SYMBOLS and UNITS

International Union of Pure and Applied Physics — SUN Commission

DOCUMENT

UIP

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The Commission on Symbols, Units, and Nomenclature of the International Union of Pure and Applied Physics directs its efforts toward arriving at some international uniformity of the symbols used for various physical quantities and concepts, the names and definitions of units in which physical quantities are measured and to certain nomenclature questions. Uniformity in the use of symbols, units, and nomenclature is difficult to achieve for many reasons and complete agreement on such matters will probably not be arrived at in the foreseeable future. Some degree of international consistency in the usage of physical terms can, however, be had and Document UIP 6 (1955), reproduced here, is the most recent publication on this matter by the International Union of Pure and Applied Physics in this respect. The Commission hopes to enlarge this work in succeeding years. It will welcome suggestions regarding the present work, which it recognizes as imperfect, and regarding the manner and the scope of the proposed extension of its work. Such suggestions may be sent to the chairman of the Commission, Professor Harald H. Nielsen, Department of Physics and Astronomy, The Ohio State University, Columbus, Ohio.

I. General Principles and Recommendations

1. Physical quantities

(1) Symbols for physical quantities should be printed in italic (cursive) type.

The symbol for a physical quantity ("grandeur physique," *Fr;* "physical magnitude," *Am;* "physikalische Grösse," *G*) is equivalent to the product of the numerical value or measure, being a pure number, and a unit:

physical quantity = numerical value × unit.

(2) Abbreviations, i.e. shortened forms of names or expressions, should not be used in physical equations. In the text the abbreviations should be written in ordinary roman type (e.g.: pf for partition function, EMF for electromotive force, etc.).

Remark:

This report, composed by the commission of Symbols, Units, and Nomenclature of the IUPAP, has been approved by the General Assemblies of the Union of Physics, held in 1948, 1951, and 1954.

The recommendations on the use of symbols for units, for physical quantities, and for mathematical constants and operations contained in this report are in general in agreement with important international recommendations, *viz:*

(1) International Standardizing Organization (ISO)—Project ISO. TC 12.
(2) Conférence Générale des Poids et Mesures (9ème C.G. 1948; 10-ème C.G. 1954).
(3) Union Internationale de Chimie Pure et Appliquée (1947, 1949, 1951).
(4) International Electrotechnical Committee (Int. Letter Symbols Publ. 27, 1953).

2. Units

(1) Symbols for units of physical quantities should be printed in roman (upright) type.

(2) Symbols for units should *not* be followed by a full stop.

(3) Symbols for units derived from proper names should start with a capital roman letter. All other units should be printed in lower case roman type.

(4) Symbols for prefixes should be printed in lower case roman type, with the single exception of the prefixes: M = mega, G = giga, and T = tera.

(5) Symbols for units should *not* be written in plural (e.g. do *not* write: 7 watts, but: 7 watt or 7 W).

3. Mathematical operations and signs

(1) Symbols for mathematical operations should be printed in roman (upright) type. (e.g.: $\sin kx$, $\exp \alpha t$, $\log A$).

(2) Symbols for mathematical operations should *not* be followed by a full stop.

(3) Numbers should be printed in upright figures. A comma or point may be used only to separate the whole numbers from the decimals.

(4) To facilitate the reading of large numbers the figures may be grouped in groups of three but *no* comma or point should be used (e.g. 2 573 421 736).

4. Chemical elements

(1) Symbols for chemical elements should be written in roman (upright) type and are not followed by a full stop (e.g. Ca, C, H, D, He).

(2) The attached numerals should have the following meaning:

mass number / atomic number $^{14}_{7}\mathrm{N}_{2}$ atoms/molecule

The right superscript place is left for indicating, if required, a state of ionization or nuclear excited states (e.g. Ca^{2+}, PO_4^{3-}). It may be of advantage to omit the atomic number when there is no special reason for indicating it.

(3) A species of atoms identical as regards atomic number and mass number should be indicated by the word *nuclide*. The name *isotopes* should be reserved for atoms with the same atomic number, whereas *isobars* are atoms having the same mass number.

II. Symbols for Physical Quantities

Remark:

(1) Where several symbols are given for one quantity, and no special indication is made, they are on equal footing.

(2) In general no special attention is paid to the name of the quantity.

1. Space, time

length	l
breadth	b
height	h
radius	r
diameter: $d = 2r$	d
path: $L = \int ds$	L, s
area	A, S
volume	V, v
plane angle	$\alpha, \beta, \gamma, \theta, \vartheta, \varphi$
solid angle	ω, Ω
wave length	λ
wave number: $\sigma = 1/\lambda$	$\sigma, \tilde{\nu}$
($\tilde{\nu}$ is exclusively used in molecular spectroscopy)	
circular —: $k = 2\pi/\lambda$	k
time	t
period	T
frequency: $\nu = 1/T$	ν, f
(In physics: ν)	
pulsatance: $\omega = 2\pi\nu$	ω
velocity: $v = ds/dt$	v
angular velocity: $\omega = d\varphi/dt$	ω
acceleration: $a = dv/dt$	a
angular acceleration: $\alpha = d\omega/dt$	α
gravitational —	g
standard — —	g_n
v/c	β

2. Mechanics

mass	m
density: $\rho = m/V$	ρ
reduced mass	μ
momentum: $p = mv$	$\boldsymbol{p}, p$
moment of inertia: $I = \int r^2 dm$	I, J
force	$\boldsymbol{F}, F$
weight	$G, (W)$
(Preferred symbol: G)	
force moment	$\boldsymbol{M}, M$
pressure	p
traction	σ
shear stress	τ
gravitational constant: $F(r) = G\, m_1 m_2/r^2$	G
modulus of elasticity, Young's modulus: $\sigma = E\, \Delta l/l$	E
shear modulus: $\tau = G \operatorname{tg} \gamma$	G
compressibility: $\varkappa = -(1/V)dV/dp$	$\varkappa$
bulk modulus: $K = 1/\varkappa$	K
viscosity	η
kinematic viscosity: $\nu = \eta/\rho$	ν
friction coefficient	f
surface tension	γ, σ
energy	E, U
potential energy	V, E_p
kinetic energy	T, E_k
work	W, A
power	P
efficiency	η
Hamiltonian function	H
Lagrangian function	L
relative density	d

3. Kinetic theory of gases

number of molecules	N
— per mole	N_0, N
— per volume, number density	n
mol. velocity vector with components	$\boldsymbol{c}$, (c_x, c_y, c_z)
	$\boldsymbol{u}$, (u_x, u_y, u_z)
mol. position vector with components	$\boldsymbol{r}$, (x, y, z)
mol. momentum vector with components	$\boldsymbol{p}$, (p_x, p_y, p_z)
average velocity	c_0, u_0, $\bar{c}$, $\bar{u}$,
most probable speed	$\hat{c}$, $\hat{u}$
mean free path	l
velocity distribution function: $n = \int f\, du_x du_y du_z$	$f(c)$
Boltzmann's function	H
generalized coordinate	q
generalized momentum	p
volume in γ phase space	Ω
thermodynamic temperature (Preferred symbol: T)	T, (Θ)
Boltzmann's constant	k
$1/kT$ in exponential functions	β
gas constant per mole	R
characteristic temperature	Θ
Debye —: $\Theta_D = h\nu_D/k$	Θ_D
Einstein —: $\Theta_E = h\nu_E/k$	Θ_E
rotational —: $\Theta_r = h^2/8\pi^2 Ik$	Θ_r
vibrational —: $\Theta_v = h\nu/k$	Θ_v

4. Thermodynamics

quantity of heat	Q
work	W, A
temperature (Preferred symbol: t)	t, (ϑ)
thermodynamic temperature (Preferred symbol: T)	T, (Θ)
entropy	S
internal energy	U
free energy, Helmholtz function: $F = U - TS$	F
enthalpy, heat function: $H = U + pV$	H
Gibbs function: $G = U + pV - TS$	G
linear expansion coefficient	α
cubic expansion coefficient	γ
thermal conductivity	λ
specific heat	c_p, c_v
molar heat capacity	C_p, C_v
Joule-Thomson coefficient	μ
ratio of specific heats	$\varkappa$, γ

5. Electricity

quantity of electricity	Q
charge density	ρ
surface charge density	σ
electric potential	V
electric field	$\boldsymbol{E}$, E
electric displacement	$\boldsymbol{D}$, D
capacity	C
permittivity: $\epsilon = D/E$	ϵ
permittivity of vacuum	ϵ_0
relative permittivity: $\epsilon_r = \epsilon/\epsilon_0$	ϵ_r
dielectric polarization: $\boldsymbol{D} = \epsilon_0 \boldsymbol{E} + \boldsymbol{P}$†	$\boldsymbol{P}$, P
electric susceptibility	χ_e
electric dipole moment	$\boldsymbol{p}$, p
electric current	I
electric current density	$\boldsymbol{J}$, J
magnetic field	$\boldsymbol{H}$, H
magnetic induction	$\boldsymbol{B}$, B
magnetic flux	Φ
permeability: $\mu = B/H$	μ
permeability of vacuum	μ_0
relative permeability: $\mu_r = \mu/\mu_0$	μ_r
magnetization: $\boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M})$†	$\boldsymbol{M}$, M
magnetic susceptibility	χ_m
electromagnetic moment	$\boldsymbol{\mu}$, μ
magnetic polarization: $\mu_0 \boldsymbol{M}$ (No symbol is recommended)	
magnetic dipole moment	$\boldsymbol{m}$, m
resistance	R
reactance	X
impedance: $Z = R + iX$	Z
conductance: $G = R/Z^2$	G
susceptance: $B = -X/Z^2$	B
admittance: $Y = 1/Z = G + iB$	Y
resistivity	ρ
conductivity: $1/\rho$	γ, σ
self-inductance	L
mutual inductance	M, L_{12}
phase number	m
loss angle	δ
number of turns	N
power	P
Poynting vector	$\boldsymbol{S}$, S
vector potential	$\boldsymbol{A}$

6. Light

quantity of light	Q
flux of light	Φ
luminous intensity: $d\Phi/d\omega$	I
illumination: $d\Phi/dS$	E
luminance: $dI/dS \cos\vartheta$	L, B
luminous radiance: $d\Phi/dS$	H
absorption factor: Φ_a/Φ_0	α
reflection factor: Φ_r/Φ_0	ρ
transmission factor: Φ_{tr}/Φ_0	τ

† Written in the rational form. See p. 27.

absorption coefficient	a
extinction coefficient	$\varkappa$
speed of light in empty space	c
refractive index: $n = c/c_n$	n

7. Atomic and nuclear physics

atomic number	Z
mass number	A
proton number: $P = Z$	P
neutron number: $N = A - Z$	N
charge of electron	$-e$
electron mass	m
proton mass	M_{p}
neutron mass	M_{n}
meson mass	m_π, m_μ
nuclear mass	M
atomic mass	M_{a}
magnetic moment of particle	μ
magnetic moment of proton	μ_{p}
magnetic moment of neutron	μ_{n}
magnetic moment of electron	μ_{e}
Bohr magneton	μ_{B}, β
principal quantum number	n, n_i
orbital angular momentum quantum number	L, l_i
spin quantum number	S, s_i
total angular momentum quantum number	J, j_i
magnetic quantum number	M, m_i
nuclear spin quantum number	I
hyperfine quantum number	F
rotational quantum number	J, K
vibrational quantum number	v
quadrupole moment	Q
Rydberg constant	R

III. Mathematical Operations and Symbols

1. Analysis

equal to	$=$
approximately equal to	$\simeq$, $\approx$
proportional to	$\propto$
tends to	$\rightarrow$
asymptotically equal to	$\sim$
corresponds to	$\widehat{=}$
plus or minus	$\pm$
sum of	$\sum$
Product of	$\prod$
infinity	∞
pi	π
base of natural logarithm	e
factorial n	$n!$
binomial coefficient: $n!/p!(n-p)!$	$\binom{n}{p}$
variation of x	δx
increase of x (Greek capital delta, not triangle!)	Δx
exponential of x	$\exp x$, e^x
decadic log of x (In case of ambiguity $^{10}\log x$ or $\log_{10} x$)	$\log x$
natural log of x	$\ln x$
real part of z	$\mathrm{Re}\, z$
imaginary part of z	$\mathrm{Im}\, z$
modulus of z	$\lvert z \rvert$
complex conjugate of z	z^*
complex conjugate matrix A: $(A^*)_{jk} = (A_{jk})^*$	A^*
Hermitian conjugate of matrix A: $(A^\dagger)_{jk} = A_{kj}{}^*$	$A^\dagger$
adjoint of matrix A: $\tilde{A}_{jk} = A_{kj}$	$\tilde{A}$

2. Vectors and tensors

To avoid the usage of subscripts it is often recommended to indicate vectors and tensors of the second rank by letters of a special type.

The following choice is recommended:

(1) *Vectors should be printed in bold type by preference bold italic type.*

(2) *Tensors of the second rank should be printed in sans serif type.*

(3) In manuscripts vectors may be indicated by an arrow and tensors by a double arrow on top.

vector	$\boldsymbol{A}$, $\boldsymbol{a}$
absolute value	$\lvert \boldsymbol{A} \rvert$, $\lvert \boldsymbol{a} \rvert$
scalar product	$\boldsymbol{A} \cdot \boldsymbol{B}$
vector product	$\boldsymbol{A} \frown \boldsymbol{B}$, $\boldsymbol{A} \times \boldsymbol{B}$
nabla operator	∇
gradient	grad φ, $\nabla \varphi$
divergence	div $\boldsymbol{A}$
curl	curl $\boldsymbol{A}$, rot $\boldsymbol{A}$
Laplacian	$\triangle \varphi$, $\nabla^2 \varphi$
dyadic product	$\boldsymbol{A}\,\boldsymbol{B}$
tensor	T
tensor product: $\Sigma_k S_{ik} T_{kl}$	$\mathsf{S} \cdot \mathsf{T}$
scalar product: $\Sigma_k \Sigma_i S_{ik} T_{ki}$	$\mathsf{S} : \mathsf{T}$
product of vector and tensor: $\Sigma_k A_k T_{ki}$; $\Sigma_i T_{ki} A_i$	$\boldsymbol{A} \cdot \mathsf{T}$; $\mathsf{T} \cdot \boldsymbol{A}$

IV. Symbols for Units

1. Symbols for prefixes

deci	$(= 10^{-1})$	d	pico	$(= 10^{-12})$	p
centi	$(= 10^{-2})$	c	kilo	$(= 10^{3})$	k
milli	$(= 10^{-3})$	m	mega	$(= 10^{6})$	M
micro	$(= 10^{-6})$	μ	giga	$(= 10^{9})$	G
nano	$(= 10^{-9})$	n	tera	$(= 10^{12})$	T

2. CGS-Units

	Unit	Symbol
l, b, h	centimeter	cm
t	second	s
m	gram	g
f, ν	hertz $(= s^{-1})$	Hz
F	dyne	dyn
E	erg	erg
p	barye $(= dyn/cm^2)$	barye
η	poise $(= dyn\ s/cm^2)$	P
T	degree Kelvin	°K
t	degree Celsius	°C
H	oersted	Oe
B	gauss	G
Φ	maxwell	Mx
F_M	gilbert	Gi
I	candela	cd
Φ	lumen $(= cd.sr)$	lm
L, B	stilb $(= cd/cm^2)$	sb
E	phot $(= lm/cm^2)$	phot
α	radian	rad
ω	steradian	sr

3. MKSA Units

	Unit	Symbol
l, b, h	meter	m
t	second	s
m	kilogram	kg
ν, f, ω	hertz	Hz
F	newton	N
E	joule	J
P	watt	W
I	ampere	A
Q	coulomb	C
V	volt	V
C	farad	F
R	ohm	Ω
L	henry	H
Φ	weber	Wb
I	candela	cd
Φ	lumen	lm
L, B	nit $(= cd/m^2)$	nt
E	lux $(= lm/m^2)$	lx

4. Noncoherent Units

	Unit	Symbol
l	ångström	Å
V	liter	l
t	minute	min
t	hour	h
p	atmosphere	atm
P	kilowatt-hour	kWh
Q	calorie	cal
Q	kilocalorie	kcal
m	tonne (= 1000 kg)	t
p	bar $(= 10^5$ barye)	bar

Remark on Rationalization

(1) In 1951 the IUPAP accepted the following *resolution:*
"The General Assembly of the Union of Physics considers that, in the case that the equations are rationalized, the rationalization should be effected by the introduction of new quantities."

(2) When confusion is possible between rational and nonrational quantities it is recommended to add to the name of the quantity the adjective *"rational"* or *"nonrational"* and to provide the symbol of the quantity with a left subscript n or r respectively, e.g.:

nonrational magnetic field $= {}_nH$
rational magnetic field $= {}_rH$
$${}_rD = {}_nD/4\pi \quad \text{but} \quad {}_nE = {}_rE = E$$
$${}_rH = {}_nH/4\pi \quad \text{but} \quad {}_nB = {}_rB = B$$

(3) In order to transform an equation between nonrational quantities into an equation between rational quantities, the following table gives the rational quantities and the equivalent expressions in terms of the nonrational quantities:

rational	nonrational	rational	nonrational
Q	Q	I	I
ρ	ρ	J	J
E	E	B	B
D	$D/4\pi$	H	$H/4\pi$
P	P	M	M
ϵ	$\epsilon/4\pi$	μ	$4\pi\mu$
ϵ_0	$\epsilon_0/4\pi$	μ_0	$4\pi\mu_0$
ϵ_r	ϵ_r	μ_r	μ_r

(4) *Example:*

The horizontal component of the magnetic induction of the earth's magnetic field is in Europe approximately:

$$B = 0.2\ \text{G} = 0.2 \times 10^{-4}\ \text{Wb/m}^2$$

This value *is unaffected by rationalization.*

The corresponding nonrational magnetic field is:

$${}_nH = 0.2\ \text{Oe} = 0.2 \times 10^3\ \text{A/m}$$

and the corresponding rational magnetic field is:

$${}_rH = (0.2/4\pi)\ \text{Oe} = (0.2 \times 10^3/4\pi)\ \text{A/m} = 15.9\ \text{A/m}$$

As the numerical value of the magnetic field *is affected by rationalization,* it is advisable to use when possible the magnetic induction expressed in gauss or in Wb/m^2.