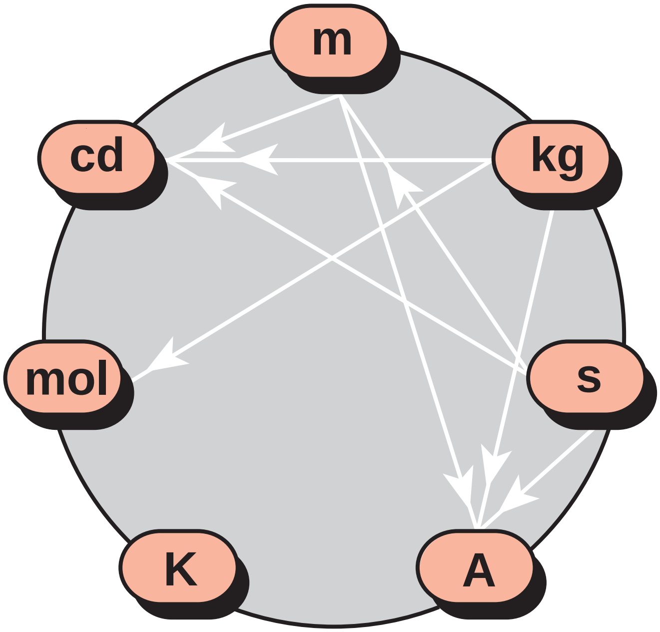
Physikalisch Technische Bundesanstalt

Braunschweig and Berlin



The legal units in Germany

PTB

Foreword

The *International System of Units SI* (Système International d' Unités), which has developed from the Metric System, has seven base units.

From these base units, SI derived units are (coherently) formed by multiplication or division by the factor 1.

Certain derived units have been given special names and symbols, for example newton (N) for the unit of force and volt (V) for the electric potential.

The SI has been adopted worldwide in international and national standardization (e. g. ISO 1000, DIN 1301). In the EC member states it forms the basis of the directive on units in metrology (EEC directives 80/181 and 89/617).

In the Federal Republic, the *Act on Units in Metrology* (Units Act) forms the legal basis for stating physical quantities in legal units. It prescribes their application in commercial and official transactions.

The *Regulation implementing the Act on Units in Metrology* (Units Regulation) refers to the standard DIN 1301. One of its annexes lists the legal units in alphabetical order.

Tasks of the PTB

According to the Units Act, the Physikalisch-Technische Bundesanstalt has to

- realize the legal units
- realize the temperature scale in compliance with the International Temperature Scale of the Metre Convention
- link up with the international prototypes or etalons, in compliance with the International Metre Convention, prototypes of the Federal Republic of Germany as well as the embodiments of the units and the standards, or have them linked up
- maintain the prototypes of the Federal Republic of Germany as well as the embodiments of the units and the standards
- provide information on methods by which non-embodied units, including the unit of time and the time scales as well as the unit of temperature and the temperature scales, are realized.

The Units Act specifies the tasks with which the PTB has been entrusted in the field of units. In addition, according to section 2 of the Time Act dated 25.7.1978 (Federal Law Gazette I, p. 1110 and 1262), the PTB has to realize and disseminate the legal time. Further tasks of the PTB have been listed in sections 11 and 13 of the Verification Act.

SI base units

Base quantity	Base unit Name	Symbol	Definition (cf. also DIN 1301)
length	**metre**	**m**	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.
mass	**kilogram**	**kg**	The kilogram is equal to the mass of the international prototype of the kilogram.
time	**second**	**s**	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.
electric current	**ampere**	**A**	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.
temperature	**kelvin**	**K**	The kelvin is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water.
amount of substance	**mole**	**mol**	The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0,012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.
luminous intensity	**candela**	**cd**	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

SI prefixes

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

Legal units

Non-legal units

Quantity	Name of unit	Symbol	Relation and Remarks			
length	**metre**		**m**	**SI base unit**		
	astronomical unit*	AU	1 AU	$= 149{,}597\,870 \cdot 10^9$ m		
	parsec	pc	1 pc	= 206 265 AU	$= 30{,}857 \cdot 10^{15}$ m	
	light year	l. y.	1 l. y.	$= 9{,}460\,530 \cdot 10^{15}$ m = 63 240 AU = 0,30 659 pc		
	ångström	Å	1 Å	$= 10^{-10}$ m		
	typographical point	p	1 p	= 0,376 065 mm		• in printing industry
	*inch***	in	1 in	= 2,5**4** $\cdot 10^{-2}$ m = 25,**4** mm***		
	foot	ft	1 ft	= 0,304**8** m	= 30,4**8** cm	
	yard	yd	1 yd	= 0,914**4** m		
	mile	mile	1 mile	= 1609,34**4** m		
	international nautical mile	n. m.	1 n. m.	= 185**2** m		
plane angle	radian	rad	1 rad	= 1 m/m		• central angle r = 1 m, arc = 1 m
	perigon angle			$= 2\pi \cdot$ rad	= 360° = 400 gon	
	degree	°	1°	= (π/180) rad		= 1,1111 gon
	minute	’	1’	= 1°/60		• also angular minute
	second	”	1”	= 1’/60	= 1°/3600	• also angular second
	gon	gon	1 gon	= (π/200) rad		= 0,9° • referred to as grade
	grade	^{g}	1^g	= 1 gon	$= 0{,}5\pi \cdot 10^{-2}$ rad	
	centesimal minute	^{c}	1^c	$= 10^{-2}$ gon	$= 0{,}5\pi \cdot 10^{-4}$ rad	
	centesimal second	^{cc}	1^{cc}	$= 10^{-4}$ gon	$= 0{,}5\pi \cdot 10^{-6}$ rad	
solid angle	steradian	sr	1 sr	$= 1\ m^2/m^2$		• r = 1 m, area of spherical cap = 1 m^2
refractive power	dioptre	dpt	1 dpt	= 1/m		• in optical systems only
area	square metre	m^2				• do not use “qm”
	are	a	1 a	= 100 m^2		• for real estate and parcels of land only
	hectare	ha	1 ha	= 100 a	$= 10^4\ m^2$	
	barn	b	1 b	$= 10^{-28}\ m^2$		• in atomic and nuclear physics
	Morgen		1 Morgen	= 0,25 ha	= 2500 m^2	• varies from region to region
	square foot	ft^2	1 ft^2	= 0,09 290 306 m^2		
	acre	ac	1 ac	= 4046,85**6** m^2		

* approx. the mean distance of the earth from the sun

** in italics: permissible in some countries acc. to EC directive

*** last digit in bold face: value considered to be exact (cf. also ISO 31)

Quantity	Name of unit	Symbol	Relation and Remarks		
volume	cubic metre	m^3			• do not use “cbm”
	litre	l oder L	1 l = 1 L	= 10^{-3} m^3 = 1 dm^3 = 10^3 cm^3	• do not use “ccm
	Festmeter	Fm	1 Fm	= 1 m^3	• for timber industry only
	Raummeter	Rm	1 Rm	= 1 m^3	• for timber industry only
	barrel	bbl	1 barrel	= 158,988 l	• for crude oil only
	fluid ounce	fl oz	1 fl oz	= 28,4131 · 10^{-6} m^3 = 28,4131 ml	29,5735 ml*
	pint	pt	1 pt	= 0,568262 · 10^{-3} m^3= 568,262 ml	473,176 ml*
	quart	qt	1 qt	= 1,13652 · 10^{-3} m^3 = 1,13652 l	0,946353 l*
	gallon	gal	1 gal	= 4,54609 · 10^{-3} m^3 = 4,54609 l	3,78541 l*
measure of	register ton	R. T.	1 R. T.	= l00 ft^3 = 2,83168 m^3	* american values
capacity	gross register ton	G. R. T.	a ship's permanently closed-in spaces in R. T.		
for ships	net register ton	N. R. T.	overall capacity less spaces required for running the ship, in R, T.		
volume flow rate		m^3/s	1 m^3/s	= 60 · 10^3 l/min	= 3600 m^3/h
specific volume		m^3/kg	1 m^3/kg	= 1 l/g	
mass	**kilogram**	**kg**	**SI base unit**		
mass	gram	g	1 g	= 10^{-3} kg	• do not use “gr.” or “Gr.”
(weighed value of	tonne	t	1 t	= 10^3 kg	
goods quantities	metric carat		1 carat**	= 0,2 g = 0,2 · 10^{-3} kg	• for precious stones only
in commercial	unified atomic	u	1 u	= 1,6605655 · 10^{-27} kg	
transactions)	mass unit***				
	Pfund	℔	1 ℔	= 0,5 kg	• no legal unit since 1884
	Zentner	ztr	1 ztr	= 50 kg	• metric hundred-wight
	quintal	q	1 q	= 100 kg	
	ounce (avoirdupois)	oz	1 oz	= 28,3495 · 10^{-3} kg = 28,3495 g	
	troy ounce	oz tr	1 oz tr	= 31,10 · 10^{-3} kg = 31,10 g	• for precious metals
	pound	lb	1 lb	= 0,4535923**7** kg = 453,5923**7** g	
weight ton	tons/deadweight	ton dw	1 ton dw	= 1016 kg	• tonnage of ships
		t dw	1 t dw	= 1000 kg	
mass per unit	tex	tex	1 tex	= 10^{-6} kg/m = 1 g/km	• for textiles only
length	denier	den	1 den	= 1/9 tex = 1/9 g/km	
mass per unit area		kg/m^2	1 kg/m^2	= 1 mg/mm^2	
mass flow		kg/s	1 kg/s	= 60 kg/min	= 3,6 t/h = 86,4 t/d
density		kg/m^3	1 kg/m^3	= 1 g/l	= 10^{-3} kg/l
specific gravity of the must	degree Öchsle	Oe°	The specific gravity of the must (in degree Öchsle) corresponds to the numerical value of the density (of grape must) in kg/m^3 minus 1000.		

** symbols “Kt” and “ct” also used

*** 1/12 of the mass of an atom of the nuclide ^{12}C

Quantity	Name of unit	Symbol	Relation and Remarks	
time	**second**	**s**	**SI base unit**	• prefixes to be used with s only
space of time, duration	minute	min	1 min = 60 s	
	hour	h	1 h = 60 min = 3600 s	
	day	d	1 d = 24 h = 1440 min = 86 400 s	
frequency	hertz	Hz	1 Hz = 1/s	
number of revolutions (per unit time), rotational speed*	reciprocal second	1/s		• do not use “rps” or “rpm”
	reciprocal minute	1/min	1/min = 1/(60 s)	
velosity	meter per second	m/s	1 m/s = 3,6 km/h	
	knot	kn	1 kn = 1 n. m./h = 0,514$\overline{4}$ m/s	
acceleration		m/s^2	9,80 665 m/s^2 = standard acceleration due to gravity g_n	
	gal	Gal	1 Gal = 10^{-2} m/s^2	• in geodesy only
angular velocity		rad/s		
force	newton	N	1 N = 1 kg · m/s^2	
	dyne	dyn	1 dyn = 10^{-5} N	
	pond	p	1 p = 9,80 66**5** · 10^{-3} N	• 1 kp ≈10 N
pulse		N · s	1 N · s = 1 kg · m/s	• mass times velocity
sound pressure**	pascal	Pa	1 Pa = 1 N/m^2	
sound power**		W		• DIN 1332
sound intensity**, sound energy flux density		W/m^2		• DIN 1332
noise dose***		$Pa^2 \cdot s$		• DIN 45 644
pressure, mechanical stress	pascal	Pa	1 Pa = 1 N/m^2 = 1 kg/(s^2 · m) ≈ 0,75 · 10^{-2} mmHg	
	bar	bar	1 bar = 10^5 Pa = 10^3 mbar = 10^5 kg/(s^2 · m)	
	conventional millimetres of mercury	mmHg	1 mmHg = 133,32**2** Pa = 1,33 322 mbar	• permissible in medicine only
	stand. atmosphere	atm	1 atm = 1,01 32**5** bar	
	techn. atmosphere	at	1 at = 1 kp/cm^2 = 0,980 66**5** bar	
	torr	torr	1 torr = (101 325/760) Pa = 1,333 224 mbar	
	conventional metres head of water	mWS	1 mWS = 9806,6**5** Pa = 98,066**5** mbar	
	psi	lb/in^2	1 lb/in^2 = 68,950 mbar = 6895,0 Pa	

* in electrical engineering: angular frequency

** In acoustics, logarithmierte Verhältnisgrößen acc. to DIN 5493 part 1, are often used (e. g. sound power level).

*** referred to as sound dose when related nominal value

Quantity	Name of unit	Symbol	Relation and Remarks
dynamic viscosity	pascal second	Pa · s	1 Pa · s = 1 N · s/m² = 1 kg/(s · m) • DIN 1342
	poise	P	1 P = 0,1 Pa · s = 0,1 N · s/m²
kinematic viscosity		m^2/s	• DIN 1342
	stokes	St	1 St = 10^{-4} m^2/s
energy, work, quantity of heat	joule	J	1 J = 1 N · m = 1 W · s = (1/3,6) · 10^{-6} kW · h = 1 kg · m^2/s^2
	kilowatt hour	kW · h	1 kW · h = 3,6 MJ
	electron volt	eV	1 eV = 160,21 892 · 10^{-21} J
	erg	erg	1 erg = 10^{-7} J
	calorie	cal	1 cal = 4,1868 J = 1,163 · 10^{-3} W · h
calorific value*		kcal/l	1 kcal/l = 4,1868 kJ/l
		kcal/kg	1 kcal/kg = 4,1868 kJ/kg
	coal equivalent**	C. E.	1 t C. E. = 7 · 10^6 kcal = 29,3076 · 10^9 J = 8,141 · 10^3 kW · h
heat capacity		J/K	1 J/K = 1 m^2 · kg/(s^2 · K) • entropy
energy density		J/m^3	1 J/m^3 = 1 kg/(m · s^2)
specific energy		J/kg	1 J/kg = 1 m^2/s^2
molar energy		J/mol	1 J/mol = 1 W · s/mol = 1 m^2 · kg/(s^2 · mol)
molar heat capacity		J/(mol · K)	1 J/(mol · K) = 1 m^2 · kg/(s^2 · K · mol) • molar entropy
power, energy flux, heat flux	watt	W	1 W = 1 J/s = 1 N · m/s = 1 V · A = 1 m^2 · kg/s^3
	volt-amperes	Va	1 Va = 1 W • apparent power
	VAr	VAr	1 VAr = 1 W • reactive power
	horse power	hp	1 hp = 75 m · kp /s = 0,73 549 875 kW
heating power		kcal/h	1 kcal/h = 1,163 W
thermal conductivity		W/(m · K)	1 W/(m · K) = 1 m · kg/(s^3 · K)
		kcal/(m · h · °C)	1 kcal/(m · h · °C =1,163 W/(m · K)
heat transition coefficient		W/(m^2 · K)	1 W/(m^2 · K) = 1 m · kg/(s^3 · m · K)
		kcal/(m^2 · h · °C)	1 kcal/(m^2 · h · °C) = 1,163 W/(m^2 · K)
heat flux density, irradiance		W/m^2	1 W/m^2 = 1 kg/s^3
radiant intensity		W/sr	1 W/sr = 1 m^2 · kg/(s^3 · sr)
radiance		W/(m^2 · sr)	1 W/(m^2 · sr) = 1 kg/(s^3 · sr)

* also referred to as gross calorific value

** The unit “coal equivalent per ton” is based on a calorific value of 7000 kcal/kg.

Quantity	Name of unit	Symbol	Relation and Remarks
electric current	**ampere**	**A**	**SI base unit**
voltage, electric potential, electromotive force	volt	V	1 V = 1 W/A = 1 kg · $m^2/(A \cdot s^3)$
electric resistance	ohm	Ω	1 Ω = 1 V/A = 1/S = 1 W/A^2 = 1 kg · $m^2/(A^2 \cdot s^3)$
electric conductance	siemens	S	1 S= 1 A/V = 1/Ω = 1 W/V^2 = 1 $A^2 \cdot s^3/(kg \cdot m^2)$
electric charge, quantity of electricity	coulomb	C	1 C = 1 A · s
	ampere-hour	A · h	1 A · h =3600 A · s= 3600 C
electric charge density		C/m^3	1 C/m^3 = 1 A · s/m^3
electric flux density, displacement		C/m^2	1 C/m^2 = 1 A · s/m^2
capacitance	farad	F	1 F = 1 C/V = 1 A · s/V = 1 $A^2 \cdot s^4/(kg \cdot m^2)$
permittivity		F/m	1 F/m = 1 A · s/(V · m) = 1 $A^2 \cdot s^4/(kg \cdot m^3)$
electr. field strength		V/m	1 V/m = 1 kg · $m/(A \cdot s^3)$ • DIN 1357
magnetic flux	weber	Wb	1 Wb = 1 V · s = 1 T · m^2 = 1 A · H = 1 kg · $m^2/(A \cdot s^2)$
magn. flux density, magnetic induction	tesla	T	1 T = 1 Wb/m^2 = 1 V · s/m^2 = 1 $kg/(s^2 \cdot A)$
inductance, magn. conductance	henry	H	1 H = 1 Wb/A = V · s/A = 1 kg · $m^2/(A^2 \cdot s^2)$
permeability		H/m	1 H/m = 1 V · s/(A · m) = 1 kg · $m/(A^2 \cdot s^2)$
magn. field strength		A/m	
	oersted	Oe	1 Oe = $[10^3/(4\pi)]$ · A/m ≈ 80 A/m
temperature	**kelvin**	**K**	**SI base unit**
(thermodyn.: "*T*") (Celsius: "*t*")	degree Celsius	°C	1 °C = 1 K • as temperature difference triple point of H_2O = 0,01 °C • t = T – 273,15*
	degree Fahrenheit	°F	1 °F = (5/9) K • t = (5/9) · (t_F – 32)*
	degree Kelvin	°K	1 °K = 1 K
	Grad	grd	1 grd = 1 K
luminous intensity	**candela**	**cd**	**SI base unit**
luminance		cd/m^2	• DIN 5031 part 3
	stilb	sb	1 sb = 10^4 cd/m^2
luminous flux	lumen	lm	1 lm = 1 cd · sr • DIN 5031 part 3
illuminance	lux	lx	1 lx = 1 lm/m^2 = 1 cd · sr/m^2 • DIN 5031 part 3

* The respective numerical values must be inserted for t, T und t_F.

Quantity	Name of unit	Symbol	Relation and Remarks			
aktivity (of a radio-active substance)	becquerel	Bq	1 Bq	= 1/s		• DIN 6814 part 4
	curie	Ci	1 Ci	= 37 GBq		
absorbed dose, kerma	gray	Gy	1 Gy	= 1 J/kg	= 1 W · s/kg = 1 m^2/s^2	
	rad	rd	1 rd	= 1 cGy	= 0,01 Gy	
dose equivalent	sievert	Sv	1 Sv	= 1 J/kg	= 1 W · s/kg = 1 m^2/s^2	
	rem	rem	1 rem	= 1 cSv	= 0,01 Sv	
absorbed dose rate	gray per second	Gy/s	1 Gy/s	= 1 W/kg	= 1 m^2/s^3	
	rad per second	rd/s	1 rd/s	= 0,01 Gy/s		
dose equivalent rate	sievert per second	Sv/s	1 Sv/s	= 1 W/kg	= 1 m^2/s^3	
	rem per second	rem/s	1 rem/s	= 0,01 Sv/s		
exposure	coulomb per kg	C/kg	1 C/kg	= 1 A · s/kg		• do not use this quantity any longer
	röntgen	R	1 R	= 258 · 10^{-6} C/kg		
amount of substance	**mole**	**mol**	**SI base unit**			• DIN 32625
concentration (of amount of substance)		mol/l	1 mol/l	= 10^3 mol/m^3		• DIN 1310
molar volume		l/mol	1 l/mol	= 10^{-3} m^3/mol		
molar mass		g/mol	1 g/mol	= 10^{-3} kg/mol		
molar entropy		J/(mol · K)	1 J/(mol · K)			= 1 kg · $m^2/(s^2$ · mol · K)
molar intrinsic energy		J/mol				• DIN 1345
volume concentration*		l/l oder l/m^3				
substance amount fraction**, mole fraction		1				• DIN 1310
mass fraction**,		1				• DIN 1310
volume fraction**,		1				• DIN 1310
mass per unit volume***, partial density***		kg/l or g/l	1 kg/l	= 10^3 kg/m^3		• DIN 1310
particle concentration		1/m^3				• e. g. dust particles per m^3

* referred to as volume fraction if the mixing process does not change the volume

** The fraction can also be indicated in per cent (1% = 1/100) or per thousand (1 ‰ = 1/1000).

*** do not refer to “g/(100 ml)” as “%” and to “mg/(100 ml)” as “mg %” (DIN 1310)

Legal regulations and standards

Act on Units in Metrology
of July 2, 1969 (Federal Law Gazette I, p. 709) in the version as published on February 22, 1985 (Federal Law Gazette 408)

Regulation implementing the Act on Units in Metrology
of December 13, 1985 (Federal Law Gazette I, p. 2272) and Amending Ordinance of March 22, 1991

Act on Metrology and Verification (Verification Act)
amended version of March 23, 1992 (Federal Law Gazette I, pp. 711 to 718)

Council Directive 80/181/EEC on units in metrology of 20.12.1979 (Official Journal No. L 39/40 of 15.12.1980), amended by the Directive 89/617/EEC.

DIN 1301 part 1, 12.85
Einheiten; Einheitennamen, Einheitenzeichen (Units; names, symbols)

DIN 1301 part 1, supplementary sheet 1, 04.82
Einheiten; Einheitenähnliche Namen und Zeichen
(Units; names and symbols similar to units)

DIN 1301 part 3, 10.79
Einheiten, Umrechnungen für nicht mehr anzuwendende Einheiten
(Units; conversion of units to be used no longer)

DIN 1301 part 2, 02.78
Einheiten; Allgemein angewendete Teile und Vielfache
(Units; sub-multiples and multiples for general use)

DIN 1304 part 1, 03.89
Formelzeichen; Allgemeine Formelzeichen
(General symbols for use in formulae)

DIN 5493 part 1, draft 08.91
Logarithmische Größen und Einheiten (Logarithmic quantities and units)

ISO 1000: 1981
SI units and recommendations for the use of their multiples and of certain other units

ISO 31-0 to ISO 31-XIII
(comprise principles of quantities and units as well as units for special physical quantities)

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