

Lesson 01 - Working with Units

When working with numerical problems and calculations it is good practice to indicate the unit with each number the first time it appears in the calculation. It is a required practice in this course that all numerical answers must include the appropriate unit(s).

Note: The various SI units will be introduced at the appropriate points in the course. Students will be responsible for unit names and unit abbreviations only after they are introduced in class.

SI Base Units		
Quantity	Unit 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

Note: Students are responsible for SI prefixes (*that means spelling, numerical factor, and abbreviations*) from femto- to peta- (*except for hecto- and deca-*), immediately. If a prefixed unit is raised to a power, the exponent applies to the whole unit, not just to un-prefixed part, i.e. read cm^2 as $(\text{cm})^2$, not $\text{c}(\text{m}^2)$.

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

Inspiration for this handout comes from the online page created by

Author: [Dan Thomas](http://www.chembio.uoguelph.ca/educmat/chm386/convfact.htm) at url: <http://www.chembio.uoguelph.ca/educmat/chm386/convfact.htm>

Note: The various derived SI units will be introduced at the appropriate points in the course. Students will be responsible for unit names, unit abbreviations, and component units (*in the case of these derived units*) only after they are introduced in class.

<h2>SI Derived Units</h2>			
Quantity	Unit Name	Symbol	Equivalent Compound Unit
plane angle	radian	rad	m/m or unitless
solid angle	steradian	sr	m ² /m ² or unitless
velocity			m/s
acceleration			m/s ²
angular velocity			rad/s
angular acceleration			rad/s ²
frequency	hertz	Hz	s ⁻¹
force	newton	N	kg m/s ²
pressure	pascal	Pa	N/m ²
work, energy, heat	joule	J	N m kg m ² /s ²
impulse, momentum			N s kg m/s
power	watt	W	J/s
electric charge	coulomb	C	A s
electric potential	volt	V	J/C W/A
resistance	ohm	Ω	V/A
conductance	siemens	S	A/V Ω ⁻¹
magnetic flux	weber	Wb	V s
inductance	henry	H	Wb/A
capacitance	farad	F	C/V
electric field strength			V/m N/C
magnetic flux density	tesla	T	Wb/m ² N/(A m)
electric displacement			C/m ²
celsius temperature	degree celsius	°C	K + 273.15
luminous flux	lumen	lm	cd sr
illuminance	lux	lx	lm/m ²
radioactivity	becquerel	Bq	s ⁻¹

Note: While most of the units used in the course are SI units there are some useful exceptions. Foremost among these is the conversion from the SI unit of length to the American Customary unit of length. By international agreement this can only be accomplished by converting between centimeters and inches. By definition:

$$1.00000\dots \text{ inch} = 2.54000000\dots \text{ cm}$$

Both numbers have as many zeroes as you want. They are defined numbers and as such are not subject to any error.

Other useful non-SI units include the following:

Accepted Non-SI Units			
Quantity	Unit Name	Symbol	Definition
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h = 86 400 s
	year	yr	1 yr = 365.25 d
plane angle	degree	°	1 ° = $\pi/180$ rad
	arc-minute	'	1 ' = $1/60$ °
	arc-second	"	1 " = $1/60'$
volume	liter	L	1 L = 1 dm ³ = 10 ⁻³ m ³
mass	metric ton	t	1 t = 1000 kg
land area	hectare	ha	1 ha = 10 000 m ²
energy	electron volt	eV	1 eV = 1.602 177 33 x 10 ⁻¹⁹ J
mass	atomic mass unit	amu	1 amu = 1.660 540 2 x 10 ⁻²⁷ kg

Special Note Regarding unitless Quantities: Certain mathematical operations cannot be performed on quantities with units. These operations include:

Exponentiation (10^x or e^x , for example)

Logarithms ($\log x$ or $\ln x$, for example)

Trigonometric functions ($\sin x$, $\cos x$, or $\tan x$, for example)

Anytime you perform one of these operations make sure the units of the collection of numbers all cancel with each other. The exponent and the arguments for the logarithmic and trigonometric functions (x in the examples above) must always be unitless.

Some numbers in your calculations are naturally unitless. These are the mathematically exact numbers that appear, usually due to some theoretical consideration. These include numbers that frequently appear in the basic equations of physics, such as

2 , $\frac{1}{2}$, π , e (base of the natural logarithms), and some others.

In addition to being unitless, these numbers also have arbitrarily high precision.

Style Conventions and Usage

This material comes from an article by R.A. Nelson in the August 1996 issue of *Physics Today*, entitled **Guide for Metric Practice**. (*Students should familiarize themselves with these rules in order to read some numerical problems even though these rules are not always followed strictly and uniformly in this course, in the textbook, or in the other sources they we may consult.*)

1. Letter symbols for physical quantities are set in italics while symbols for units are set in upright fonts. For instance, $F = 15 \text{ N}$ (the force equals 15 newtons).
2. Symbols for unit names derived from proper names have the first letter capitalized. Otherwise they are lowercase. The unit names, however, are not capitalized. Hence, we have, tesla, T; meter, m; newton, N; coulomb, C; second, s; kilogram, kg.
3. A unit symbol is a mathematical entity - not an abbreviation. It is never followed by a period and the plural does not have "s" added. Therefore, we have 6 kg; never "6 kg." or "6 kgs".
4. The word "degree" (symbol " $^{\circ}$ ") is not a valid unit for thermodynamic temperature, K; kelvin. It is, however used with celsius temperatures, $^{\circ}\text{C}$; degrees celsius ($\text{K} = ^{\circ}\text{C} + 273.15$).
5. Numbers with more than four digits should be grouped in groups of three separated by a space, rather than a comma in order to avoid confusion with the European usage of the comma and decimal which is opposite to that in North America. Hence the speed of light should be written as 299 792 458 m/s rather than 299,792,458 m/s. This holds true on the right of a decimal point too. Then, in both North America and Europe one can interpret 34 567.89 T and 34 567,89 T as identical values for the magnetic flux density without ambiguity.
6. There must be a space between the numerical value and the symbol for the unit. For instance a common film format is 35 mm, not 35mm or 35-mm.
7. A zero should be placed in front of the decimal marker for fractions, so that one should read 0.75 N rather than .75 N.
8. The appropriate prefix for a unit should be chosen to ensure that the numerical value is in a range that is most practical, usually between 0.1 and 1000. Hence one would expect to find a given voltage written as 0.47 MV or 470 kV, rather than as 470 000 V.
9. There is no space between the prefix and the symbol (kV not k V) and compound prefixes are not allowed (12 pA must be used rather than 12 $\mu\mu\text{A}$).
10. When a unit name is written out, the prefix should be written out in full also, beginning with a lowercase letter. We write MHz or megahertz rather than Megahertz or Mhertz or mega Hz.
11. Multiplication of units is indicated by using a centered dot or leaving a space (N m or N•m). Division can be written with a solidus or a negative exponent (V/cm or V cm^{-1} or $\text{V}\cdot\text{cm}^{-1}$). Repeated use of the solidus is not permitted (m/s^2 but never $\text{m}/\text{s}/\text{s}$). Use parentheses or negative exponents when more than one unit appears in the denominator ($\text{W}/(\text{m}^2 \text{K}^4)$ or $\text{W m}^{-2} \text{K}^{-4}$).

Unit names should not be mixed with unit symbols for mathematical operations. We can write "meter per second", but not "meter/second" or "meter second⁻¹". When writing out the product of two units use a space or a hyphen but never a centered dot. Hence, write "newton meter" or "newton-meter".