

1. TENSORIAL ASPECTS OF PHYSICAL PROPERTIES

Table 1.5.10.1. Conversion of Gaussian to SI units

Symbol	Quantity	Gaussian unit and its SI equivalent
B	Magnetic induction	1 gauss (G) = 10 ⁻⁴ tesla (T)
H	Magnetic field	1 oersted (Oe) = 10 ³ /(4π) A m ⁻¹
M	Magnetization (= magnetic moment per unit volume)	1 emu cm ⁻³ = 10 ³ A m ⁻¹
α	Linear magnetoelectric tensor (rationalized units)	1 (dimensionless units) = 4π × 10 ⁻⁸ /3 s m ⁻¹
Λ	Piezomagnetic tensor	1 Oe ⁻¹ = 4π × 10 ⁻³ m A ⁻¹ = 4π × 10 ⁻³ T Pa ⁻¹
χ	Magnetic volume susceptibility	1 (dimensionless units) = 4π (dimensionless units)
χ_g	Magnetic mass susceptibility	1 cm ³ g ⁻¹ = 4π × 10 ⁻⁶ m ³ g ⁻¹
χ_{mol}	Magnetic molar susceptibility	1 cm ³ mol ⁻¹ = 4π × 10 ⁻⁶ m ³ mol ⁻¹

We used here the modified equation (1.5.9.7):

$$\frac{1}{2}c_{ijkl}S_{ij}^*S_{kl}^* = -\frac{1}{2}V_{ij}^0S_{ij}^* \quad (1.5.9.30)$$

Substituting the values for the spontaneous magnetostriction, the final equation for the anisotropy energy measured at atmospheric pressure may be written as

$$\begin{aligned} U_a &= U_a^0 + \frac{1}{2}V_{ij}^0S_{ij}^* \\ &= (K_{ij}^0 + K'_{ij})n_i n_j + (K_{ijkl}^0 + K'_{ijkl})n_i n_j n_k n_l \\ &\quad + (K_{ijklmn}^0 + K'_{ijklmn})n_i n_j n_k n_l n_m n_n + \dots \end{aligned} \quad (1.5.9.31)$$

As an example, for the ferromagnets with a cubic prototype this equation may be written as

$$U_a = (K_1^0 + K_1')S(n_1^2 n_2^2) + (K_2^0 + K_2')n_1^2 n_2^2 n_3^2. \quad (1.5.9.32)$$

The coefficients K_1' and K_2' may be expressed in terms of the saturation magnetostriction constants h_0, \dots, h_5 [see (1.5.9.12)] and the elastic stiffnesses $c_{\alpha\beta}$:

$$\begin{aligned} K_1' &= c_{11}[h_0(2h_4 - 3h_3) + h_1(h_1 - h_3 + 3h_4) - h_4(h_3 - 2h_4)] \\ &\quad + c_{12}[2h_0(2h_4 - 3h_3) - (h_1 + h_4)(h_1 + 2h_3)] - \frac{1}{2}c_{44}h_2^2, \end{aligned} \quad (1.5.9.33)$$

$$\begin{aligned} K_2' &= -c_{11}[3h_4(h_1 + h_3) + (h_4 - h_3)(4h_4 - 3h_3)] \\ &\quad + c_{12}[3h_4(h_1 + h_3) + h_3(5h_4 - 6h_3)] \\ &\quad - \frac{1}{2}c_{44}(6h_2 + h_5)h_5. \end{aligned} \quad (1.5.9.34)$$

For cubic crystals, K_1^0 and K_1' are of the same magnitude. As an example, for Ni one has $K_1^0 = 80\,000 \text{ erg cm}^{-3} = 8000 \text{ J m}^{-3}$ and $K_1' = -139\,000 \text{ erg cm}^{-3} = -13\,900 \text{ J m}^{-3}$.

1.5.10. Transformation from Gaussian to SI units

Numerical values of magnetic quantities are given in Gaussian units in this chapter. For each quantity that appears in a table or figure, Table 1.5.10.1 gives the corresponding Gaussian unit and its value expressed in SI units. More details on the transformation between Gaussian and SI units are given e.g. in the Appendix of Jackson (1999).

1.5.11. Glossary

α_{ij}	(linear) magnetoelectric tensor
β_{ijk}	nonlinear magnetoelectric tensor <i>EHH</i>
γ_{ijk}	nonlinear magnetoelectric tensor <i>HEE</i>
Δ	Weiss constant
Δn	magnetic birefringence
ϵ_{ij}	dielectric permittivity
λ	constant describing magnetostriction
Λ_{ijk}	tensor describing the piezomagnetic effect
$\Lambda_{i\alpha}$	matrix describing the piezomagnetic effect
μ_{ij}	magnetic permeability

μ	magnetic moment
μ_B	Bohr magneton
π_{ijkl}	piezomagnetoelectric tensor
$\rho(\mathbf{r})$	charge density
Φ	thermodynamic potential
χ_{ij}^e	dielectric susceptibility
χ_{ij}, χ_{ij}^m	magnetic susceptibility
B	magnetic induction
c	speed of light
c_{ijkl}	elastic stiffness
$d\tau$	volume element
e	charge of the electron
E	electric field
g	Landé <i>g</i> -factor
H	magnetic field
$\mathbf{j}(\mathbf{r})$	current density
J	total angular momentum
k	position vector in reciprocal space
k_B	Boltzmann factor
\mathbf{l}_i	sum of the magnetic moments in a unit cell, in which some of the moments are taken with opposite sign
\mathbf{L}_i	antiferromagnetic vector
L	orbital angular momentum (Section 1.5.1.1), antiferromagnetic vector (remainder of this chapter)
$\mathbf{m}(\mathbf{r})$	magnetic moment density
m	sum of the magnetic moments in a unit cell
M	magnetization (= magnetic moment per unit volume = ferromagnetic vector)
N	No. of atoms per unit volume
P	effective number of Bohr magnetons (Section 1.5.1), pressure (remainder of this chapter)
P	electric polarization
r	position vector in space
S(r)	spin density
S	spin angular momentum (of an atom or ion)
s_{ijkl}	elastic compliance
S_{ij}	strain tensor
T_{ij}	stress tensor
T	temperature
T_c	transition temperature, in particular Curie temperature
T_N	Néel temperature
U	energy
U_a	anisotropy energy
U_{el}	elastic energy
U_{me}	magnetoelastic energy
v	velocity
Z	atomic number (= number of electrons per atom)

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