=Bohr magneton;

moment=not specified but presumably in the same units as ub ;

J=magnetic polarization, G(gauss), Oe(oersted), emu (electromagnetic unit), T(tesla), A (ampere).

Magnetization axis Label	Field axis Label
Am^2/kg	T
Am^2/kg	A/m
emu/g	T
emu	T
emu oe/mole	T
A/m	kOe
J(T)	kOe
J(T)	u_oH (T)
u_oM (T)	A/m
moment/u_b	T
moment/u_b	Oe
G	kOe
Arbitrary	T, kOe, A/m

brief survey of magnetic units used in 198 peer-reviewed papers in 6 physics and engineering journals published in 2015 shows that Gaussian units are still preferred over SI by magnetists outside the GP community (Figure 1). In addition, Table 1 shows the variety of units used in figures of hysteresis loops (*M-H*, *B-H*) within the same group of publications.

The electromagnetic unit system (emu) worked well in the restricted sphere of magnetic and electromagnetic studies, but did not include phenomena involving electric fields, for which a separate system of electrostatic units (esu) was used. The logical advantage of the SI system is that both are combined in a single comprehensive system in which μ_0 and the permittivity of free space, ε_0, are related by $(\mu_0\varepsilon_0) = 1/c^2$, where *c* is the speed of light, which, in both the present and proposed revised SI systems is a defined constant (as *h*, *k*, *e* and N_A will become in the revised system). This will give the individual parameters, μ_0 and ε_0, anticorrelated observational uncertainties, but for most purposes those uncertainties will be inconsequentially small (0.32 ppb, Newell, 2014). However, the formal uncertainty in μ_0, with the vacuum condition $B = \mu_0 H$, re-opens the contentious debate about the roles of the *H* and *B* fields in presentations of the magnetic properties of materials in general and rocks and minerals in particular.

When the rock magnetism community became constrained by the general adoption of SI units for all science, a quasi-political division developed between *H*-fundamentalists and *B*-fundamentalists. To many of us who came into the subject from a Physics base, *H* is primary and *B* is a material dependent consequence, but others took an opposite view, treating *B* as fundamental. A third, agnostic, stance was to argue that, as long as μ_0 was regarded as a fixed constant of nature, with the vacuum relationship $B = \mu_0 H$, there is really no dif-

Symbol	**Kennelly**	**Kennelly (Neel unit)**	**Sommerfeld**	**Crangle-Gibbs**
	$B= \mu_0 H + M$		$B= \mu_0 (H + M)$	$B= B_0 + \mu_0 M$
H	[A/m]		[A/m]	none
B	[Tesla] ([weber/m^2])		[Tesla] ([weber/m^2])	[Tesla] ([weber/m^2])
B_o	---		---	[T]
μ_0	$4\pi x10^{-7}$ H/m		$4\pi x10^{-7}$ H/m	$4\pi x10^{-7}$ H/m
m(dipole moment)	[Wb m]	[Neel m^3]	[A m^2] ([J/T])	[J/T]
M(magnetization)	[T] ([Wb/m^2])	[Neel]	[A/m]	[J/T m^3]
σ (magnetization/mass)	[Wb m/kg]	[Neel m^3/kg]	[A m^2/kg]	[J/T kg]
χ (by volume)	[T m/A], [H/m] or [Wb/m A]	[Neel m/A]	dimensionless	[J/T^{2}m^3] or [m/H]
χ (by mass)	[Wb m^2/A kg] or [H m^2/kg]	[Neel m^4/kg A]	[m^3/kg]	[J/T^2 kg]
Saturation Mag. Magnetite (by volume) Magnetite (by mass)	0.6 T (0.6 Wb/m^2) $1.15x10^{-4}$ Wb m/ kg	0.6 Nl $1.15x10^{-4}$ Nl m^3/kg	480 kA/m 92 Am^2/kg	480 J/T m^3 92 J/T kg
Dipole moment of Earth	$1x10^{17}$ Wb-m	$1x10^{17}$ Nl m^3	$8x10^{22}$ Am^2	$8x10^{22}$ J/T
Bohr magneton	$1.165x10^{-29}$ Wb m	$1.165x10^{-29}$ Nl m^3	$0.927x10^{-23}$ A m^2	$0.927x10^{-23}$ J/T
NRM (basalt, by volume) NRM (limestone)	$1.26x10^{-6}$ T (1.26 μT) $1.26x10^{-10}$ T (126 pT)	1.26 μNl 126 pNl	1 A/m 10^{-4} A/m	1 J/T m^3 10^{-4} J/T m^3
χ_0 (MD magnetite, by vol) χ_0 (basalt)	$3\mu_0$ ($3.77x10^{-6}$ H/m) $10^{-3}\mu_0$ ($1.26x10^{-9}$ H/m)	3.77 μNl m/A 1.26 nNl m/A	3 10^{-3}	$3/\mu_0$ ($2.39x10^6$ J/T^{2}m^3) $10^{-3}/\mu_0$ (796 J/T^{2}m^3)
χ_0 (MD magnetite, by mass)	$7.25x10^{-10}$ Wb m^2/A kg	$7.25x10^{-10}$ Nl m^4/kg A	$5.8x10^{-4}$ m^3/kg	$10^{-4}/\mu_0$ (79.6 J/T^2 kg)
N (demagnetizing factor)	$0 \le N \le 1/\mu_0$ [m/H]	$0 \le N \le 1/\mu_0$] ([A/Nl m])	$0 \le N \le 1$ (dimensionless)	$0 \le N \le \mu_0$ [H/m]
μ (permeability)	$\chi+\mu_0$ ([H/m])	$\chi+\mu_0$ [Nl m/A]	$\mu_0(1+\chi)$ [H/m]	$1+\mu_0\chi$ (dimensionless)
Energy of dipole	MH [J/m^3]	MH [J/m^3]	μ_0MH [J/m^3]	MB$_o$ [J/m^3]
Demagnetizing Energy	$(1/2\mu_0)NM^2$ [J/m^3]	$(1/2\mu_0)NM^2$ [J/m^3]	$(\mu_0/2)NM^2$ [J/m^3]	$(\mu_0/2)NM^2$ [J/m^3]
Néel Relaxation time	$\tau = \frac{1}{f_0}\exp\left[\frac{vM_sH_c}{2kT}\right]$		$\tau = \frac{1}{f_0}\exp\left[\frac{v\mu_0M_sH_c}{2kT}\right]$	$\tau = \frac{1}{f_0}\exp\left[\frac{vM_sB_c}{2kT}\right]$

Table 2. Comparison of Magnetism Units, Expressions and Values for Different Unit Systems. Nl (Neel), Wb (weber), T (tesla), A (ampere), H (henry), J (joule), B_0=magnetic induction in free space (=μ_0H).

ference between the approaches, but that argument fails with μ_0 relegated to the status of an observed parameter with attendant uncertainty, however small that may be. A historical review of the *B* and *H* problem appeared in IRMQ 18(1) (2008) and now is a good time to revisit it and initiate a discussion that may lead to a resolution of the problem of units applied to the magnetic properties of solids.

The philosophical significance of the change in unit definitions is summarised by Ampere's theorem, one of the fundamental bases of electromagnetism. It considers a loop l enclosing a total current i which is equated to the integral of the magnetic field around the loop

$$\int H.\mathrm{d}l = i \qquad (1)$$

This equation is independent of the medium and variations in it on the path of the integral. In a vacuum it can be rewritten

$$\int B.\mathrm{d}l = \mu_0 i \qquad (2)$$

but if the medium is not a vacuum, then a value of permeability differing from μ_0 is required. The simple case of homogeneous media represented by these equations makes it clear that the current causes *H* and that *B* is a consequence that depends on the medium. Eq. (1) is definitive for *H*, but it has not been used as such, because there is an independent definition of *B* and with $H = B/\mu_0$, and μ_0 a fixed constant, *H* could not have an independent definition. Definitions aside, Eq. (1) makes it difficult to avoid fixing the unit of *H* as A m^{-1} but this is rarely used. In the conventional SI presentation of magnetic properties the inconvenience of this unit, and its awkward conversion to the practical units (oersteds) by the factor $4\pi\times10^{-3}$, has been a stumbling block to recognition that H is a primary field and has contributed to attempts to write it out of magnetism altogether in introductory physics textbooks (e.g. Tippler and Mosca, 2007; Halliday, Resnick and Walker, 2014) and to lose sight of the underlying basic physics. Crangle and Gibbs (1994) have proposed a variation of SI magnetism units that eliminates the usage of the *H*-field entirely (see Table 2).

B has been defined in terms of the force exerted by a field on an electric current or moving charge. A charge q moving at speed v in a direction perpendicular to B experiences a force F, in a direction perpendicular to the B-v plane, of magnitude given by

$$F = qvB \qquad (3)$$

As the defining equation for B, Eq. (3) can be rewritten in an equivalent form in terms of a current instead of moving charge without affecting the definition. This means that the dimensions of B prescribe its unit as newtons per ampere metre (N A^{-1} m^{-1} or kg A^{-1} s^{-2}), and named the tesla. But this is not the conventional interpretation. Rather, the tesla is seen as the unit of magnetic flux density, Wb m^{-2}, with the weber, the unit of flux, being the quantity of fundamental interest. The reason why B appears in Eq. (3) and not H can be seen by considering the force between two currents as the variation in their mutual potential energy with separation. Each current produces a field H, but its potential energy in the field of the other one depends on the magnetic flux crossed as it moves and therefore on a product of H and B fields. We return to this point below, in considering the definition of the ampere.

The conclusion that magnetic energy is a product of H and B is useful to an understanding of the nature of our units problem. To confirm its validity we can check the dimensions of the product $H \times B$, (A m^{-1})×(N A^{-1} m^{-1}) = N m^{-2} or J m^{-3}, that is, energy per unit volume. Conventionally magnetic energy per unit volume has been written as $B^2/2\,\mu_0$, but this is unhelpful to its application to magnetic materials and it is better recognised as $H \times B/2$, with the factor ½ invoking an assumption of linearity in the $B - H$ relationship, that is

$$\text{Magnetic field energy } = \int B.\mathrm{d}H \qquad (4)$$

with the assumption $B \alpha H$. In dealing with magnetic materials, we need this integral but must abandon the linearity assumption and consider the more general situation of a hysteresis loop. This is a plot of B vs H, so that energy is represented by area in the diagram and the area enclosed by a loop is the energy dissipation per cycle. This basic relationship is lost in the now common, but fundamentally and dimensionally invalid, practice of plotting two different versions of B. The phenomenon of hysteresis introduces an irrefutable argument that, at least in dealing with magnetic materials, H is the primary, causative field. The principle of causality disallows any effect that precedes its cause. As we commonly observe, B lags H. B is not causal but a consequence and the same applies to magnetization, M, which is a contribution to B, additional to $\mu_0 H$, a point that we return to. Table 1 lists the combinations of axis labelling for hysteresis loops found in a survey of recent papers. Confusion reigns!

There is another question arising from the energy argument implied by Eq. (3) that needs to be resolved in selecting units for magnetisation, demagnetising fields and demagnetising factors. The force on a current-carrying conductor depends on B and therefore so does the torque on a current loop. This means that the report by Whitworth and Stopes-Roe (1971), that the torque on a permanent magnet depends on H not B, appears as a paradox. Their magnet was not physically equivalent to a current loop. It means that magnetisation does not respond to a field in the same way as a current loop and must be recognised as a B field, interacting with H of the external field and not as an internal H field interacting with B of the external field. The unit of magnetisation must reflect this, with corresponding demagnetisation factors. It means that the conventional SI presentation (Sommerfeld system) of the relationship between B, H and magnetisation, M, that is

$$B = \mu_0 (H + M) \qquad (5)$$

is fundamentally flawed and the system needs to recognise the validity of the Kennelly system in which

$$B = \mu_0 H + M \qquad (6)$$

The point is that M is an addition to B and not an addition to H, as implied by Eq. (5). For hysteresis to make sense, a M vs H loop must represent energy, with M having the same dimensions as B. This is recognised in two major books on magnetism (Chikazumi, 1997, and Cullity, 1972[1]), although rather pointedly most of their data are presented in oersteds and gauss anyway. This leads us directly to a suggestion about the units for M. Although it is dimensionally the same as B, it needs its own unit. In recognition of Louis Néel (1904-2000), who was awarded the 1970 Nobel prize in Physics for fundamental contributions to the magnetism of materials, we propose the Neel (Nl) as the unit for M. It is crucial to avoid writing the unit of M as A m^{-1}. Our choice of units and corresponding conversion factors are given in Tables 2 and 3.

Now we face the possibility of a circular argument involving the definition of the ampere, which is specified by the force between a pair of infinitely long parallel currents. If the currents, i, are equal and separated by a distance d then the force between them per unit length is

$$F/\,l = \mu_0\, i^2/\,2\pi d \qquad (7)$$

with μ_0 necessarily involved because this force is the variation with d of the magnetic field energy ($H \times B$). In the revised SI system circularity of the argument will be avoided by referencing everything to fundamental constants, but this means that a dramatically new, simpler system of units could be developed. The revised SI units system will still be a patched up arrangement loaded with historical compromises. We will have 7 fundamental constants, including c, h, k, e, N_A, with values

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[1] It should be noted that in the second edition of Cullity (Cullity and Graham, 2009), the conventional SI system (based equation 5) is used.

Symbol	**Sommerfeld**	**Conversion Factor**[1]	**Kennelly**	**Cgs unit**[2]
	$B = \mu_0(H + M)$		$B = \mu_0 H + M$	$B = H + 4\pi M$
H	A/m	1	A/m	$4\pi\ 10^{-3}$ Oe
B	Tesla	1	Tesla	10^4 G
m (dipole moment)	A m^2	μ_0	Neel m^3	$10^3/\mu_0$ G cm^3
M (magnetization)	A/m	μ_0	Neel	$10^{-3}/\mu_0$ emu/cm^3
σ (magnetization/mass)	A m^2/kg	μ_0	Neel m^3/kg	$1/\mu_0$ emu/g
χ (by volume)	--	μ_0	Neel m/A	$1/4\pi\mu_0$ emu/cm^3 Oe
χ (by mass)	m^3/kg	μ_0	Neel m^4/kg A	$10^3/4\pi\mu_0$ emu/g Oe

Table 3. New SI units and their Sommerfeld and cgs equivalents.

[1] Multiply a number in Sommerfeld units by conversion factor ($\mu_0 = 4\pi\ 10^{-7}$) to covert to Kennelly units (e.g., 1 Am^2/kg = μ_0 Neel m^3/kg).

[2] Cgs unit conversion to Kennelly units (e.g., 1 Neel = ($10^{-3}/\mu_0$) emu/cm^3).

defined by what they happen to be in the existing system. They will each have 8 or more digits with high positive or negative powers of 10. Instead of having fundamental constants that are consequences of history we could produce a new set, redefined from scratch, to yield a system of units that have practical values, perhaps unrelated to existing units, that solve the problem of magnetic units and avoid residual illogicalities. In particular the mass unit, kilogram, is an admission that the primary unit is the gram with the mole in its wake and the prefixes micro-, milli-, mega- etc. thrown out of kilter. If such a new system becomes possible it will be a very long term prospect and cannot be seriously addressed here. Our immediate aim is a minimalist resolution of the disruption to magnetism studies that has resulted from introduction of the SI system. We recommend the following:

- Rejection of Eq. (5) in favour of Eq. (6)
- Adoption of the Neel as the unit of magnetisation
- Consistency in plotting hysteresis loops (M-H or B-H) with the x-axis in units of the H-field (in A/m) and the y-axis in units of M (in Neel) or B (in Tesla). This means that measures of coercivity (H_c, H_{cr}, MDF) should be in units of A/m and not T or mT.
- Acceptance of self-demagnetising factors, $N = H_{demag}/M$, with $N_1 + N_2 + N_3 = 1/\mu_0$ for three orthogonal directions.

Difficulties in presenting magnetism in the SI system have been aired for many years (Stacey and Banerjee, 1974; Crangle and Gibbs, 1994; Moskowitz, 1995; Dunlop and Özdemir, 1997), but a solution to the problem has not been obvious, or not sufficiently obvious to lead to a generally acceptable resolution. It is essentially a question of units and the planned SI revision makes a revisit opportune. This note aims to provoke a clarifying discussion. To facilitate the process we have set up an online forum, which may be accessed through the IRM web site (www.irm.umn.edu), or directly at https://groups.google.com/a/umn.edu/forum/#!categories/mag-measure-peat/units.

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University of Minnesota
291 Shepherd Laboratories
100 Union Street S. E.
Minneapolis, MN 55455-0128
phone: (612) 624-5274
fax: (612) 625-7502
e-mail: irm@umn.edu
www.irm.umn.edu

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Dario Bilardello
Institute for Rock Magnetism
University of Minnesota
291 Shepherd Laboratories
100 Union Street S. E.
Minneapolis, MN 55455-0128
phone: (612) 624-5274
fax: (612) 625-7502
e-mail: dario@umn.edu
www.irm.umn.edu