Units and Dimensions

Dimension: used to designate a physical quantity under consideration (e.g., time, distance, weight).

Unit: used to designate the magnitude or size of the dimension under consideration (e.g., m for length, kg for weight).

Base unit: Base units are dimensionally independent. They are used to designate only one dimension (e.g., units of length, mass, and time).

Derived units: a combination of various dimensions. An example of a derived unit is the unit of force, which includes the dimensions of mass, length, and time.

Precision: synonymous with reproducibility, the degree of deviation of the measurements from the mean. This is often expressed as a $\pm$ term or as the smallest value of unit that can be consistently read in all determinations.

Accuracy: refers to how a measured quantity relates to a known standard. To test for accuracy of a measurement, the mean of a number of determinations is compared against a known standard. Accuracy depends on proper calibration of an instrument.

Table 2.1 Systems of Measurement.

	Dimension						
System	*Use*	*Length*	*Mass*	*Time*	*Temperature*	*Force*	*Energy*
English							
English absolute	Scientific	Foot	Pound mass	Second	°F	Poundal	BTU ft (poundal)
British Engineering	Industrial	Foot	Slug	Second	°F	Pound force	BTU ft (pound force)
American Engineering	U.S. industrial	Foot	Pound mass	Second	°F	Pound force	BTU ft (pound force)
Metric							
Cgs	Scientific	Centimeter	Gram	Second	°C	Dyne	Calorie, erg
Mks	Industrial	Meter	Kilogram	Second	°C	Kilogram force	Kilocalorie joule
SI	Universal	Meter	Kilogram	Second	°K	Newton	Joule

Table 2.2 Base Units of SI and Derived Units with Assigned Names and Symbols.

Quantity	*Unit*	*Symbol*[a]	*Formula*
Length	meter	m	–
Mass	kilogram	kg	–
Electric current	ampere	A	–
Temperature	kelvin	K	–
Amount of substance	mole	mol	–
Luminous intensity	candela	cd	–
Time	second	s	–
Frequency (of a periodic phenomenon)	hertz	Hz	1/s
Force	newton	N	kg m/s^2
Pressure, stress	pascal	Pa	N/m^2
Energy, work, quantity of heat	joule	J	N · m
Power, radient flux	watt	W	J/s
Quantity of electricity, electric charge	coulomb	C	A · s
Electric potential, potential difference, electromotive force	volt	V	W/A
Capacitance	farad	F	C/V
Electric resistance	ohm		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	1m	cd · sr[b]
Illuminance	lux	lx	$1m/m^2$
Activity (of radionuclides)	becquerel	Bq	1/s
Absorbed dose	gray	Gy	J/kg

Source: American National Standard, 1976. Metric Practice. IIEE Std. 268–1976. Institute of Electrical and Electronics Engineers, New York.
[a]Symbols are written in lowercase letters unless they are from the name of a person.
[b]sr stands for steradian, a supplementary unit used to represent solid angles.

Table 2.3 Prefixes Recommended for Use in SI

Prefix	*Multiple*	*Symbol*[a]
tera	10^{12}	T
giga	10^{9}	G
mega	10^{6}	M
kilo	1000	k
milli	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f

[a]Symbols for the prefixes are written in capital letters when the multiplying factor is 10^6 and larger. Prefixes designating multiplying factors less than 10^6 are written in lower case letters.

APPENDIX A.1

Conversion Factors Expressed as a Ratio

Denominator	*Numerators*		*Denominator*	*Numerators*	
I	II	III	I	II	III
Acre	0.4046873	Hectare	cPoise	0.001	Pa · s
Acre	43560.0	$(ft)^2$	$(cm)^3$	3.531* E – 5	$(ft)^3$
Atm (std)	101.325.0	Pascal	$(cm)^3$	0.061023	$(in)^3$
Atm (std)	14.696	lb_f/in^2	$(cm)^3$	2.642*E – 4	Gal
Atm (std)	29.921	in Hg	$(ft)^3$	7.48052	Gal
Atm (std)	76.0	cm Hg @ 0°C	$(ft)^3$	28.316	Liter
			Cup	2.36588* E – 4	$(m)^3$
Atm (std)	33.899	ft H_2O @ 32.2°F	Dyne	1.000* E – 5	Newton
			Dyne·cm	1.000* E – 7	Newton·m
BTU	1.0550* E + 10	Erg	Dyne	2.248* E – 6	lg_f
BTU	778.3	$ft{\cdot}lb_f$			
BTU	3.9292* E – 4	Hp·h	Erg	9.486* E – 11	BTU
BTU	1054.8	Joule	Erg	2.389* E – 8	Cal
BTU	252	Cal	Erg	1.000* E – 7	Joule
BTU	2.928* E – 4	kW·h			
BTU/min	0.023575	Hp	Foot	0.3048	Meter
BTU/min	0.01757	kW	$(ft)^3$	2.83168* E – 2	$(m)^3$
BTU/min	17.5725	Watt	$(ft)^2$	9.29030* E – 2	$(m)^2$
BTU/s	1054.35	Watt	$ft{\cdot}lb_f$	1.355818	Joule
BTU/h	0.29299	Watt			
$\frac{BTU}{h(ft^2)(°F)}$	5.678263	$W/m^2 \cdot K$	Gal (U.S.)	0.13368	$(ft)^3$
			Gal (U.S.)	3.78541	Liter
			Gal (U.S.)	3.78541*E−3	$(m)^3$
$\frac{BTU}{h(ft)(°F)}$	1.730735	W/m· K	Gram	2.2046* E – 3	Pound

(Continued)

Denominator	*Numerators*		*Denominator*	*Numerators*	
I	II	III	I	II	III
BTU/lb	2326.0	J/kg			
			Hectare	2.471	Acre
$\frac{\text{BTU}}{\text{lb}(^\circ\text{F})}$	4186.8	J/kg· K	Hp	42.44	BTU/min
			Hp	33,000	ft · lb_f/min
Bushel	1.2445	ft^3	Hp	0.7457	kW
Bushel	0.035239	m^3	Hp(boiler)	33,480	BTU/h
Cal	4.1868	Joule	Inch	2.5400* E − 2	Meter
Cal	3.9684* E − 3	BTU	in Hg @ 0°C	3.38638* E + 3	Pascal
Cal	4.1868* E + 7	Erg			
centimeter	0.3937	Inch	in Hg@ 0°C	0.4912	lb_f/in^2
cm Hg@ 0°C	1333.33	Pascal			
cm H_2O@ 4°C	98.0638	Pascal	Joule	9.48* E − 4	BTU
			Joule	0.23889	Cal
cPoise	0.01	g/cm·s			
cPoise	3.60	kg/m·h			
cPoise	6.72* E − 4	lb/ft·s			
Joule	10.000* E + 7	Erg	Pound	453.5924	Gram
Joule	0.73756	ft·lb_f	Pound	0.45359	kg
Joule	2.77* E − 4	W·h	lb_f	4.44823	Newton
			$lb_f/in.^2$	0.068046	Atm (std)
kg	2.2046	Pound	$lb_f/in.^2$	68947	dynes/cm^2
km	3281	Foot	$lb_f/in.^2$	2.3066	ft H_2O@39.2°F
km	0.6214	Mile	$lb_f/in.^2$	2.035	in Hg@0°C
kW	3413	BTU/h	lb_f/ft^2	47.88026	Pascal
kW·h	3.6* E + 6	Joule	$lb_f/in.^2$	6894.757	Pascal
Liter	0.03532	$(ft)^3$	Qt (U.S.)	9.4635* E + 4	$(m)^3$
Liter	0.2642	Gal (U.S.)	Qt (U.S.)	946.358	$(cm)^3$
Liter	2.113	Pint	Qt (U.S.)	57.75	$(in.)^3$
			Qt (U.S.)	0.9463	liter
Meter	3.281	Foot	Qt (U.S.)	0.25	Gallon
Meter	39.37	Inch			
			Ton (metric)	1000	kg
Newton	1.000* E+5	Dyne	Ton (metric)	2204.6	Pound
			Ton (short)	2000	Pound
Oz (liq)	29.57373	$(cm)^3$	Ton (refri)	12,000	BTU/h
Oz (liq)	1.803	$(in)^3$	Torr (mmHg @0°C)	133.322	Pascal
Oz (av)	28.3495	Gram			
Oz (av)	0.0625	Pound			
			Watt	3.413	BTU/h

(Continued)

Denominator	*Numerators*		*Denominator*	*Numerators*	
I	II	III	I	II	III
Pascal	1.4504* E − 4	$lb_f/in.^2$	Watt	44.27	$ft{\cdot}lb_f/min$
Pascal	1.0197*E − 5	kg_f/cm^2	Watt	1.341* E − 3	Hp
Pint	28.87	$(in.)^3$	Watt·h	3.413	BTU
Poise	0.1	Pa·s	Watt·h	860.01	Cal
lb_f	444823	Dyne	Watt·h	3600	Joule

To use: multiply quantities having units under Column 1 with the factors under Column II to obtain quantities having the units under Column III. Also use as a ratio in a dimensional equation Example: 10 acres = 10 × 0.4.046.873 hectares. The dimensional ratio is (0.4046873) hectare/acre. The symbol *E represents exponents of 10.9.486* $E - 11 = 9.486 \times 10^{-11}$.