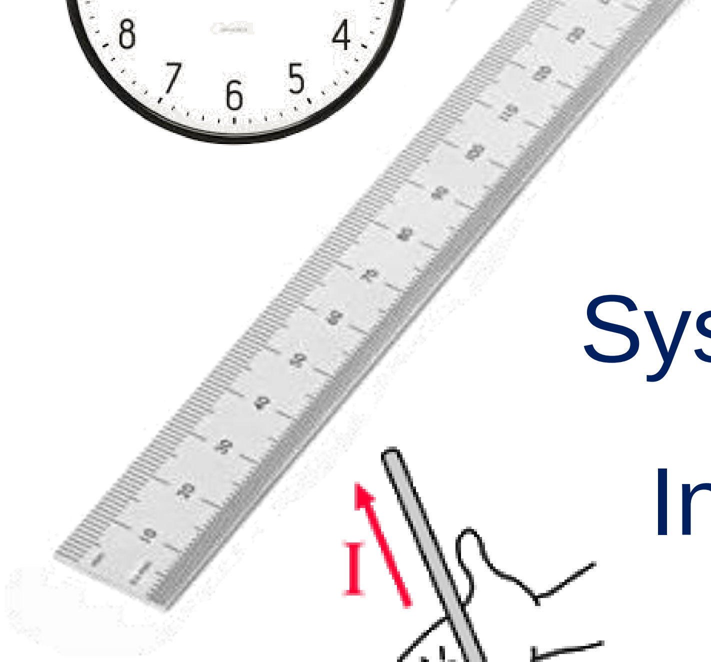
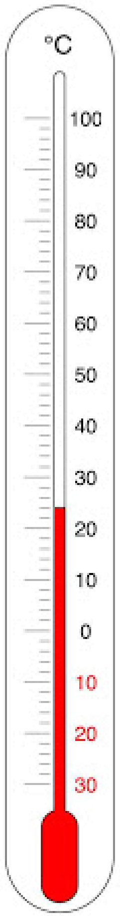
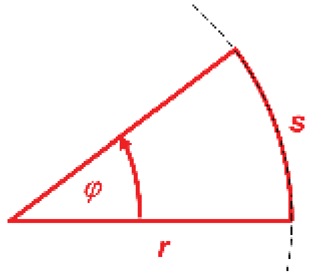
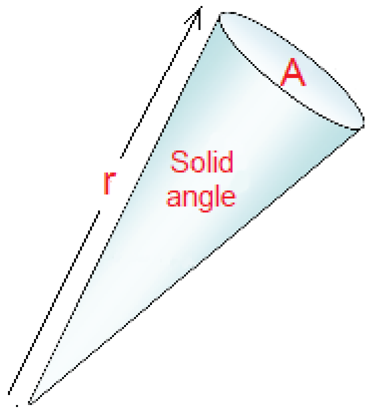
EE 1012 – Fundamentals of Electrical Engineering



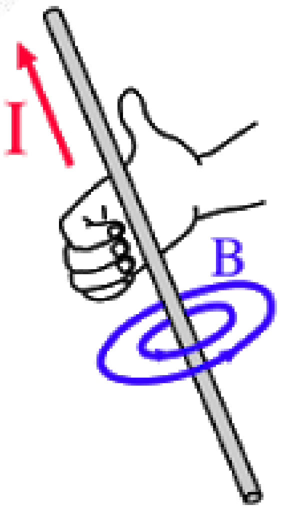


S I Units

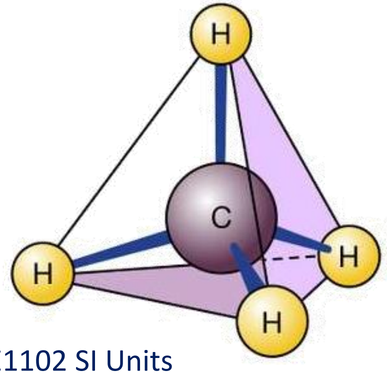


Systéme Internationale d´Unites

International System of Units



Prof Rohan Lucas



Learning outcomes

At successful completion, you should be able to

1. State the Base Units and Supplementary Units
2. State the Derived Units for common quantities
3. State the Compound Units for common quantities
4. Understand the basis of the Unit definitions
5. Use SI units and their symbols correctly
6. Use decimal multiple prefixes with units

Systems of Units

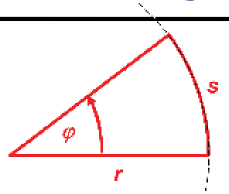
- Imperial System of Units (FPS)
  - First defined in British Weights and Measures Act of 1824
  - Official use in British Empire until metric system adopted in 1965
  - Based on foot - length, pound - mass and second - time (FPS)
- Metric system of Units (CGS)
  - Creation of decimal Metric System in the French Revolutions
  - Deposition of 2 platinum standards for meter and kilogram on 22 June 1799, in Archives de la République, Paris.
  - Metric System proposed in 1832 by Carl Friedrich Gauss based on units millimeter, milligram, and second.
  - Selection of centimeter, gram, second (CGS) in 1874 by Maxwell and Thomson including addition of electromagnetic units

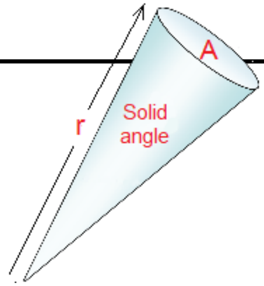
Systems of Units

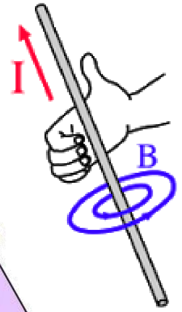
- Metric system (MKS)
  - In1889, meter, kilogram and second established a three-dimensional mechanical unit system (**MKS**) It succeeded the CGS system of units, especially engineering.
  - Adoption of a four-dimensional system based on meter, kilogram, second and ampere (**MKSA**) in 1938 by the IEC
  - In1954, introduced the ampere, kelvin and candela as base units for electric current, thermodynamic temperature and luminous intensity.
- International System of Units (SI)
  - In 1960, the MKSA units was redesignated as the International System of Units (System International d'Unites - SI)
  - In 1971 mole was added as base unit for amount of substance (present version of SI was completed)

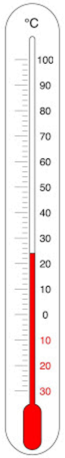
SI Units: 7 Base Units + 2 supplementary units

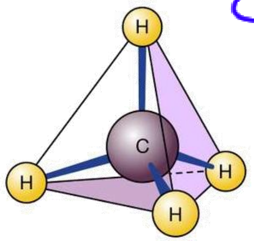
Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
plane angle	radian	rad
solid angle	steradian	sr



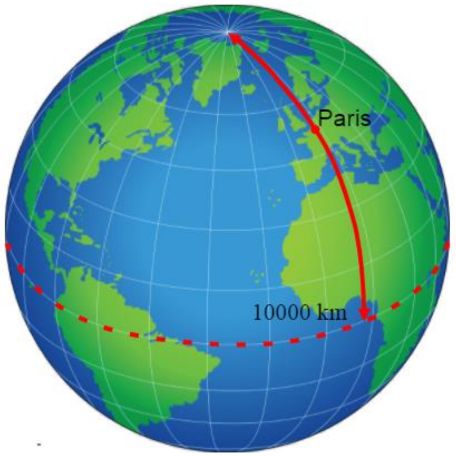




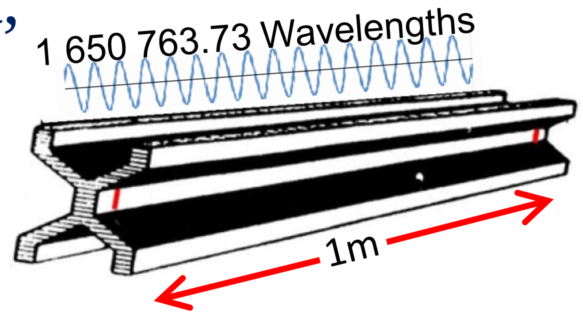




meter (m)



- 1791 French originated meter as one/ten-millionth of distance from equator to north pole along a meridian through Paris.
- 1799 New Platinum standard created based on measurement
- 1875 Upgraded to a bar of 90% Platinum + 10% Indium alloy
- 1960 Redefined as 1,650,763.73 wavelengths of orange-red light, in vacuum, produced by burning element krypton Kr-86



- 1983 Distance light travels, in a vacuum, in 1/299,792,458 s with time measured by a cesium-133 atomic clock which emits pulses of radiation at very rapid, regular intervals
- 2019 Defined by taking the fixed numerical value of the **speed of light** in vacuum *c* to be 299792458 when expressed in the unit $\mathrm{m{\cdot}s^{-1}}$, where the second is defined in terms of the caesium frequency $\Delta\nu_{\mathrm{Cs}}$.

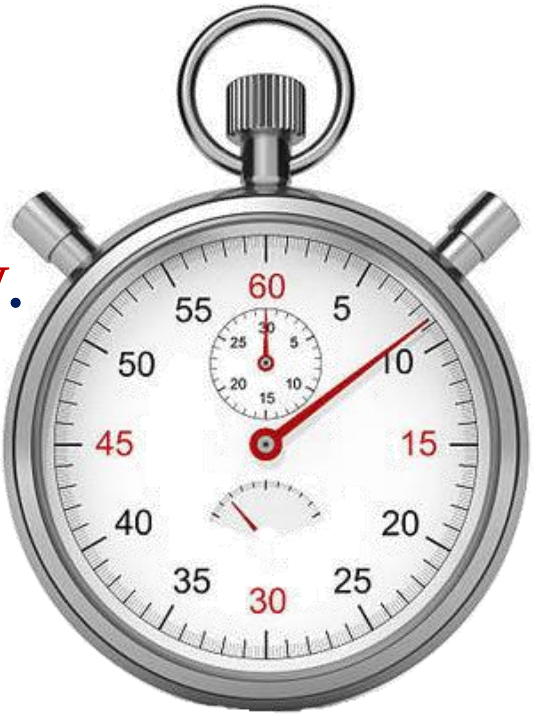
The newer definitions did not change length of meter, but allowed length to be reproduced more precisely.

kilogram (kg)

- At end of 18th century, a kilogram was the mass of a cubic decimeter of water. [1 decimeter^3 = 10^{-3} meter^3]
- In 1889, the international prototype of the kilogram was made of platinum-iridium.
- SI unit of mass, equivalent to the international standard kept at Sèvres near Paris
- 2019 Defined by taking the fixed numerical value of the Planck constant h to be $6.62607015 \times 10^{-34}$ when expressed in the unit J·s, which is equal to kg·m^2·s^{-1}, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$.

The old platinum-iridium international prototype, as kept at the International Bureau of Weights and Measures at Sèvres near Paris

second (s)



For thousands of years Earth's rotation was timekeeper.

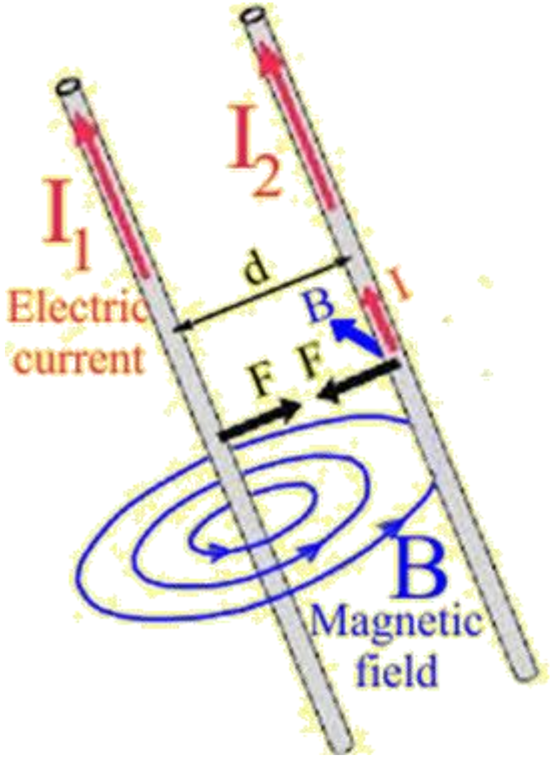
Originally defined as fraction 1/86 400 of mean solar day.

- Quartz and atomic clocks of 1930s and 1950s better timekeepers. Show that Earth does not rotate steadily.

1967 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.

2019 Defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom, to be 9192631770 when expressed in the unit Hz, which is equal to s^{-1}.

ampere (A)



1948 The constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length

2019 Defined by taking the fixed numerical value of the elementary charge e to be $1.602176634 \times 10^{-19}$ when expressed in the unit C, which is equal to A·s, where the second is defined in terms of $\Delta\nu_{Cs}$.

kelvin (K)

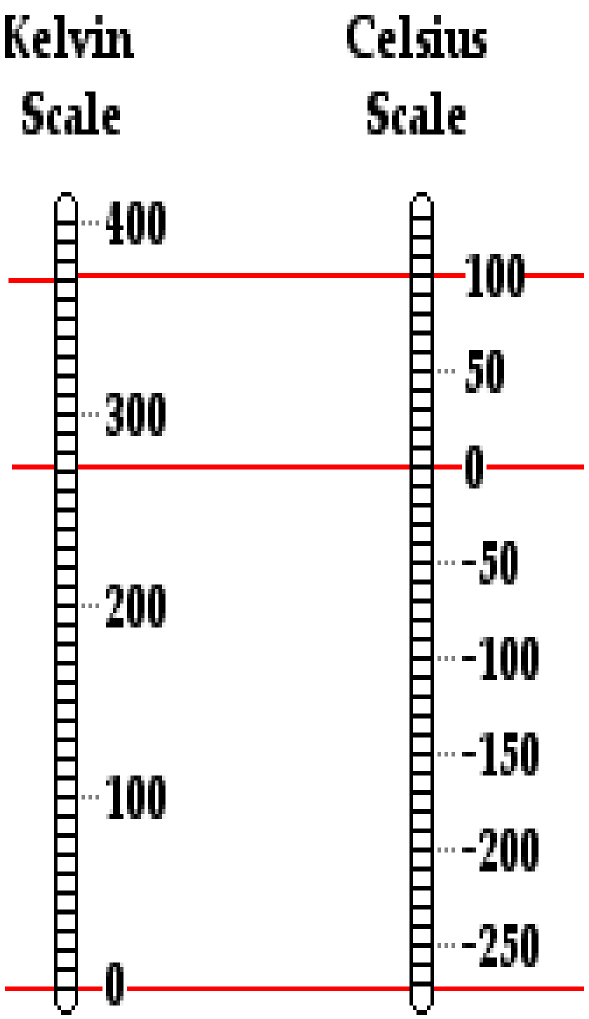
1954 Defined as the unit of thermodynamic temperature

1967 Adopted name kelvin (symbol K) instead of "degree Kelvin" (symbol °K).

The unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

The numerical value of the temperature in degrees celsius t is expressed in terms of temperature in kelvin T as t = T - 273.15

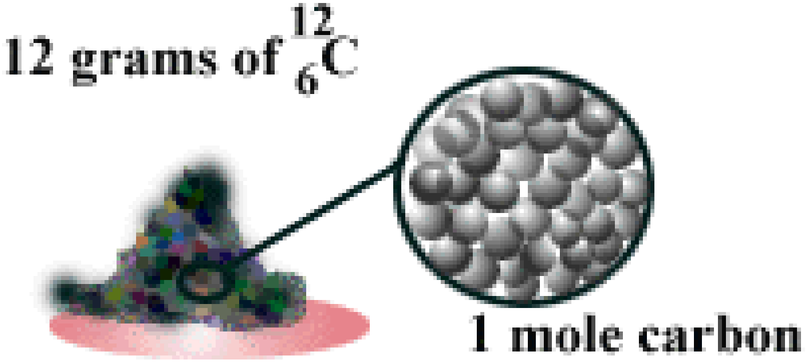
2019 Defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380649×10^{-23} when expressed in the unit $J{\cdot}K^{-1}$, which is equal to $kg{\cdot}m^2{\cdot}s^{-2}{\cdot}K^{-1}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.



mole (mol)

"Atomic weights" were originally referred to atomic weight of oxygen, by general agreement taken as 16.

Since 1959/60, physicists and chemists have agreed to assign value 12, exactly, to "atomic weight" of isotope number 12 (carbon 12, ^{12}C).



1971 The mole is the amount of substance of a system elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol"

2019 One mole contains exactly $6.02214076 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

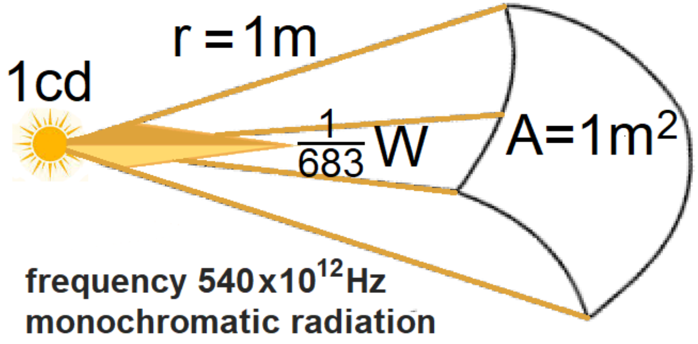
candela (cd)

1909 International candle represented by carbon filament lamps

1933 A blackbody provided a theoretically perfect solution and principle was adopted that new photometric units would be based on luminous emission of a blackbody at freezing temperature of platinum (2045 K).

1967 A new international name for this unit, the candela (cd)

1979 The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.



2019 The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit $\mathrm{lm\cdot W^{-1}}$, which is equal to $\mathrm{cd\cdot sr\cdot W^{-1}}$, or $\mathrm{cd\cdot sr\cdot kg^{-1}\cdot m^{-2}\cdot s^{3}}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.

Derived Units

Derived units are SI units which have their own names but are not independently defined

- Force = mass $\times$ acceleration

  1 newton or 1 N = 1 kg $\times$ 1 m/s^2 = 1 m.kg.s^{-2}

- Charge = current $\times$ time

  1 coulomb or 1 C = 1 A $\times$ 1 s = 1 A.s

- Electric potential difference = work done/charge

  = Force $\times$ distance / charge

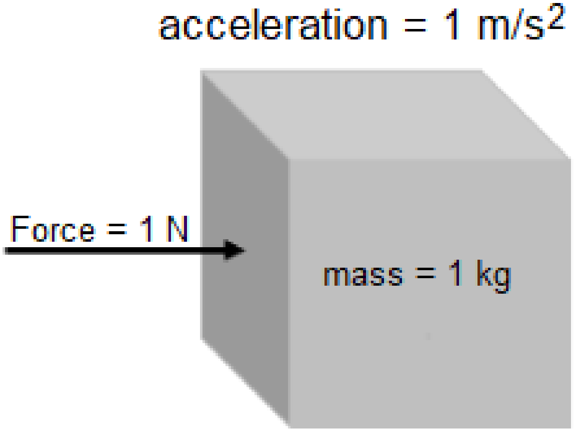
  1 volt or 1V = 1 m.kg.s^{-2} $\times$ 1m / 1 A.s

  = 1 m^2.kg. s^{-3}.A^{-1}

Definition of Derived Units

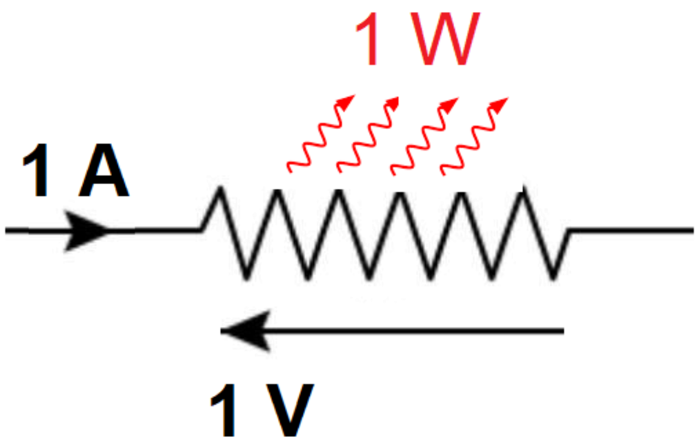
SI unit of force – newton (N)

One newton is equal to the force required to accelerate a body with the mass one kilogram by one metre per second per second



SI unit of electric potential – volt (V)

One volt is equal to the potential difference between two points of a conducting wire carrying a constant current of 1A, when the power dissipated between these points is equal to 1 W.



Prefixes - Decimal Multiples

Symbol	Prefix	Power of Ten	Common Name
Y	yotta	10^{24}	
Z	zetta	10^{21}	
E	exa	10^{18}	
P	peta	10^{15}	
T	tera	10^{12}	trillion
G	giga	10^{9}	billion
M	mega	10^{6}	million
k	kilo	10^{3}	thousand
h	hecto*	10^{2}	hundred
da	deka*	10^{1}	ten
		10^{0}	one

Prefixes - Decimal Sub-multiples

Symbol	Prefix	Power of Ten	Common Name
d	deci*	10^{-1}	tenth
c	centi*	10^{-2}	hundredth
m	milli	10^{-3}	thousandth
μ	micro	10^{-6}	millionth
n	nano	10^{-9}	billionth
p	pico	10^{-12}	trillionth
F	femto	10^{-15}	
a	atto	10^{-18}	
z	zepto	10^{-21}	
y	yocto	10^{-24}	

Use of Symbols

When spelled in full, unit names are treated like ordinary English nouns.

Example: ampere, watt, kelvin, meter, second, degree celsius

Unit symbols are printed in lower-case letters except when the name of the unit is derived from the name of a person.

Example: A, W, K, m, s, ^{o}C

Prefix symbols Y (yotta), Z (zetta), E (exa), P (peta), T (tera), G (giga), and M (mega) are printed in upper-case letters while all other prefix symbols are printed in lower-case.

Unit symbols are unaltered in the plural.

However, plural unit names are used when they are required by the rules of English grammar.

Example: farads is the plural of farad

Use of Symbols (contd)

Unit symbols are not followed by a period unless at end of a sentence.

Symbols for units formed from other units by multiplication are indicated by means of either a half-high dot or a space.

Example: N · m or N m

When the name of a derived unit formed from other units by multiplication is spelled out, a space, or a hyphen is used to separate the names of the individual units.

Example: newton-metre or newton metre

Symbols for units formed from other units by division are indicated by means of a solidus (oblique stroke /), a horizontal line, or negative exponents.

Example: m/s, or $\mathrm{m \cdot s^{-1}}$

Use of Symbols (contd)

When the name of a derived unit formed from other units by division is spelled out, the word "per" is used, not a solidus.

Example: meter per second *but not:* metre/second

Unit symbols and unit names are not used together.

Example: C·kg^{-1} or coulomb per kilogram; *but not*: coulomb/kg;

Grouping formed by a prefix symbol attached to a unit symbol constitutes a new inseparable symbol which can be raised to a positive or negative power and which can be combined with other unit symbols to form compound unit symbols.

Example: cm^2, ms^{-1}

Compound prefix symbols are not permitted.

Example: ns, pF *but not:* mμs, μμF

Non-SI units commonly used with SI

Symbol	Non-SI Unit	Customary Definition	SI Definition
Plane Angle			
°	degree (arc degree)	1/360 circle	π/180 radian
'	minute (arc minute)	1/60° = 1/21 600 circle	π/10 800 radian
"	second (arc second)	1/60 ' = 1/1 296 000 circle	π/648 000 radian
Time (solar)			
min	minute	60 s	60 s
h	hour	60 min	3600 s
d	day	24 h	86 400 s
a	year (seasonal)	~365.25 d	~31.6 Ms
Ma	megayear	million (10^6) years	~31.6 Ts
Ga	gigayear	billion (10^9) years	~31.6 Ps

Use of Symbols (contd)

For historical reasons, kilogram is the SI base unit of mass. However as compound prefixes are unacceptable, symbols for decimal multiples and submultiples of the unit of mass are formed by attaching prefix symbols to gram

Example: mg, milligram *but not:* mkg, microkilogram

When the name of a unit containing a prefix is spelled out, no space or hyphen is used between the prefix and unit name.

Examples: milligram, kilopascal *but not:* milli gram, kilo-pascal

Because it could lead to confusion, mathematical operations are not applied to unit names but only to unit symbols.

Example: joule per kilogram or J/kg or $J \cdot kg^{-1}$ *but not:* joule/kilogram or joule · kilogram^{-1}

Prefixes for binary multiples

Factor	Name	Symbol	Origin	Derivation
2^{10}	kibi	Ki	kilobinary: $(2^{10})^1$	kilo: $(10^3)^1$
2^{20}	mebi	Mi	megabinary: $(2^{10})^2$	mega: $(10^3)^2$
2^{30}	gibi	Gi	gigabinary: $(2^{10})^3$	giga: $(10^3)^3$
2^{40}	tebi	Ti	terabinary: $(2^{10})^4$	tera: $(10^3)^4$
2^{50}	pebi	Pi	petabinary: $(2^{10})^5$	peta: $(10^3)^5$
2^{60}	exbi	Ei	exabinary: $(2^{10})^6$	exa: $(10^3)^6$

End of Presentation