FUNDAMENTAL UNITS

International System of Units

The International System of Units (SI) established in 1960 by the General Conference of Weights and Measures under the Treaty of the Meter is based upon: the meter (m) for length; the kilogram (kg) for mass; the second (s) for time; the Kelvin (K) for temperature; the ampere (A) for electrical current; and the candela (cd) for luminous intensity.

All other units of SI are derived from these base units by assigning the value unity to the proportionality constants in the defining equations, e.g.,

$$1 \text{ Pa} = 1 \text{ N/m}^2 = (1 \text{ kg} \bullet \text{m} / \text{sec}^2) / \text{m}^2$$
$$= 1 \text{ kg} \bullet \text{m}^{-1} \bullet \text{sec}^{-2}.$$

'aking 1/100 of the meter as the unit for length and 1/1000 of ıe kilogram as the unit for mass gives rise similarly to the cgs 'stem, often used in physics and chemistry.

: Units

Unit	Name	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K
Electrical Current	ampere	A
Luminous Intensity	candela	cd

Supplementary SI Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Derived SI Units

Quantity	Name	SI Symbol	Formula
Area	—	—	m^2
Volume	—	—	m^3
Frequency	hertz	Hz	1/s
Velocity	—	—	m/s

Derived SI Units (cont)

Quantity	Name	SI Symbol	Formula
Acceleration	—	—	m/s^2
Density	—	—	kg/m^3
Force	newton	N	$kg \cdot m / s^2$
Energy	joule	J	$N \cdot m$
Power	watt	W	J / s
Pressure	pascal	Pa	N / m^2
Charge	coulomb	C	$A \cdot s$
Magnetic field strength	—	—	A / m
Potential	volt	V	W / A
Resistance	ohm	Ω	V / A
Capacitance	farad	F	$A \cdot s / V$
Inductance	henry	H	$V \cdot s / A$
Magnetic flux	weber	Wb	$V \cdot s$
Magnetic flux density	tesla	T	Wb / m^2

Derived cgs Units

Quantity	Name	cgs Symbol	Formula
Area	—	—	cm^2
Volume	—	—	cm^3
Velocity	—	—	cm / s
Acceleration	—	—	cm / s^2
Density	—	—	gm / cm^3
Force	dyne	dyn	$gm \cdot cm / s^2$
Energy	erg	erg	$dyn \cdot cm$
Power	—	—	$dyn \cdot cm / s$
Pressure	—	—	dyn / cm^2

British System of Units

Quantity	Name	British Symbol	Formula
Length	foot	ft	ft
Force	pound	lb	lb
Time	second	sec	sec
Velocity	—	—	ft / sec
Acceleration	—	—	ft / sec^2

British System of Units (cont)

Quantity	Name	British Symbol	Formula
Mass	slug	—	$lb \cdot sec^2 / ft$
Energy	—	—	$ft \cdot lb$
Power	—	—	$ft \cdot lb / sec$
Pressure	—	—	lb / ft^2

Mathematical Constants

$\pi = 3.14159$	$\log 2 = 0.30103$
$\pi^{-1} = 0.31831$	$\log 3 = 0.47712$
$\pi^{-2} = 0.10132$	$\log 4 = 0.60206$
$e = 2.71828$	$\log 5 = 0.69897$
$e^{-1} = 0.36788$	$\log 6 = 0.77815$
$e^{-2} = 0.13534$	$\log 7 = 0.84510$
$\log e = 0.43429$	$\log 8 = 0.90309$
$\log \pi = 0.49715$	$\log 9 = 0.95424$

$\log x$ = base 10 logarithm of x

Geodetic Constants

Geodetic constants for the international spheroid are given in the following table.

Polar radius = 6356912 meters
Equatorial radius = 6378388 meters

Latitude	Length of 1' of Longitude (m)	Length of 1' of Latitude (m)
0 °	1855.398	1842.925
15 °	1792.580	1844.170
30 °	1608.174	1847.580
45 °	1314.175	1852.256
60 °	930.047	1856.951
75 °	481.725	1860.401
90 °	0	1861.666

The length of 1' of longitude at a given latitude is very nearly 1 nm • cos(lat).

Multiplier Prefixes of the System International

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

Conversion from SI to cgs Units

Quantity	Equation
Length	$1\ m = 10^2\ cm$
Mass	$1\ kg = 10^3\ gm$
Area	$1\ m^2 = 10^4\ cm^2$
Volume	$1\ m^3 = 10^6\ cm^3$
Velocity	$1\ m/s = 10^2\ cm/s$
Acceleration	$1\ m/s^2 = 10^2\ cm/s^2$
Density	$1\ kg/m^3 = 10^{-3}\ gm/cm^3$
Force	$1\ N = 10^5\ dyn$
Energy	$1\ J = 10^7\ erg$
Power	$1\ W = 10^7\ erg/sec$
Pressure	$1\ Pa = 10\ dyn/cm^2$

Conversion from British to SI and cgs Units

Length	Area
1 in = 2.54 cm	$1\ in^2 = 6.4516\ cm^2$
1 ft = 0.3048 m	$1\ ft^2 = 0.0929\ m^2$
1 yd = 0.9144 m	$1\ yd^2 = 0.8361\ m^2$
1 mi = 1.609 km	$1\ mi^2 = 2.589\ km^2$
1 nm = 1.852 km	$1\ nm^2 = 3.430\ km^2$

Velocity	Volume
1 ft/sec = 0.3048 m/s	$1\ in^3 = 16.387\ cm^3$
1 knot (kt) = 0.5144 m/s	$1\ ft^3 = 2.832 \times 10^{-2}\ m^3$
1 mi/hr = 0.4469 m/s	$1\ yd^3 = 0.7646\ m^3$

Conversion from British to SI and cgs Units (cont)

Energy	Power
1 ft · lb = 1.356 J	1 ft · lb/sec = 1.356 W

Force	Pressure
1 lb = 4.448 N	1 lb/ft^2 = 47.88 N/m^2
1 ounce = 0.2780 N	1 lb/in^2 = 6.895x10^3 N/m^2

Temperature Conversions

Celsius to Kelvin	K = C + 273.15
Fahrenheit to Celsius	C = (F - 32) / 1.8
Fahrenheit to Kelvin	K = (F + 459.67) / 1.8
Rankine to Kelvin	K = R / 1.8

Decibel Scales

Measurements of pressure, energy, intensity, etc. in underwater acoustics are usually expressed on a decibel scale. Intensity on a decibel scale is defined as ten times the base 10 logarithm of the measured intensity level divided by a reference intensity I_0,

$$I(dB) = 10 \log_{10} (I / I_0) .$$

Pressure on a decibel scale is defined as twenty times the base 10 logarithm of the magnitude of the measured pressure level p divided by a reference pressure p_0,

$$p(dB) = 20 \log_{10} (p / p_0) .$$

Equivalent Plane Wave Intensity Level

The intensity I of an acoustic wave is defined as the mean rate of flow of energy through a unit area normal to the direction of propagation. For a plane wave of root mean squared pressure p_{rms} in a medium with density ρ and acoustic velocity c, the acoustic intensity is

$$I = \frac{p_{rms}^2}{\rho c}.$$

The decibel level of this plane wave is

$$p(\text{dB}) = 20\log_{10}(p_{rms}/p_0) = 10\log_{10}\left(\frac{p_{rms}^2/\rho c}{p_0^2/\rho c}\right)$$

$$= 10\log_{10}(I/I_0) = I(\text{dB}).$$

The standard practice in underwater acoustics is to reference measured values to a pressure level of 1 μPa. Formerly, 1 dyn/cm^2 and 0.0002 dyn/cm^2 were used as reference pressure levels.

Note: 1 μbar = 1 dyn/cm^2 = 10^{-1} Pa = 10^5 μPa
1 atmosphere = 1.013 x 10^6 dyn/cm^2
= 1.013 bar

Conversion to Decibel Levels for Reference Pressure Levels Other than 1 μPa

Reference Pressure	To Convert to dB re 1 μPa
1 dyn/cm^2 (= 1 μbar)	Add 100
0.0002 dyn/cm^2	Add 26.0
1 lb/in^2	Add 196.8

Let L_0 and L_1 respectively denote dB levels referenced to pressures p_0 and p_1. Then

$$L_1(\text{dB}) = L_0(\text{dB}) + 20\log_{10}(p_0/p_1).$$

dB to Pressure Ratio

Pressure Ratio	dB	Pressure Ratio	dB
1.000	0.0	1.000	0.0
1.122	1.0	0.891	-1.0
1.413	3.0	0.708	-3.0
1.995	6.0	0.501	-6.0
3.162	10.0	0.316	-10.0
10.000	20.0	0.100	-20.0
100.000	40.0	0.010	-40.0