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(Supersedes LC1078)

THE METRIC SYSTEM OF MEASUREMENTS (SI)

Federal Register Notice of February 26, 1982

April 19,1982

This NBS Letter Circular reproduces the Federal Register notice that interprets and modifies the International System of Units (SI), the Modernized Metric System, for the United States. This notice supersedes a similar notice dated October 26, 1977.

Also included is a chart that shows the relationships of all the SI units to which names have been assigned.

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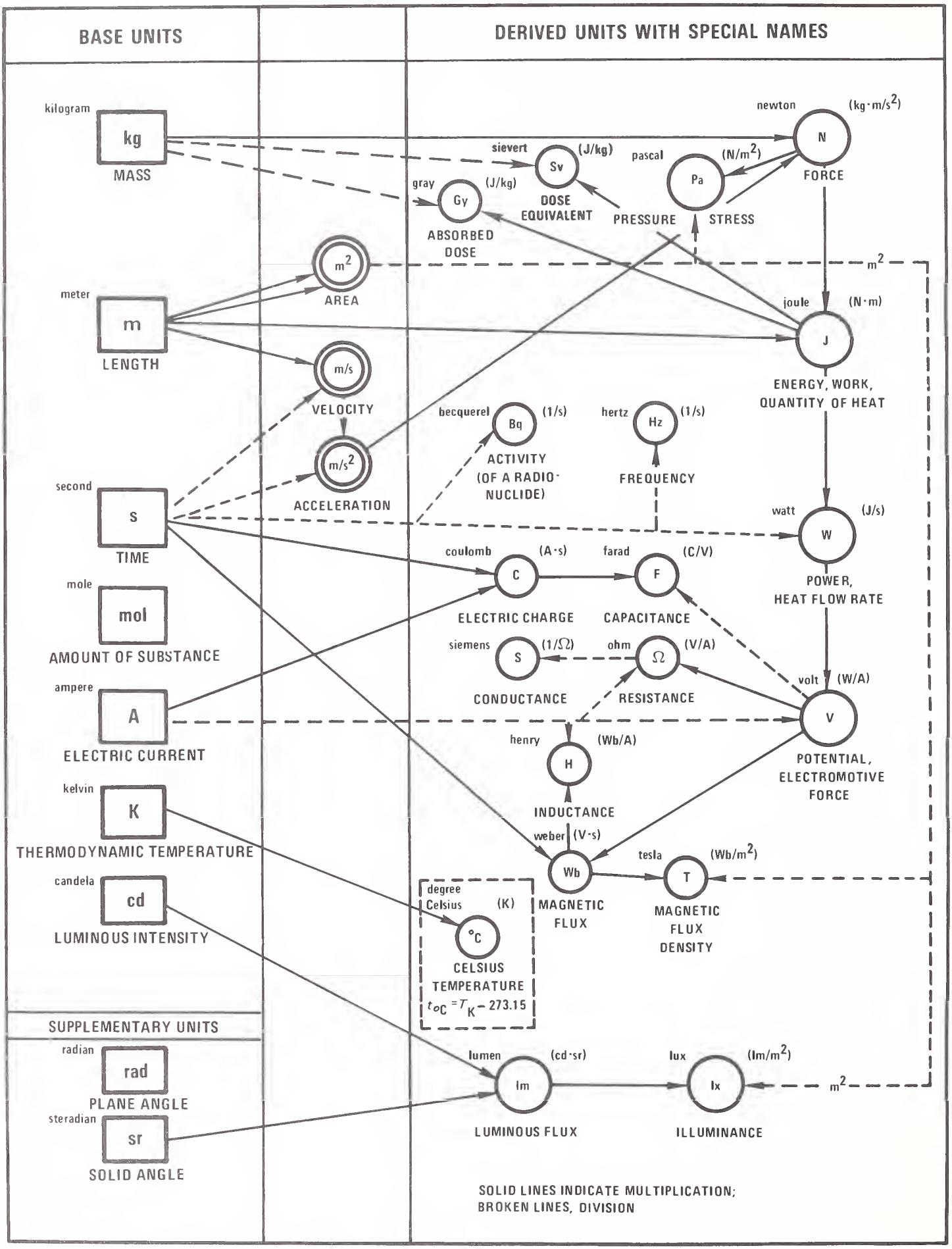
RELATIONSHIPS OF SI UNITS WITH NAMES



This chart shows graphically how the 19 SI derived units with special names listed in Table 2 of the Federal Register Notice, reprinted below, are derived in a coherent manner from the base and supplementary units. In the first column the symbols of the base and supplementary units are shown in rectangles, with the name of the unit shown toward the upper left of the rectangle and the name of the quantity (measurable attribute) shown below the rectangle. In the third column the symbols of the derived units with special names are shown in solid circles, with the name of the unit shown toward the upper left of the circle, the name of the quantity shown below the circle, and an expression of the derived unit in terms of other units shown toward the upper right. In the second column are shown those derived units without special names that are used in the derivation of the derived units with special names. In the chart the derivation of each unit is indicated by arrows bringing in numerator factors (solid lines) and denominator factors (broken lines).

The degree Celsius, shown on the chart in a broken-line rectangle, is a special name for the kelvin, for use in expressing Celsius temperatures or temperature intervals. Where it is used to express temperature intervals, it is equal to the kelvin, as shown on the chart, with the symbol K toward the upper right of the °C circle; where it is used to express Celsius temperatures, the equation below "CELSIUS TEMPERATURE" relates Celsius temperature ($t_{°C}$) to thermodynamic temperature (T_K).

National Bureau of Standards

Metric System of Measurement; Interpretation and Modification of the International System of Units for the United States

Section 3 of Pub. L. 94–168, the Metric Conversion Act of 1975, declares that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States. Section 403 of Pub. L. 93–380, the Education Amendments of 1974, states the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement as part of the regular education program. Under both these acts, the "metric system of measurement" is defined as the International System of Units as established by the General Conference on Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce (sec. 4(4), Pub. L. 94–168; sec. 403(a)(3), Pub. L. 93–380). The Secretary has delegated his authority under these subsections to the Director of the National Bureau of Standards.

In implementation of this authority, tables and associated materials were published in the **Federal Register** of October 26, 1977 (42 FR 56513–56514), setting forth the interpretation and modification of the International System of Units (hereinafter "SI") for the United States.

In accordance with recent decisions of the International Committee for Weights and Measures of the General Conference on Weights and Measures, and to refine the earlier interpretation and modification, it is deemed appropriate to amend that interpretation and modification, as published in the above-cited **Federal Register** notice of October 26, 1977. To assist interested parties and encourage the proper use of SI, the entire interpretation and modification, as hereby amended, is republished. Accordingly, this notice supersedes the notice of October 26, 1977.

The amendments consist of the inclusion in table 2 of the sievert, a special name for the SI derived unit of dose equivalent, the inclusion in table 6 of the electronvolt and the unified atomic mass unit, and the inclusion in table 7 of the rem, a unit of dose equivalent. The unit "standard atmosphere" is no longer included in table 7. The amendments are indicated by a dagger symbol (†).

The SI is constructed from seven base units for independent quantities plus two supplementary units for plane angle and solid angle, listed in table 1.

TABLE 1.—SI BASE AND SUPPLEMENTARY UNITS

Quantity	Name	Symbol
SI base units:		
length	meter	m
mass [1]	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature.	kelvin	K
amount of substance.	mole	mol
luminous intensity	candela	cd
SI supplementary units.		
plane angle	radian	rad
solid angle	steradian	sr

[1] "Weight" in common parlance is often used to mean "mass."

Units for all other quantities are derived from these nine units. In table 2 are listed 19 SI derived units with special names which were derived from the base and supplementary units in a coherent manner, which means, in brief, that they are expressed as products and quotients of the nine base and supplementary units without numerical factors.

TABLE 2.—SI DERIVED UNITS WITH SPECIAL NAMES

Quantity	SI unit		
	Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg\,m/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	N·m
power, radiant flux	watt	W	J/s
electric charge, quantity of electricity	coulomb	C	A·s
electric potential, potential difference, electromotive force.	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	lm/m^2
Celsius temperature [1]	degree Celsius.	°C	K
activity (of a radionuclide).	becquerel	Bq	s^{-1}
absorbed dose, specific energy imparted, kerma, absorbed dose index.	gray	Gy	J/kg
†dose equivalent, dose equivalent index.	sievert	Sv	J/kg

[1] In addition to the thermodynamic temperature (symbol T) expressed in kelvins (see table 1), use is also made of Celsius temperature (symbol t) defined by the equation

$$t = T - T_0$$

where $T_0 = 273.15$ K by definition. The unit "degree Celsius" is equal to the unit "kelvin," but "degree Celsius" is a special name in place of "kelvin" for expressing Celsius temperature. A temperature interval or a Celsius temperature difference can be expressed in degrees Celsius as well as in kelvins.

All other SI derived units, such as those in tables 3 and 4, are similarly derived in a coherent manner from the 28 base, supplementary, and special-name SI units.

TABLE 3.—EXAMPLES OF SI DERIVED UNITS EXPRESSED IN TERMS OF BASE UNITS

Quantity	SI unit	Unit symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared.	m/s^2
wave number	1 per meter	m^{-1}
density, mass density	kilogram per cubic meter.	kg/m^3
specific volume	cubic meter per kilogram.	m^3/kg
current density	ampere per square meter.	A/m^2
magnetic field strength	ampere per meter.	A/m
concentration (of amount of substance)	mole per cubic meter	mol/m^3
luminance	candela per square meter.	cd/m^2

TABLE 4.—EXAMPLES OF SI DERIVED UNITS EXPRESSED BY MEANS OF SPECIAL NAMES

Quantity	Name	Unit symbol
dynamic viscosity	pascal second	Pa·s
moment of force	newton meter	N·m
surface tension	newton per meter	N/m
heat flux density, irradiance	watt per square meter	W/m^2
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter kelvin	W/(m·K)
energy density	joule per cubic meter	J/m^3
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter.	C/m^3
electric flux density	coulomb per square meter	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity.	joule per mole kelvin	J/(mol·K)
exposure (x and γ rays).	coulomb per kilogram	C/kg
absorbed dose rate	gray per second	Gy/s

For use with the SI units there is a set of 16 prefixes (see table 5) to form multiples and submultiples of these units. It is important to note that the kilogram is the only SI unit with a prefix. Because double prefixes are not to be used, the prefixes of table 5, in the case of mass, are to be used with gram (symbol g) and not with kilogram (symbol kg).

TABLE 5.—SI PREFIXES

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Certain units that are not part of the SI are used so widely that it is impractical to abandon them. The units that are accepted for continued use in the United States with the International System are listed in table 6.

TABLE 6.—UNITS IN USE WITH THE INTERNATIONAL SYSTEM

Name	Symbol	Value in SI unit
minute (time)	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s
degree (angle)	°	$1° = (\pi/180)$ rad
minute (angle)	′	$1′ = (1/60)°$ $= (\pi/10\,800)$ rad
second (angle)	″	$1″ = (1/60)′$ $= (\pi/648\,000)$ rad
liter	L*	1 L = 1 $dm^3 = 10^{-3}$ m^3
metric ton	t	1 t = 10^3 kg
hectare (land area)	ha	1 ha = 10^4 m^2
†electronvolt	eV	1 eV = 1.602×10^{-19} J, approximately**
†unified atomic mass unit.	u	1 u = $1.660\ 57 \times 10^{-27}$ kg, approximately**

* Both L and l are international symbols for liter. Because "l" can easily be confused with the numeral "1" the symbol "L" is recommended for United States use.
** The values of these units in terms of SI units are obtained experimentally.

In those cases where their usage is already well established, the use, for a limited time, of the units in table 7 is accepted, subject to future review.

TABLE 7.—UNITS IN USE TEMPORARILY WITH THE INTERNATIONAL SYSTEM

nautical mile	angstrom	curie
knot	barn	roentgen
	bar	rad [2]
	gal [1]	†rem [3]

[1] Unit of acceleration.
[2] Unit of absorbed dose.
[3] Unit of dose equivalent.

Metric units, symbols, and terms that are not in accordance with the foregoing Interpretation and Modification are no longer accepted for continued use in the United States with the International System of Units. Accordingly, the following units and terms listed in the table of metric units in section 2 of the Act of July 28, 1866 that legalized the metric system of weights and measures in the United States are no longer accepted for use in the United States:

myriameter
stere
millier or tonneau
quintal
myriagram
kilo (for kilogram)

For more information regarding the International System of Units, contact Dr. David T. Goldman, National Measurement Laboratory, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234, telephone (301) 921–3304.

Dated: February 2, 1982.

Ernest Ambler,

Director.

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