This manual is for GNU Units (version 2.12), which performs units conversions and units calculations.


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Table of Contents

1 Overview of units ............................................. 1

2 Interacting with units ........................................ 1

3 Using units Non-Interactively .............................. 4

4 Unit Definitions ............................................... 4
   4.1 English Customary Units ................................. 5

5 Unit Expressions ............................................... 6
   5.1 Operators .................................................. 6
   5.2 Sums and Differences of Units ......................... 8
   5.3 Numbers as Units ......................................... 9
   5.4 Built-in Functions ........................................ 9
   5.5 Previous Result .......................................... 10
   5.6 Complicated Unit Expressions ......................... 11
   5.7 Backwards Compatibility: ‘*’ and ‘-’ ................. 12

6 Nonlinear Unit Conversions .................................. 12
   6.1 Temperature Conversions ................................ 13
   6.2 Other Nonlinear Units ................................. 14

7 Unit Lists: Conversion to Sums of Units ................. 15

8 Logging Calculations ......................................... 19

9 Invoking units ................................................ 20

10 Adding Your Own Definitions .............................. 25
   10.1 Units Data Files ......................................... 25
   10.2 Defining New Units and Prefixes ..................... 26
   10.3 Defining Nonlinear Units ............................ 27
   10.4 Defining Piecewise Linear Units .................. 29
   10.5 Defining Unit List Aliases .......................... 31

11 Numeric Output Format ..................................... 31
   11.1 Format Specification .................................. 32
   11.2 Flags ...................................................... 32
   11.3 Field Width ............................................. 33
   11.4 Precision ............................................... 33
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Localization</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>12.1 Locale</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>12.2 Additional Localization</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>Environment Variables</td>
<td>37</td>
</tr>
<tr>
<td>14</td>
<td>Data Files</td>
<td>38</td>
</tr>
<tr>
<td>15</td>
<td>Unicode Support</td>
<td>38</td>
</tr>
<tr>
<td>16</td>
<td>Readline Support</td>
<td>39</td>
</tr>
<tr>
<td>17</td>
<td>Updating Currency Exchange Rates</td>
<td>40</td>
</tr>
<tr>
<td>18</td>
<td>Database Command Syntax</td>
<td>40</td>
</tr>
<tr>
<td>19</td>
<td>GNU Free Documentation License</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>49</td>
</tr>
</tbody>
</table>
1 Overview of units

The units program converts quantities expressed in various systems of measurement to their equivalents in other systems of measurement. Like many similar programs, it can handle multiplicative scale changes. It can also handle nonlinear conversions such as Fahrenheit to Celsius; see Section 6.1 [Temperature Conversions], page 13. The program can also perform conversions from and to sums of units, such as converting between meters and feet plus inches.

Basic operation is simple: you enter the units that you want to convert from and the units that you want to convert to. You can use the program interactively with prompts, or you can use it from the command line.

Beyond simple unit conversions, units can be used as a general-purpose scientific calculator that keeps track of units in its calculations. You can form arbitrary complex mathematical expressions of dimensions including sums, products, quotients, powers, and even roots of dimensions. Thus you can ensure accuracy and dimensional consistency when working with long expressions that involve many different units that may combine in complex ways; for an illustration, see Section 5.6 [Complicated Unit Expressions], page 11.

The units are defined in an external data file. You can use the extensive data file that comes with this program, or you can provide your own data file to suit your needs. You can also use your own data file to supplement the standard data file.

You can change the default behavior of units with various options given on the command line. See Chapter 9 [Invoking Units], page 20, for a description of the available options.

2 Interacting with units

To invoke units for interactive use, type units at your shell prompt. The program will print something like this:

Currency exchange rates from www.timegenie.com on 2014-03-05
2860 units, 109 prefixes, 85 nonlinear units

You have:

At the ‘You have:’ prompt, type the quantity and units that you are converting from. For example, if you want to convert ten meters to feet, type 10 meters. Next, units will print ‘You want:’. You should type the units you want to convert to. To convert to feet, you would type feet. If the readline library was compiled in then tab will complete unit names. See Chapter 16 [Readline Support], page 39, for more information about readline. To quit the program under Unix, press Ctrl-C or Ctrl-D. Under Windows, press Ctrl-C or Ctrl-Z; with the latter, you may also need to press Enter.

The result will be displayed in two ways. The first line of output, which is marked with a ‘*’ to indicate multiplication, gives the result of the conversion you have asked for. The

---

1 But Fahrenheit to Celsius is linear, you insist. Not so. A transformation \( T \) is linear if \( T(x + y) = T(x) + T(y) \) and this fails for \( T(x) = ax + b \). This transformation is affine, but not linear.
second line of output, which is marked with a ‘/’ to indicate division, gives the inverse of the conversion factor. If you convert 10 meters to feet, units will print

\[
\begin{align*}
&* 32.808399 \\
&/ 0.03048
\end{align*}
\]

which tells you that 10 meters equals about 32.8 feet. The second number gives the conversion in the opposite direction. In this case, it tells you that 1 foot is equal to about 0.03 dekameters since the dekameter is 10 meters. It also tells you that 1/32.8 is about 0.03.

The units program prints the inverse because sometimes it is a more convenient number. In the example above, for example, the inverse value is an exact conversion: a foot is exactly 0.03048 dekameters. But the number given the other direction is inexact.

If you convert grains to pounds, you will see the following:

You have: grains
You want: pounds
* 0.00014285714
/ 7000

From the second line of the output you can immediately see that a grain is equal to a seven thousandth of a pound. This is not so obvious from the first line of the output. If you find the output format confusing, try using the --verbose option:

You have: grain
You want: aeginamina
  grain = 0.00010416667 aeginamina
  grain = (1 / 9600) aeginamina

If you request a conversion between units that measure reciprocal dimensions, then units will display the conversion results with an extra note indicating that reciprocal conversion has been done:

You have: 6 ohms
You want: siemens
  reciprocal conversion
  * 0.16666667
  / 6

Reciprocal conversion can be suppressed by using the --strict option. As usual, use the --verbose option to get more comprehensible output:

You have: tex
You want: typ
  reciprocal conversion
  1 / tex = 496.05465 typ
  1 / tex = (1 / 0.0020159069) typ

You have: 20 mph
You want: sec/mile
  reciprocal conversion
  1 / 20 mph = 180 sec/mile
  1 / 20 mph = (1 / 0.0055555556) sec/mile
If you enter incompatible unit types, the *units* program will print a message indicating that the units are not conformable and it will display the reduced form for each unit:

```
You have: ergs/hour
You want: fathoms kg^-2 / day
conformability error
  2.7777778e-11 kg m^-2 / sec^-3
  2.1166667e-05 kg^-2 m / sec
```

If you only want to find the reduced form or definition of a unit, simply press *Enter* at the ‘You want:’ prompt. Here is an example:

```
You have: jansky
You want:
Definition: fluxunit = 1e-26 W/m^-2 Hz = 1e-26 kg / s^-2
```

The output from *units* indicates that the jansky is defined to be equal to a fluxunit which in turn is defined to be a certain combination of watts, meters, and hertz. The fully reduced (and in this case somewhat more cryptic) form appears on the far right.

Some named units are treated as dimensionless in some situations. These units include the radian and steradian. These units will be treated as equal to 1 in units conversions. Power is equal to torque times angular velocity. This conversion can only be performed if the radian is dimensionless.

```
You have: (14 ft lbf) (12 radians/sec)
You want: watts
  * 227.77742
  / 0.0043902509
```

It is also possible to compute roots and other non-integer powers of dimensionless units; this allows computations such as the altitude of geosynchronous orbit:

```
You have: cuberoot(G earthmass / (circle/siderealday)^2) - earthradius
You want: miles
  * 22243.267
  / 4.4957425e-05
```

Named dimensionless units are not treated as dimensionless in other contexts. They cannot be used as exponents so for example, ‘meter^radian’ is forbidden.

If you want a list of options you can type `?` at the ‘You want:’ prompt. The program will display a list of named units that are conformable with the unit that you entered at the ‘You have:’ prompt above. Conformable unit *combinations* will not appear on this list.

Typing `help` at either prompt displays a short help message. You can also type `help` followed by a unit name. This will invoke a pager on the units data base at the point where that unit is defined. You can read the definition and comments that may give more details or historical information about the unit. (You can generally quit out of the page by pressing ‘q’.)

Typing `search` *text* will display a list of all of the units whose names contain *text* as a substring along with their definitions. This may help in the case where you aren’t sure of the right unit name.
3 Using units Non-Interactively

The units program can perform units conversions non-interactively from the command line. To do this, type the command, type the original unit expression, and type the new units you want. If a units expression contains non-alphanumeric characters, you may need to protect it from interpretation by the shell using single or double quote characters.

If you type

```
units "2 liters" quarts
```

then units will print
```
* 2.1133764
/ 0.47317647
```
and then exit. The output tells you that 2 liters is about 2.1 quarts, or alternatively that a quart is about 0.47 times 2 liters.

If the conversion is successful, then units will return success (zero) to the calling environment. If you enter non-conformable units then units will print a message giving the reduced form of each unit and it will return failure (nonzero) to the calling environment.

When you invoke units with only one argument, it will print out the definition of the specified unit. It will return failure if the unit is not defined and success if the unit is defined.

4 Unit Definitions

The conversion information is read from a units data file that is called definitions.units and is usually located in the /usr/share/units directory. If you invoke units with the -V option, it will print the location of this file. The default file includes definitions for all familiar units, abbreviations and metric prefixes. It also includes many obscure or archaic units.

Many constants of nature are defined, including these:

```
pi         ratio of circumference to diameter
\text{c}     speed of light
\text{e}     charge on an electron
\text{force} acceleration of gravity
\text{mole}  Avogadro's number
\text{water} pressure per unit height of water
\text{Hg}    pressure per unit height of mercury
\text{au}    astronomical unit
\text{k}     Boltzman's constant
\text{mu0}  permeability of vacuum
\text{epsilon0}  permittivity of vacuum
\text{G}  Gravitational constant
\text{mach} speed of sound
```

The standard data file includes atomic masses for all of the elements and numerous other constants. Also included are the densities of various ingredients used in baking so that
'2 cups flour_sifted' can be converted to 'grams'. This is not an exhaustive list. Consult the units data file to see the complete list, or to see the definitions that are used.

The 'pound' is a unit of mass. To get force, multiply by the force conversion unit 'force' or use the shorthand 'lbf'. (Note that 'g' is already taken as the standard abbreviation for the gram.) The unit 'ounce' is also a unit of mass. The fluid ounce is 'fluidounce' or 'floz'. When British capacity units differ from their US counterparts, such as the British Imperial gallon, the unit is defined both ways with 'br' and 'us' prefixes. Your locale settings will determine the value of the unprefixed unit. Currency is prefixed with its country name: 'belgiumfranc', 'britainpound'.

When searching for a unit, if the specified string does not appear exactly as a unit name, then the units program will try to remove a trailing 's', 'es'. Next units will replace a trailing 'ies' with 'y'. If that fails, units will check for a prefix. The database includes all of the standard metric prefixes. Only one prefix is permitted per unit, so 'micromicrofarad' will fail. However, prefixes can appear alone with no unit following them, so 'micro*microfarad' will work, as will 'micro microfarad'.

To find out which units and prefixes are available, read the standard units data file, which is extensively annotated.

### 4.1 English Customary Units

English customary units differ in various ways in different regions. In Britain a complex system of volume measurements featured different gallons for different materials such as a wine gallon and ale gallon that different by twenty percent. This complexity was swept away in 1824 by a reform that created an entirely new gallon, the British Imperial gallon defined as the volume occupied by ten pounds of water. Meanwhile in the USA the gallon is derived from the 1707 Winchester wine gallon, which is 231 cubic inches. These gallons differ by about twenty percent. By default if units runs in the 'en_GB' locale you will get the British volume measures. If it runs in the 'en_US' locale you will get the US volume measures. In other locales the default values are the US definitions. If you wish to force different definitions then set the environment variable UNITS_ENGLISH to either 'US' or 'GB' to set the desired definitions independent of the locale.

Before 1959, the value of a yard (and other units of measure defined in terms of it) differed slightly among English-speaking countries. In 1959, Australia, Canada, New Zealand, the United Kingdom, the United States, and South Africa adopted the Canadian value of 1 yard = 0.9144 m (exactly), which was approximately halfway between the values used by the UK and the US; it had the additional advantage of making 1 inch = 2.54 cm (exactly). This new standard was termed the International Yard. Australia, Canada, and the UK then defined all customary lengths in terms of the International Yard (Australia did not define the furlong or rod); because many US land surveys were in terms of the pre-1959 units, the US continued to define customary surveyors' units (furlong, chain, rod, and link) in terms of the previous value for the foot, which was termed the US survey foot. The US defined a US survey mile as 5280 US survey feet, and defined a statute mile as a US survey mile. The US values for these units differ from the international values by about 2 ppm.

The units program uses the international values for these units; the US values can be obtained by using either the 'US' or the 'survey' prefix. In either case, the simple familiar relationships among the units are maintained, e.g., 1 'furlong' = 660 'ft', and
1 ‘USfurlong’ = 660 ‘USft’, though the metric equivalents differ slightly between the two cases. The ‘US’ prefix or the ‘survey’ prefix can also be used to obtain the US survey mile and the value of the US yard prior to 1959, e.g., ‘USmile’ or ‘surveymile’ (but not ‘USsurveymile’). To get the US value of the statute mile, use either ‘USstatutemile’ or ‘USmile’.

Except for distances that extend over hundreds of miles (such as in the US State Plane Coordinate System), the differences in the miles are usually insignificant:

\[
\begin{align*}
\text{You have:} & \quad 100 \text{ surveymile} - 100 \text{ mile} \\
\text{You want:} & \quad \text{inch} \\
\times & \quad 12.672025 \\
\div & \quad 0.078913984
\end{align*}
\]

The pre-1959 UK values for these units can be obtained with the prefix ‘UK’.

In the US, the acre is officially defined in terms of the US survey foot, but units uses a definition based on the international foot. If you want the official US acre use ‘USacre’ and similarly use ‘USacrefoot’ for the official US version of that unit. The difference between these units is about 4 parts per million.

## 5 Unit Expressions

### 5.1 Operators

You can enter more complicated units by combining units with operations such as multiplication, division, powers, addition, subtraction, and parentheses for grouping. You can use the customary symbols for these operators when units is invoked with its default options. Additionally, units supports some extensions, including high priority multiplication using a space, and a high priority numerical division operator (’|’) that can simplify some expressions.

You multiply units using a space or an asterisk (’*’). The next example shows both forms:

\[
\begin{align*}
\text{You have:} & \quad \text{arabicfoot} \times \text{arabictradepound} \times \text{force} \\
\text{You want:} & \quad \text{ft lbf} \\
\times & \quad 0.7296 \\
\div & \quad 1.370614
\end{align*}
\]

You can divide units using the slash (’/’) or with ‘per’:

\[
\begin{align*}
\text{You have:} & \quad \text{furlongs per fortnight} \\
\text{You want:} & \quad \text{m/s} \\
\times & \quad 0.00016630986 \\
\div & \quad 6012.8727
\end{align*}
\]

You can use parentheses for grouping:

\[
\begin{align*}
\text{You have:} & \quad (1/2) \text{ kg} / (\text{kg/meter}) \\
\text{You want:} & \quad \text{league} \\
\times & \quad 0.00010356166 \\
\div & \quad 9656.0833
\end{align*}
\]
Units Conversion

Multiplication using a space has a higher precedence than division using a slash and is evaluated left to right; in effect, the first ‘/’ character marks the beginning of the denominator of a unit expression. This makes it simple to enter a quotient with several terms in the denominator: ‘J / mol K’. The ‘*’ and ‘/’ operators have the same precedence, and are evaluated left to right; if you multiply with ‘*’, you must group the terms in the denominator with parentheses: ‘J / (mol * K)’.

The higher precedence of the space operator may not always be advantageous. For example, ‘m/s s/day’ is equivalent to ‘m / s s day’ and has dimensions of length per time cubed. Similarly, ‘1/2 meter’ refers to a unit of reciprocal length equivalent to 0.5/meter, perhaps not what you would intend if you entered that expression. The get a half meter you would need to use parentheses: ‘(1/2) meter’. The ‘*’ operator is convenient for multiplying a sequence of quotients. For example, ‘m/s * s/day’ is equivalent to ‘m/day’.

Similarly, you could write ‘1/2 * meter’ to get half a meter.

The units program supports another option for numerical fractions: you can indicate division of numbers with the vertical bar (‘|’), so if you wanted half a meter you could write ‘1|2 meter’. You cannot use the vertical bar to indicate division of non-numerical units (e.g., ‘m|s’ results in an error message).

Powers of units can be specified using the ‘^’ character, as shown in the following example, or by simple concatenation of a unit and its exponent: ‘cm3’ is equivalent to ‘cm^3’; if the exponent is more than one digit, the ‘^’ is required. You can also use ‘**’ as an exponent operator.

You have: cm^3
You want: gallons
* 0.00026417205
/ 3785.4118

Concatenation only works with a single unit name: if you write ‘(m/s)2’, units will treat it as multiplication by 2. When a unit includes a prefix, exponent operators apply to the combination, so ‘centimeter3’ gives cubic centimeters. If you separate the prefix from the unit with any multiplication operator (e.g., ‘centi meter^3’), the prefix is treated as a separate unit, so the exponent applies only to the unit without the prefix. The second example is equivalent to ‘centi * (meter^-3)’, and gives a hundredth of a cubic meter, not a cubic centimeter. The units program is limited internally to products of 99 units; accordingly, expressions like ‘meter^100’ or ‘joule^34’ (represented internally as ‘kg^34 m^68 / s^68’) will fail.

The ‘|’ operator has the highest precedence, so you can write the square root of two thirds as ‘2|3^1|2’. The ‘^-’ operator has the second highest precedence, and is evaluated right to left, as usual:

You have: 5 * 2^-3^-2
You want:
Definition: 2560

With a dimensionless base unit, any dimensionless exponent is meaningful (e.g., ‘pi^-exp(2.371)’). Even though angle is sometimes treated as dimensionless, exponents cannot have dimensions of angle:
You have: 2\textsuperscript{radian}  

Exponent not dimensionless

If the base unit is not dimensionless, the exponent must be a rational number \( p/q \), and the dimension of the unit must be a power of \( q \), so ‘\text{gallon}^{2/3}’ works but ‘\text{acre}^{2/3}’ fails. An exponent using the slash (‘/’) operator (e.g., ‘\text{gallon}^{(2/3)}’) is also acceptable; the parentheses are needed because the precedence of ‘\text{^}’ is higher than that of ‘/’. Since \text{units} cannot represent dimensions with exponents greater than 99, a fully reduced exponent must have \( q < 100 \). When raising a non-dimensional unit to a power, \text{units} attempts to convert a decimal exponent to a rational number with \( q < 100 \). If this is not possible \text{units} displays an error message:

You have: \text{ft}^{1.234}  
Base unit not dimensionless; rational exponent required

A decimal exponent must match its rational representation to machine precision, so ‘\text{acre}^{1.5}’ works but ‘\text{gallon}^{0.666}’ does not.

5.2 Sums and Differences of Units

You may sometimes want to add values of different units that are outside the SI. You may also wish to use \text{units} as a calculator that keeps track of units. Sums of conformable units are written with the ‘\text{+}’ character, and differences with the ‘\text{-}’ character.

You have: 2 \text{ hours} + 23 \text{ minutes} + 32 \text{ seconds}  
You want: \text{seconds}  
\begin{align*}
\times 8612 \\
/ 0.00011611705 
\end{align*}

You have: 12 \text{ ft} + 3 \text{ in}  
You want: \text{cm}  
\begin{align*}
\times 373.38 \\
/ 0.0026782366 
\end{align*}

You have: 2 \text{ btu} + 450 \text{ ft lbf}  
You want: \text{btu}  
\begin{align*}
\times 2.5782804 \\
/ 0.38785542 
\end{align*}

The expressions that are added or subtracted must reduce to identical expressions in primitive units, or an error message will be displayed:

You have: 12 \text{ printerspoint} - 4 \text{ heredium}  

Illegal sum of non-conformable units

As usual, the precedence for ‘\text{+}’ and ‘\text{-}’ is lower than that of the other operators. A fractional quantity such as 2 1/2 cups can be given as ‘\text{(2+1/2) cups}’; the parentheses are necessary because multiplication has higher precedence than addition. If you omit the parentheses, \text{units} attempts to add ‘2’ and ‘1/2 \text{ cups}’, and you get an error message:
You have: 2+1\text{1/2} \text{ cups}

Illegal sum or difference of non-conformable units

The expression could also be correctly written as \((2+1/2) \text{ cups}\). If you write \(2 \text{ 1/2 cups}\) the space is interpreted as \text{multiplication} so the result is the same as \(1 \text{ cup}\).

The '+' and '-' characters sometimes appears in exponents like \(3.43e+8\). This leads to an ambiguity in an expression like \(3e+2 \text{ yC}\). The unit 'e' is a small unit of charge, so this can be regarded as equivalent to \((3e+2) \text{ yC}\) or \((3 \text{ e})+(2 \text{ yC})\). This ambiguity is resolved by always interpreting '+' and '-' as part of an exponent if possible.

5.3 Numbers as Units

For \textit{units}, numbers are just another kind of unit. They can appear as many times as you like and in any order in a unit expression. For example, to find the volume of a box that is 2 ft by 3 ft by 12 ft in steres, you could do the following:

You have: 2 ft 3 ft 12 ft
You want: stere
* 2.038813
/ 0.49048148

You have: $5 / \text{ yard}$
You want: cents / \text{ inch}$
* 13.888889
/ 0.072

And the second example shows how the dollar sign in the units conversion can precede the five. Be careful: \textit{units} will interpret '5' with no space as equivalent to 'dollar^5'.

5.4 Built-in Functions


You have: \text{sin}(30 \text{ degrees})
You want:
  Definition: 0.5

You have: \text{sin}(\pi/2)
You want:
  Definition: 1

You have: \text{sin}(3 \text{ kg})

Unit not dimensionless

The other functions on the list require dimensionless arguments. The inverse trigonometric functions return arguments with dimensions of angle.
If you wish to take roots of units, you may use the ‘sqrt’ or ‘cuberoot’ functions. These functions require that the argument have the appropriate root. You can obtain higher roots by using fractional exponents:

You have: sqrt(acre)
You want: feet
   * 208.71074
   / 0.0047913202

You have: (400 W/m^2 / stefanboltzmann)^1/4
You have:
   Definition: 289.80882 K

You have: cuberoot(hectare)

Unit not a root

5.5 Previous Result

You can insert the result of the previous conversion using the underscore (‘_’). It is useful when you want to convert the same input to several different units, for example

You have: 2.3 tonrefrigeration
You want: btu/hr
   * 27600
   / 3.6231884e-005
You have: _
You want: kW
   * 8.0887615
   / 0.12362832

Suppose you want to do some deep frying that requires an oil depth of 2 inches. You have 1/2 gallon of oil, and want to know the largest-diameter pan that will maintain the required depth. The nonlinear unit ‘circlearea’ gives the radius of the circle (see Section 6.2 [Other Nonlinear Units], page 14, for a more detailed description) in SI units; you want the diameter in inches:

You have: 1|2 gallon / 2 in
You want: circlearea
   0.10890173 m
You have: 2 _
You want: in
   * 8.5749393
   / 0.1166189

In most cases, surrounding white space is optional, so the previous example could have used ‘2’. If ‘_’ follows a non-numerical unit symbol, however, the space is required:

You have: m_

Parse error
When \_ is followed by a digit, the operation is multiplication rather than exponentiation, so that \_2 is equivalent to \_* 2_ rather than \_^2_.

You can use the \_ symbol any number of times; for example,

You have: m
You want:
definition: 1 m
You have: _
You want:
definition: 1 m^2

Using \_ before a conversion has been performed (e.g., immediately after invocation) generates an error:

You have: _
no previous result; \_ not set

Accordingly, \_ serves no purpose when units is invoked non-interactively.

If units is invoked with the --verbose option (see Chapter 9 [Invoking Units], page 20), the value of \_ is not expanded:

You have: mile
You want: ft
mile = 5280 ft
mile = (1 / 0.00018939394) ft
You have: _
You want: m
_ = 1609.344 m
_ = (1 / 0.00062137119) m

You can give \_ at the ‘You want:’ prompt, but it usually is not very useful.

## 5.6 Complicated Unit Expressions

The units program is especially helpful in ensuring accuracy and dimensional consistency when converting lengthy unit expressions. For example, one form of the Darcy–Weisbach fluid-flow equation is

$$\Delta P = \frac{8 \pi^2 \rho f L Q^2}{d^5}$$

where \(\Delta P\) is the pressure drop, \(\rho\) is the mass density, \(f\) is the (dimensionless) friction factor, \(L\) is the length of the pipe, \(Q\) is the volumetric flow rate, and \(d\) is the pipe diameter. It might be desired to have the equation in the form

$$\Delta P = A_1 \rho f L \frac{Q^2}{d^5}$$

that accepted the user’s normal units; for typical units used in the US, the required conversion could be something like

You have: (8/pi^2)lbm/ft^3ft*ft^3/s^2(1/in^5)
You want: psi
* 43.533969
/ 0.022970568
The parentheses allow individual terms in the expression to be entered naturally, as they might be read from the formula. Alternatively, the multiplication could be done with the ‘*’ rather than a space; then parentheses are needed only around ‘ft^3/s’ because of its exponent:

You have: \( \frac{8}{\pi^2} \times \frac{\text{lbm}}{\text{ft}^3} \times \text{ft} \times (\text{ft}^3/\text{s})^2 \times \frac{\text{in}^{-5}}{} \)
You want: psi
\[
* \frac{43.533969}{0.022970568}
\]

Without parentheses, and using spaces for multiplication, the previous conversion would need to be entered as

You have: \( 8 \times \frac{\text{lb}}{\text{ft} \times \text{ft}^3} \times \frac{\text{ft} \times \text{ft}^3}{\pi^2 \times \text{ft}^3 \times \text{ft}^2 \times \text{in}^5} \)
You want: psi
\[
* \frac{43.533969}{0.022970568}
\]

5.7 Backwards Compatibility: ‘*’ and ‘-’

The original units assigned multiplication a higher precedence than division using the slash. This differs from the usual precedence rules, which give multiplication and division equal precedence, and can be confusing for people who think of units as a calculator.

The star operator (‘*’) included in this units program has, by default, the same precedence as division, and hence follows the usual precedence rules. For backwards compatibility you can invoke units with the --oldstar option. Then ‘*’ has a higher precedence than division, and the same precedence as multiplication using the space.

Historically, the hyphen (‘-’) has been used in technical publications to indicate products of units, and the original units program treated it as a multiplication operator. Because units provides several other ways to obtain unit products, and because ‘-’ is a subtraction operator in general algebraic expressions, units treats the binary ‘-’ as a subtraction operator by default. For backwards compatibility use the --product option, which causes units to treat the binary ‘-’ operator as a product operator. When ‘-’ is a multiplication operator it has the same precedence as multiplication with a space, giving it a higher precedence than division.

When ‘-’ is used as a unary operator it negates its operand. Regardless of the units options, if ‘-’ appears after ‘-’ or after ‘*’ then it will act as a negation operator. So you can always compute 20 degrees minus 12 minutes by entering ‘20 degrees + -12 arcmin’. You must use this construction when you define new units because you cannot know what options will be in force when your definition is processed.

6 Nonlinear Unit Conversions

Nonlinear units are represented using functional notation. They make possible nonlinear unit conversions such as temperature.
6.1 Temperature Conversions

Conversions between temperatures are different from linear conversions between temperature increments—see the example below. The absolute temperature conversions are handled by units starting with ‘temp’, and you must use functional notation. The temperature-increment conversions are done using units starting with ‘deg’ and they do not require functional notation.

You have: tempF(45)
You want: tempC
7.2222222

You have: 45 degF
You want: degC
* 25
/ 0.04

Think of ‘tempF(x)’ not as a function but as a notation that indicates that x should have units of ‘tempF’ attached to it. See Section 10.3 [Defining Nonlinear Units], page 27. The first conversion shows that if it’s 45 degrees Fahrenheit outside, it’s 7.2 degrees Celsius. The second conversion indicates that a change of 45 degrees Fahrenheit corresponds to a change of 25 degrees Celsius. The conversion from ‘tempF(x)’ is to absolute temperature, so that

You have: tempF(45)
You want: degR
* 504.67
/ 0.0019814929
gives the same result as

You have: tempF(45)
You want: tempR
* 504.67
/ 0.0019814929

But if you convert ‘tempF(x)’ to ‘degC’, the output is probably not what you expect:

You have: tempF(45)
You want: degC
* 280.37222
/ 0.0035666871

The result is the temperature in K, because ‘degC’ is defined as ‘K’, the Kelvin. For consistent results, use the ‘tempX’ units when converting to a temperature rather than converting a temperature increment.

The ‘tempC()’ and ‘tempF()’ definitions are limited to positive absolute temperatures, and giving a value that would result in a negative absolute temperature generates an error message:

You have: tempC(-275)

Argument of function outside domain
6.2 Other Nonlinear Units

Some other examples of nonlinear units are numerous different ring sizes and wire gauges, the grit sizes used for abrasives, the decibel scale, shoe size, scales for the density of sugar (e.g., baume). The standard data file also supplies units for computing the area of a circle and the volume of a sphere. See the standard units data file for more details. Wire gauges with multiple zeroes are signified using negative numbers where two zeroes is ‘-1’. Alternatively, you can use the synonyms ‘g00’, ‘g000’, and so on that are defined in the standard units data file.

You have: wiregauge(11)
You want: inches
* 0.090742002
/ 11.020255

You have: brwiregauge(g00)
You want: inches
* 0.348
/ 2.8735632

You have: 1 mm
You want: wiregauge
18.201919

You have: grit_P(600)
You want: grit_ansicoated
342.76923

The last example shows the conversion from P graded sand paper, which is the European standard and may be marked “P600” on the back, to the USA standard.

You can compute the area of a circle using the nonlinear unit, ‘circlearea’. You can also do this using the circularinch or circleinch. The next example shows two ways to compute the area of a circle with a five inch radius and one way to compute the volume of a sphere with a radius of one meter.

You have: circlearea(5 in)
You want: in2
* 78.539816
/ 0.012732395

You have: 10^-2 circleinch
You want: in2
* 78.539816
/ 0.012732395

You have: spherevol(meter)
You want: ft3
* 147.92573
/ 0.0067601492
The inverse of a nonlinear conversion is indicated by prefixing a tilde (‘~’) to the nonlinear unit name:

You have: ~wiregauge(0.090742002 inches)
You want: 
Definition: 11

You can give a nonlinear unit definition without an argument or parentheses, and press Enter at the ‘You want:’ prompt to get the definition of a nonlinear unit; if the definition is not valid for all real numbers, the range of validity is also given. If the definition requires specific units this information is also displayed:

You have: tempC
Definition: tempC(x) = x K + stdtemp
defined for x >= -273.15

You have: ~tempC
Definition: ~tempC(tempC) = (tempC +(-stdtemp))/K
defined for tempC >= 0 K

You have: circlearea
Definition: circlearea(r) = pi r^2
r has units m

To see the definition of the inverse use the ‘~’ notation. In this case the parameter in the functional definition will usually be the name of the unit. Note that the inverse for ‘tempC’ shows that it requires units of ‘K’ in the specification of the allowed range of values.

Nonlinear unit conversions are described in more detail in Section 10.3 [Defining Nonlinear Units], page 27.

7 Unit Lists: Conversion to Sums of Units

Outside of the SI, it is sometimes desirable to convert a single unit to a sum of units—for example, feet to feet plus inches. The conversion from sums of units was described in Section 5.2 [Sums and Differences of Units], page 8, and is a simple matter of adding the units with the ‘+’ sign:

You have: 12 ft + 3 in + 3\frac{1}{8} in
You want: ft
* 12.28125
/ 0.081424936

Although you can similarly write a sum of units to convert to, the result will not be the conversion to the units in the sum, but rather the conversion to the particular sum that you have entered:

You have: 12.28125 ft
You want: ft + in + 1\frac{1}{8} in
* 11.228571
/ 0.089058524

The unit expression given at the ‘You want:’ prompt is equivalent to asking for conversion to multiples of ‘1 ft + 1 in + 1\frac{1}{8} in’, which is 1.09375 ft, so the conversion in the previous example is equivalent to
You have: 12.28125 ft
You want: 1.09375 ft
  * 11.228571
  / 0.089058524

In converting to a sum of units like miles, feet and inches, you typically want the largest integral value for the first unit, followed by the largest integral value for the next, and the remainder converted to the last unit. You can do this conversion easily with units using a special syntax for lists of units. You must list the desired units in order from largest to smallest, separated by the semicolon (';') character:

You have: 12.28125 ft
You want: ft;in;1|8 in
  12 ft + 3 in + 3|8 in

The conversion always gives integer coefficients on the units in the list, except possibly the last unit when the conversion is not exact:

You have: 12.28126 ft
You want: ft;in;1|8 in
  12 ft + 3 in + 3.00096 * 1|8 in

The order in which you list the units is important:

You have: 3 kg
You want: oz;lb
  105 oz + 0.051367866 lb

You have: 3 kg
You want: lb;oz
  6 lb + 9.8218858 oz

Listing ounces before pounds produces a technically correct result, but not a very useful one. You must list the units in descending order of size in order to get the most useful result.

Ending a unit list with the separator ';' has the same effect as repeating the last unit on the list, so 'ft;in;1|8 in;' is equivalent to 'ft;in;1|8 in;1|8 in'. With the example above, this gives

You have: 12.28126 ft
You want: ft;in;1|8 in;
  12 ft + 3 in + 3|8 in + 0.00096 * 1|8 in

in effect separating the integer and fractional parts of the coefficient for the last unit. If you instead prefer to round the last coefficient to an integer you can do this with the --round (-r) option. With the previous example, the result is

You have: 12.28126 ft
You want: ft;in;1|8 in
  12 ft + 3 in + 3|8 in (rounded down to nearest 1|8 in)

When you use the -r option, repeating the last unit on the list has no effect (e.g., 'ft;in;1|8 in;1|8 in' is equivalent to 'ft;in;1|8 in'), and hence neither does ending a list with a ';'. With a single unit and the -r option, a terminal ';' does have an effect: it causes units to treat the single unit as a list and produce a rounded value for the single unit. Without the
extra ‘;’, the -r option has no effect on single unit conversions. This example shows the output using the -r option:

```
You have: 12.28126 ft
You want: in
* 147.37512
/ 0.0067854058
```

```
You have: 12.28126 ft
You want: in;
147 in (rounded down to nearest in)
```

Each unit that appears in the list must be conformable with the first unit on the list, and of course the listed units must also be conformable with the unit that you enter at the ‘You have:’ prompt.

```
You have: meter
You want: ft;kg
- conformability error
  ft = 0.3048 m
  kg = 1 kg
```

```
You have: meter
You want: lb;oz
- conformability error
  1 m
  0.45359237 kg
```

In the first case, units reports the disagreement between units appearing on the list. In the second case, units reports disagreement between the unit you entered and the desired conversion. This conformability error is based on the first unit on the unit list.

Other common candidates for conversion to sums of units are angles and time:

```
You have: 23.437754 deg
You want: deg;arcmin;arcsec
23 deg + 26 arcmin + 15.9144 arcsec
```

```
You have: 7.2319 hr
You want: hr;min;sec
7 hr + 13 min + 54.84 sec
```

In North America, recipes for cooking typically measure ingredients by volume, and use units that are not always convenient multiples of each other. Suppose that you have a recipe for 6 and you wish to make a portion for 1. If the recipe calls for 2 1/2 cups of an ingredient, you might wish to know the measurements in terms of measuring devices you have available, you could use units and enter

```
You have: (2+1|2) cup / 6
You want: cup;1|2 cup;1|3 cup;1|4 cup;tbsp;tsp;1|2 tsp;1|4 tsp
1|3 cup + 1 tbsp + 1 tsp
```
By default, if a unit in a list begins with fraction of the form \( \frac{1}{x} \) and its multiplier is an integer, the fraction is given as the product of the multiplier and the numerator; for example,

You have: 12.28125 ft
You want: ft;in;\frac{1}{8} \text{ in};
\[ 12 \text{ ft} + 3 \text{ in} + 3\frac{1}{8} \text{ in} \]

In many cases, such as the example above, this is what is wanted, but sometimes it is not. For example, a cooking recipe for 6 might call for 5 \( \frac{1}{4} \) cup of an ingredient, but you want a portion for 2, and your 1-cup measure is not available; you might try

You have: \((5+\frac{1}{4}) \text{ cup} / 3\)
You want: \(\frac{1}{2} \text{ cup};\frac{1}{3} \text{ cup};\frac{1}{4} \text{ cup}\)
\[ 3\frac{1}{2} \text{ cup} + \frac{1}{4} \text{ cup} \]

This result might be fine for a baker who has a 1 1/2-cup measure (and recognizes the equivalence), but it may not be as useful to someone with more limited set of measures, who does want to do additional calculations, and only wants to know “How many 1/2-cup measures do I need to add?” After all, that’s what was actually asked. With the `--show-factor` option, the factor will not be combined with a unity numerator, so that you get

You have: \((5+\frac{1}{4}) \text{ cup} / 3\)
You want: \(\frac{1}{2} \text{ cup};\frac{1}{3} \text{ cup};\frac{1}{4} \text{ cup}\)
\[ 3 \times \frac{1}{2} \text{ cup} + \frac{1}{4} \text{ cup} \]

A user-specified fractional unit with a numerator other than 1 is never overridden, however—if a unit list specifies ‘3\( \frac{4}{4} \text{ cup};1\frac{1}{2} \text{ cup} \)’, a result equivalent to 1 1/2 cups will always be shown as ‘2 \( \times \frac{3}{4} \text{ cup} \)’ whether or not the `--show-factor` option is given.

Some applications for unit lists may be less obvious. Suppose that you have a postal scale and wish to ensure that it’s accurate at 1 oz, but have only metric calibration weights. You might try

You have: 1 oz
You want: 100 g;50 g; 20 g;10 g;5 g;2 g;1 g;
\[ 20 \text{ g} + 5 \text{ g} + 2 \text{ g} + 1 \text{ g} + 0.34952312 \times 1 \text{ g} \]

You might then place one each of the 20 g, 5 g, 2 g, and 1 g weights on the scale and hope that it indicates close to

You have: 20 g + 5 g + 2 g + 1 g
You want: oz;
\[ 0.98767093 \text{ oz} \]

Appending ’;’ to ‘oz’ forces a one-line display that includes the unit; here the integer part of the result is zero, so it is not displayed.

A unit list such as

\[ \text{cup;1|2} \text{ cup;1|3} \text{ cup;1|4} \text{ cup};\text{tbsp;1|2 tsp;1|4 tsp} \]
can be tedious to enter. The `units` program provides shorthand names for some common combinations:

\[ \begin{align*}
\text{hms} & \quad \text{hours, minutes, seconds} \\
\text{dms} & \quad \text{angle: degrees, minutes, seconds}
\end{align*} \]
time  years, days, hours, minutes and seconds
usvol  US cooking volume: cups and smaller

Using these shorthands, or *unit list aliases*, you can do the following conversions:

- You have: anomalistic year
  You want: time
  1 year + 25 min + 3.4653216 sec

- You have: 1/6 cup
  You want: usvol
  2 tbsp + 2 tsp

You cannot combine a unit list alias with other units: it must appear alone at the
‘You want:’ prompt.

You can display the definition of a unit list alias by entering it at the ‘You have:’ prompt:

- You have: dms
  Definition: unit list, deg;arcmin;arcsec

When you specify compact output with *--compact, --terse* or -t and perform conversion
to a unit list, *units* lists the conversion factors for each unit in the list, separated by
semicolons.

- You have: year
  You want: day;min;sec
  365;348;45.974678

Unlike the case of regular output, zeros *are* included in this output list:

- You have: liter
  You want: cup;1/2 cup;1/4 cup;tbsp
  4;0;0;3.6280454

8 Logging Calculations

The *--log* option allows you to save the results of calculations in a file; this can be useful
if you need a permanent record of your work. For example, the fluid-flow conversion in
Section 5.6 [Complicated Unit Expressions], page 11, is lengthy, and if you were to use
it in designing a piping system, you might want a record of it for the project file. If the
interactive session

```text
# Conversion factor A1 for pressure drop
# dP = A1 rho f L Q^2/d^5
You have: (8/pi^2) (lbm/ft^3)ft(ft^3/s)^2(1/in^5) # Input units
You want: psi
  * 43.533969
  / 0.022970568
```

were logged, the log file would contain
### Log started Fri Oct 02 15:55:35 2015

# Conversion factor A1 for pressure drop
# dP = A1 rho f L Q²/d⁵
From: (8/pi²) (lbm/ft³)ft(ft³/s)²(1/in⁵)  # Input units
To: psi
  * 43.533969
  / 0.022970568

The time is written to the log file when the file is opened.

The use of comments can help clarify the meaning of calculations for the log. The log includes conformability errors between the units at the ‘You have:’ and ‘You want:’ prompts, but not other errors, including lack of conformability of items in sums or differences or among items in a unit list. For example, a conversion between zenith angle and elevation angle could involve

You have: 90 deg - (5 deg + 22 min + 9 sec)

Illegal sum or difference of non-conformable units
You have: 90 deg - (5 deg + 22 arcmin + 9 arcsec)
You want: dms
  84 deg + 37 arcmin + 51 arcsec
You have: _
You want: deg
  * 84.630833
  / 0.011816024

The log file would contain

From: 90 deg - (5 deg + 22 arcmin + 9 arcsec)
To:   deg;arcmin;arcsec
  84 deg + 37 arcmin + 51 arcsec
From: _
To:   deg
  * 84.630833
  / 0.011816024

The initial entry error (forgetting that minutes have dimension of time, and that arcminutes must be used for dimensions of angle) does not appear in the output. When converting to a unit list alias, units expands the alias in the log file.

The ‘From:’ and ‘To:’ tags are written to the log file even if the --quiet option is given. If the log file exists when units is invoked, the new results are appended to the log file. The time is written to the log file each time the file is opened. The --log option is ignored when units is used non-interactively.

9 Invoking units

You invoke units like this:

    units [options] [from-unit [to-unit]]
If the *from-unit* and *to-unit* are omitted, the program will use interactive prompts to determine which conversions to perform. See Chapter 2 [Interactive Use], page 1. If both *from-unit* and *to-unit* are given, *units* will print the result of that single conversion and then exit. If only *from-unit* appears on the command line, *units* will display the definition of that unit and exit. Units specified on the command line may need to be quoted to protect them from shell interpretation and to group them into two arguments. See Chapter 3 [Command Line Use], page 4.

The default behavior of *units* can be changed by various options given on the command line. In most cases, the options may be given in either short form (a single ‘-’ followed by a single character) or long form (‘--’ followed by a word or hyphen-separated words). Short-form options are cryptic but require less typing; long-form options require more typing but are more explanatory and may be more mnemonic. With long-form options you need only enter sufficient characters to uniquely identify the option to the program. For example, ‘--out %f’ works, but ‘--o %f’ fails because *units* has other long options beginning with ‘o’. However, ‘--q’ works because ‘--quiet’ is the only long option beginning with ‘q’.

Some options require arguments to specify a value (e.g., ‘-d 12’ or ‘--digits 12’). Short-form options that do not take arguments may be concatenated (e.g., ‘-ers’ is equivalent to ‘-e -r -S’); the last option in such a list may be one that takes an argument (e.g., ‘-ed 12’). With short-form options, the space between an option and its argument is optional (e.g., ‘-ed 12’). Long-form options may not be concatenated, and the space between a long-form option and its argument is required. Short-form and long-form options may be intermixed on the command line. Options may be given in any order, but when incompatible options (e.g., ‘--output-format’ and ‘--exponential’) are given in combination, behavior is controlled by the last option given. For example, ‘-o%.12f -e’ gives exponential format with the default eight significant digits).

The following options are available:

- **-c**
  --check
  Check that all units and prefixes defined in the units data file reduce to primitive units. Print a list of all units that cannot be reduced. Also display some other diagnostics about suspicious definitions in the units data file. Only definitions active in the current locale are checked. You should always run *units* with this option after modifying a units data file.

--check-verbose
--verbose-check
Like the --check option, this option prints a list of units that cannot be reduced. But to help find unit definitions that cause endless loops, it lists the units as they are checked. If *units* hangs, then the last unit to be printed has a bad definition. Only definitions active in the current locale are checked.

- **-d ndigits**
  --digits ndigits
  Set the number of significant digits in the output to the value specified (which must be greater than zero). For example, ‘-d 12’ sets the number of significant digits to 12. With exponential output *units* displays one digit to the left of
the decimal point\(^2\) and eleven digits to the right of the decimal point. On most systems, the maximum number of internally meaningful digits is 15; if you specify a greater number than your system's maximum, units will print a warning and set the number to the largest meaningful value. To directly set the maximum value, give an argument of \texttt{max} (e.g., \texttt{--max}). Be aware, of course, that “significant” here refers only to the display of numbers; if results depend on physical constants not known to this precision, the physically meaningful precision may be less than that shown. The \texttt{--digits} option conflicts with the \texttt{--output-format} option.

\textbf{-e}

\texttt{--exponential}

Set the numeric output format to exponential (i.e., scientific notation), like that used in the Unix \texttt{units} program. The default precision is eight significant digits (seven digits to the right of the decimal point); this can be changed with the \texttt{--digits} option. The \texttt{--exponential} option conflicts with the \texttt{--output-format} option.

\textbf{-o format}

\texttt{--output-format format}

This option affords complete control over the numeric output format using the specified \texttt{format}. The format is a single floating point numeric format for the \texttt{printf()} function in the C programming language. All compilers support the format types ‘g’ and ‘G’ to specify significant digits, ‘e’ and ‘E’ for scientific notation, and ‘f’ for fixed-point decimal. The ISO C99 standard introduced the ‘F’ type for fixed-point decimal and the ‘a’ and ‘A’ types for hexadecimal floating point; these types are allowed with compilers that support them. The default format is ‘%.8g’; for greater precision, you could specify ‘%.15g’. See Chapter 11 [Numeric Output Format], page 31, and the documentation for \texttt{printf()} for more detailed descriptions of the format specification. The \texttt{--output-format} option affords the greatest control of the output appearance, but requires at least rudimentary knowledge of the \texttt{printf()} format syntax. If you don’t want to bother with the \texttt{printf()} syntax, you can specify greater precision more simply with the \texttt{--digits} option or select exponential format with \texttt{--exponential}. The \texttt{--output-format} option is incompatible with the \texttt{--exponential} and \texttt{--digits} options.

\textbf{-f filename}

\texttt{--file filename}

Instruct units to load the units file \textit{filename}. You can specify up to 25 units files on the command line. When you use this option, units will load only the files you list on the command line; it will not load the standard file or your personal units file unless you explicitly list them. If \textit{filename} is the empty string (‘\texttt{-f ""}’), the default units file (or that specified by \texttt{UNITSFILE}) will be loaded in addition to any others specified with ‘\texttt{-f}’.

\(2\) This document refers to “decimal point,” but strictly, the \textit{radix} separates the integer and fractional parts of a floating-point number; in English-speaking countries, the radix is a point (‘.’), but in most other countries it is a comma (‘,’).
-L logfile
--log logfile
Save the results of calculations in the file logfile; this can be useful if it is important to have a record of unit conversions or other calculations that are to be used extensively or in a critical activity such as a program or design project. If logfile exits, the new results are appended to the file. This option is ignored when units is used non-interactively. See Chapter 8 [Logging Calculations], page 19, for a more detailed description and some examples.

-H filename
--history filename
Instruct units to save history to filename, so that a record of your commands is available for retrieval across different units invocations. To prevent the history from being saved set filename to the empty string (‘-H “”’). This option has no effect if readline is not available.

-h
--help
Print out a summary of the options for units.

-m
--minus
Causes ‘-’ to be interpreted as a subtraction operator. This is the default behavior.

-p
--product
Causes ‘-’ to be interpreted as a multiplication operator when it has two operands. It will act as a negation operator when it has only one operand: ‘(-3)’. By default ‘-’ is treated as a subtraction operator.

--oldstar
Causes ‘*’ to have the old-style precedence, higher than the precedence of division so that ‘1/2*3’ will equal ‘1/6’.

--newstar
Forces ‘*’ to have the new (default) precedence that follows the usual rules of algebra: the precedence of ‘*’ is the same as the precedence of ‘/’, so that ‘1/2*3’ will equal ‘3/2’.

--compact
Give compact output featuring only the conversion factor. This turns off the --verbose option.

-q
--quiet
--silent
Suppress prompting of the user for units and the display of statistics about the number of units loaded.

-n
--nolists
Disable conversion to unit lists.
-r
--round When converting to a combination of units given by a unit list, round the value of the last unit in the list to the nearest integer.

-S
--show-factor When converting to a combination of units specified in a list, always show a non-unity factor before a unit that begins with a fraction with a unity denominator. By default, if the unit in a list begins with fraction of the form 1/x and its multiplier is an integer other than 1, the fraction is given as the product of the multiplier and the numerator (e.g., ‘3|8 in’ rather than ‘3 * 1|8 in’). In some cases, this is not what is wanted; for example, the results for a cooking recipe might show ‘3 * 1|2 cup’ as ‘3|2 cup’. With the --show-factor option, a result equivalent to 1.5 cups will display as ‘3 * 1|2 cup’ rather than ‘3|2 cup’. A user-specified fractional unit with a numerator other than 1 is never overridden, however—if a unit list specifies ‘3|4 cup;1|2 cup’, a result equivalent to 1 1/2 cups will always be shown as ‘2 * 3|4 cup’ whether or not the --show-factor option is given.

-s
--strict Suppress conversion of units to their reciprocal units. For example, units will normally convert hertz to seconds because these units are reciprocals of each other. The strict option requires that units be strictly conformable to perform a conversion, and will give an error if you attempt to convert hertz to seconds.

-1
--one-line Give only one line of output (the forward conversion). Do not print the reverse conversion. If a reciprocal conversion is performed then units will still print the “reciprocal conversion” line.

-t
--terse Give terse output when converting units. This option can be used when calling units from another program so that the output is easy to parse. This option has the combined effect of these options: --strict --quiet --one-line --compact. When combined with --version it produces a display showing only the program name and version number.

-v
--verbose Give slightly more verbose output when converting units. When combined with the -c option this gives the same effect as --check-verbose. When combined with --version produces a more detailed output, equivalent to the --info option.

-V
--version Print the program version number, tell whether the readline library has been included, tell whether UTF-8 support has been included; give the locale, the location of the default units data file, and the location of the personal units data file; indicate if the personal units data file does not exist.
When given in combination with the --terse option, the program prints only
the version number and exits.

When given in combination with the --verbose option, the program, the
--version option has the same effect as the --info option below.

-I
--info
Print the information given with the --version option, show the pathname
of the units program, show the status of the UNITSFILE and MYUNITSFILE
environment variables, and additional information about how units locates
the related files. On systems running Microsoft Windows, the status of the
UNITSLOCALE environment variable and information about the related locale
map are also given. This option is usually of interest only to developers and
administrators, but it can sometimes be useful for troubleshooting.
Combining the --version and --verbose options has the same effect as giving
--info.

-U
--unitsfile
Print the location of the default units data file and exit; if the file cannot be
found, print “Units data file not found”.

-l locale
--locale locale
Print the information given with the --version option, show the Force a spec-
ified locale such as ‘en_GB’ to get British definitions by default. This over-
rides the locale determined from system settings or environment variables. See
Section 12.1 [Locale], page 34, for a description of locale format.

10 Adding Your Own Definitions

10.1 Units Data Files
The units and prefixes that units can convert are defined in the units data file, typically
/usr/share/units/definitions.units. If you can’t find this file, run units --version
to get information on the file locations for your installation. Although you can extend
or modify this data file if you have appropriate user privileges, it’s usually better to put
extensions in separate files so that the definitions will be preserved if you update units.

You can include additional data files in the units database using the ‘!include’ command
in the standard units data file. For example

!include /usr/local/share/units/local.units

might be appropriate for a site-wide supplemental data file. The location of the ‘!include’
statement in the standard units data file is important; later definitions replace earlier ones,
so any definitions in an included file will override definitions before the ‘!include’ state-
ment in the standard units data file. With normal invocation, no warning is given about
redefinitions; to ensure that you don’t have an unintended redefinition, run units -c after
making changes to any units data file.
If you want to add your own units in addition to or in place of standard or site-wide supplemental units data files, you can include them in the `.units` file in your home directory. If this file exists it is read after the standard units data file, so that any definitions in this file will replace definitions of the same units in the standard data file or in files included from the standard data file. This file will not be read if any units files are specified on the command line. (Under Windows the personal units file is named `unitdef.units`.) Running `units -V` will display the location and name of your personal units file.

The `units` program first tries to determine your home directory from the `HOME` environment variable. On systems running Microsoft Windows, if `HOME` does not exist, `units` attempts to find your home directory from `HOMEDRIVE`, `HOMEPATH` and `USERPROFILE`. You can specify an arbitrary file as your personal units data file with the `MYUNITSFILE` environment variable; if this variable exists, its value is used without searching your home directory. The default units data files are described in more detail in Chapter 14 [Data Files], page 38.

### 10.2 Defining New Units and Prefixes

A unit is specified on a single line by giving its name and an equivalence. Comments start with a `#` character, which can appear anywhere in a line. The backslash character (`\`) acts as a continuation character if it appears as the last character on a line, making it possible to spread definitions out over several lines if desired. A file can be included by giving the command `!include` followed by the file’s name. The `!` must be the first character on the line. The file will be sought in the same directory as the parent file unless you give a full path. The name of the file to be included cannot contain the comment character `#`.

Unit names must not contain any of the operator characters `+`, `-`, `*`, `/`, `|`, `^`, `;`, `~`, the comment character `#`, or parentheses. They cannot begin or end with an underscore `_`, a comma `,` or a decimal point `. `. The figure dash (U+2012), typographical minus (U+2013), and en dash (`–`; U+2013) are converted to the operator `−`, so none of these characters can appear in unit names. Names cannot begin with a digit, and if a name ends in a digit other than zero, the digit must be preceded by a string beginning with an underscore, and afterwards consisting only of digits, decimal points, or commas. For example, `foo_2`, `foo_2,1`, or `foo_3.14` are valid names but `foo2` or `foo_a2` are invalid. You could define nitrous oxide as

```
N2O     nitrogen 2 + oxygen
```

but would need to define nitrogen dioxide as

```
NO_2    nitrogen + oxygen 2
```

Be careful to define new units in terms of old ones so that a reduction leads to the primitive units, which are marked with `!` characters. Dimensionless units are indicated by using the string `!dimensionless` for the unit definition.

When adding new units, be sure to use the `-c` option to check that the new units reduce properly. If you create a loop in the units definitions, then `units` will hang when invoked with the `-c` option. You will need to use the `--check-verbose` option, which prints out each unit as it is checked. The program will still hang, but the last unit printed will be the unit that caused the infinite loop.

If you define any units that contain `+` characters, carefully check them because the `-c` option will not catch non-conformable sums. Be careful with the `-` operator as well.
When used as a binary operator, the ‘-’ character can perform addition or multiplication depending on the options used to invoke units. To ensure consistent behavior use ‘-’ only as a unary negation operator when writing units definitions. To multiply two units leave a space or use the ‘*’ operator with care, recalling that it has two possible precedence values and may require parentheses to ensure consistent behavior. To compute the difference of ‘foo’ and ‘bar’ write ‘foo+(-bar)’ or even ‘foo+-bar’.

Here is an example of a short data file that defines some basic units:

```
m ! # The meter is a primitive unit
sec ! # The second is a primitive unit
rad !dimensionless # A dimensionless primitive unit
micro- 1e-6 # Define a prefix
minute 60 sec # A minute is 60 seconds
hour 60 min # An hour is 60 minutes
inch 0.0254 m # Inch defined in terms of meters
ft 12 inches # The foot defined in terms of inches
mile 5280 ft # And the mile
```

A unit that ends with a ‘-’ character is a prefix. If a prefix definition contains any ‘/’ characters, be sure they are protected by parentheses. If you define ‘half- 1/2’ then ‘halfmeter’ would be equivalent to ‘1 / (2 meter)’.

### 10.3 Defining Nonlinear Units

Some unit conversions of interest are nonlinear; for example, temperature conversions between the Fahrenheit and Celsius scales cannot be done by simply multiplying by conversion factors.

When you give a linear unit definition such as ‘inch 2.54 cm’ you are providing information that units uses to convert values in inches into primitive units of meters. For nonlinear units, you give a functional definition that provides the same information.

Nonlinear units are represented using a functional notation. It is best to regard this notation not as a function call but as a way of adding units to a number, much the same way that writing a linear unit name after a number adds units to that number. Internally, nonlinear units are defined by a pair of functions that convert to and from linear units in the database, so that an eventual conversion to primitive units is possible.

Here is an example nonlinear unit definition:

```
tempF(x) units=[1;K] domain=[-459.67,) range=[0,) \n(x+(-32)) degF + stdtemp ; (tempF+(stdtemp))/degF + 32
```

A nonlinear unit definition comprises a unit name, a formal parameter name, two functions, and optional specifications for units, the domain, and the range (the domain of the inverse function). The functions tell units how to convert to and from the new unit. To produce valid results, the arguments of these functions need to have the correct dimensions and be within the domains for which the functions are defined.

The definition begins with the unit name followed immediately (with no spaces) by a ‘(’ character. In the parentheses is the name of the formal parameter. Next is an optional specification of the units required by the functions in the definition. In the example above, the ‘units=[1;K]’ specification indicates that the ‘tempF’ function requires an input
argument conformable with ‘1’ (i.e., the argument is dimensionless), and that the inverse function requires an input argument conformable with ‘K’. For normal nonlinear units definition, the forward function will always take a dimensionless argument; in general, the inverse function will need units that match the quantity measured by your nonlinear unit. Specifying the units enables units to perform error checking on function arguments, and also to assign units to domain and range specifications, which are described later.

Next the function definitions appear. In the example above, the ‘tempF’ function is defined by

\[ \text{tempF}(x) = (x+(-32)) \text{ degF} + \text{stdtemp} \]

This gives a rule for converting ‘x’ in the units ‘tempF’ to linear units of absolute temperature, which makes it possible to convert from tempF to other units.

To enable conversions to Fahrenheit, you must give a rule for the inverse conversions. The inverse will be ‘x(tempF)’ and its definition appears after a ‘;’ character. In our example, the inverse is

\[ x(\text{tempF}) = (\text{tempF}+(-\text{stdtemp}))/\text{degF} + 32 \]

This inverse definition takes an absolute temperature as its argument and converts it to the Fahrenheit temperature. The inverse can be omitted by leaving out the ‘;’ character and the inverse definition, but then conversions to the unit will not be possible. If the inverse definition is omitted, the --check option will display a warning. It is up to you to calculate and enter the correct inverse function to obtain proper conversions; the --check option tests the inverse at one point and prints an error if it is not valid there, but this is not a guarantee that your inverse is correct.

With some definitions, the units may vary. For example, the definition

\[ \text{square}(x) = x^2 \]

can have any arbitrary units, and can also take dimensionless arguments. In such a case, you should not specify units. If a definition takes a root of its arguments, the definition is valid only for units that yield such a root. For example,

\[ \text{squirt}(x) = \sqrt{x} \]

is valid for a dimensionless argument, and for arguments with even powers of units.

Some definitions may not be valid for all real numbers. In such cases, units can handle errors better if you specify an appropriate domain and range. You specify the domain and range as shown below:

\[ \text{baume}(d) \quad \text{units}=[1;\text{g/cm}^3] \quad \text{domain}=[0,130.5] \quad \text{range}=[1,10] \quad (145/(145-d)) \text{ g/cm}^3 \quad (\text{baume}+\text{g/cm}^3) 145 / \text{baume} \]

In this example the domain is specified after ‘domain=’ with the endpoints given in brackets. In accord with mathematical convention, square brackets indicate a closed interval (one that includes its endpoints), and parentheses indicate an open interval (one that does not include its endpoints). An interval can be open or closed on one or both ends; an interval that is unbounded on either end is indicated by omitting the limit on that end. For example, a quantity to which decibel (dB) is applied may have any value greater than zero, so the range is indicated by ‘(0,)’:

\[ \text{decibel}(x) \quad \text{units}=[1;1] \quad \text{range}=(0,) \quad 10^-(x/10); \quad 10 \log(\text{decibel}) \]

If the domain or range is given, the second endpoint must be greater than the first.
The domain and range specifications can appear independently and in any order along with the units specification. The values for the domain and range endpoints are attached to the units given in the units specification, and if necessary, the parameter value is adjusted for comparison with the endpoints. For example, if a definition includes ‘units=[1;ft]’ and ‘range=[3,)’, the range will be taken as 3 ft to infinity. If the function is passed a parameter of ‘900 mm’, that value will be adjusted to 2.9527559 ft, which is outside the specified range. If you omit the units specification from the previous example, units can not tell whether you intend the lower endpoint to be 3 ft or 3 microfurlongs, and can not adjust the parameter value of 900 mm for comparison. Without units, numerical values other than zero or plus or minus infinity for domain or range endpoints are meaningless, and accordingly they are not allowed. If you give other values without units then the definition will be ignored and you will get an error message.

Although the units, domain, and range specifications are optional, it’s best to give them when they are applicable; doing so allows units to perform better error checking and give more helpful error messages. Giving the domain and range also enables the --check option to find a point in the domain to use for its point check of your inverse definition.

You can make synonyms for nonlinear units by providing both the forward and inverse functions; inverse functions can be obtained using the ‘~’ operator. So to create a synonym for ‘tempF’ you could write

\[
\text{fahrenheit}(x) \text{ units}=[1;K] \text{ tempF}(x); \sim\text{tempF(fahrenheit)}
\]

This is useful for creating a nonlinear unit definition that differs slightly from an existing definition without having to repeat the original functions. For example,

\[
\text{dBW}(x) \text{ units}=[1;W] \text{ range}=[0,) \text{ dB}(x) \text{ W } ; \sim\text{dB(dBW/W)}
\]

If you wish a synonym to refer to an existing nonlinear unit without modification, you can do so more simply by adding the synonym with appended parentheses as a new unit, with the existing nonlinear unit—without parentheses—as the definition. So to create a synonym for ‘tempF’ you could write

\[
\text{fahrenheit() tempF}
\]

The definition must be a nonlinear unit; for example, the synonym

\[
\text{fahrenheit() meter}
\]

will result in an error message when units starts.

You may occasionally wish to define a function that operates on units. This can be done using a nonlinear unit definition. For example, the definition below provides conversion between radius and the area of a circle. This definition requires a length as input and produces an area as output, as indicated by the ‘units=’ specification. Specifying the range as the nonnegative numbers can prevent cryptic error messages.

\[
\text{circlearea}(r) \text{ units}=[m;m^2] \text{ range}=[0,) \pi r^2 ; \sqrt{\text{circlearea}/\pi}
\]

10.4 Defining Piecewise Linear Units

Sometimes you may be interested in a piecewise linear unit such as many wire gauges. Piecewise linear units can be defined by specifying conversions to linear units on a list of points. Conversion at other points will be done by linear interpolation. A partial definition of zinc gauge is

\[
\text{zincgauge[in]} 1 0.002, 10 0.02, 15 0.04, 19 0.06, 23 0.1
\]
In this example, ‘zincgauge’ is the name of the piecewise linear unit. The definition of such a unit is indicated by the embedded ‘[’ character. After the bracket, you should indicate the units to be attached to the numbers in the table. No spaces can appear before the ‘]’ character, so a definition like ‘foo[kg meters]’ is invalid; instead write ‘foo[kg*meters]’.

The definition of the unit consists of a list of pairs optionally separated by commas. This list defines a function for converting from the piecewise linear unit to linear units. The first item in each pair is the function argument; the second item is the value of the function at that argument (in the units specified in brackets). In this example, we define ‘zincgauge’ at five points. For example, we set ‘zincgauge(1)’ equal to ‘0.002 in’. Definitions like this may be more readable if written using continuation characters as

\[
\text{zincgauge}[\text{in}] \\ \\
\quad 1 \ 0.002 \ \\
\quad 10 \ 0.02 \ \\
\quad 15 \ 0.04 \ \\
\quad 19 \ 0.06 \ \\
\quad 23 \ 0.1
\]

With the preceding definition, the following conversion can be performed:

You have: zincgauge(10)
You want: in
\* 0.02
/ 50
You have: .01 inch
You want: zincgauge
5

If you define a piecewise linear unit that is not strictly monotonic, then the inverse will not be well defined. If the inverse is requested for such a unit, units will return the smallest inverse.

After adding nonlinear units definitions, you should normally run units --check to check for errors. If the ‘units’ keyword is not given, the --check option checks a nonlinear unit definition using a dimensionless argument, and then checks using an arbitrary combination of units, as well as the square and cube of that combination; a warning is given if any of these tests fail. For example,

Warning: function 'squirt(x)' defined as 'sqrt(x)'
failed for some test inputs:
squirt(7(kg K)^1): Unit not a root
squirt(7(kg K)^3): Unit not a root

Running units --check will print a warning if a non-monotonic piecewise linear unit is encountered. For example, the relationship between ANSI coated abrasive designation and mean particle size is non-monotonic in the vicinity of 800 grit:

\[
\text{ansicoated}[\text{micron}] \ \\
\quad . . . \\
\quad 600 \ 10.55 \ \\
\quad 800 \ 11.5 \ \\
\quad 1000 \ 9.5
\]

Running units --check would give the error message
Table 'ansicoated' lacks unique inverse around entry 800

Although the inverse is not well defined in this region, it's not really an error. Viewing such error messages can be tedious, and if there are enough of them, they can distract from true errors. Error checking for nonlinear unit definitions can be suppressed by giving the 'noerror' keyword; for the examples above, this could be done as

```
squirt(x) noerror domain=[0,), range=[0,) sqrt(x); sqrt^2
ansicoated[micron] noerror 
...```

Use the 'noerror' keyword with caution. The safest approach after adding a nonlinear unit definition is to run `units --check` and confirm that there are no actual errors before adding the 'noerror' keyword.

### 10.5 Defining Unit List Aliases

Unit list aliases are treated differently from unit definitions, because they are a data entry shorthand rather than a true definition for a new unit. A unit list alias definition begins with '!unitlist' and includes the alias and the definition; for example, the aliases included in the standard units data file are

```
!unitlist hms hr;min;sec
!unitlist time year;day;hr;min;sec
!unitlist dms deg;arcmin;arcsec
!unitlist ftin ft;in;1/8 in
!unitlist usvol cup;3/4 cup;1/2 cup;1/3 cup;1/4 cup;1/8 tsp
tbsp;1/2 tsp;1/4 tsp;1/8 tsp
```

Unit list aliases are only for unit lists, so the definition must include a ';'. Unit list aliases can never be combined with units or other unit list aliases, so the definition of 'time' shown above could not have been shortened to 'year;day;hms'.

As usual, be sure to run `units --check` to ensure that the units listed in unit list aliases are conformable.

### 11 Numeric Output Format

By default, `units` shows results to eight significant digits. You can change this with the --exponential, --digits, and --output-format options. The first sets an exponential format (i.e., scientific notation) like that used in the original Unix `units` program, the second allows you to specify a different number of significant digits, and the last allows you to control the output appearance using the format for the `printf()` function in the C programming language. If you only want to change the number of significant digits or specify exponential format type, use the --digits and --exponential options. The --output-format option affords the greatest control of the output appearance, but requires at least rudimentary knowledge of the `printf()` format syntax. See Chapter 9 [Invoking Units], page 20, for descriptions of these options.
11.1 Format Specification

The format specification recognized with the `--output-format` option is a subset of that for `printf()`. The format specification has the form `%%flags[width][.precision]type`; it must begin with `%%`, and must end with a floating-point type specifier: `g` or `G` to specify the number of significant digits, `e` or `E` for scientific notation, and `f` for fixed-point decimal. The ISO C99 standard added the `F` type for fixed-point decimal and the `a` and `A` types for hexadecimal floating point; these types are allowed with compilers that support them. Type length modifiers (e.g., `L` to indicate a long double) are inapplicable and are not allowed.

The default format for `units` is `%.8g`; for greater precision, you could specify `-%.15g`. The `g` and `G` format types use exponential format whenever the exponent would be less than −4, so the value 0.000013 displays as ‘1.3e-005’. These types also use exponential notation when the exponent is greater than or equal to the precision, so with the default format, the value $5 \times 10^7$ displays as ‘50000000’ and the value $5 \times 10^8$ displays as ‘5e+008’. If you prefer fixed-point display, you might specify `-%.8f`; however, small numbers will display very few significant digits, and values less than $5 \times 10^{-8}$ will show nothing but zeros.

The format specification may include one or more optional flags: `+`, `'` (space), `#`, `-`, or `0` (the digit zero). The digit-grouping flag `'` (apostrophe) is allowed with compilers that support it. Flags are followed by an optional value for the minimum field width, and an optional precision specification that begins with a period (e.g., `'6`). The field width includes the digits, decimal point, the exponent, thousands separators (with the digit-grouping flag), and the sign if any of these are shown.

11.2 Flags

The `+` flag causes the output to have a sign (`+` or `−`). The space flag `'` is similar to the `+` flag, except that when the value is positive, it is prefixed with a space rather than a plus sign; this flag is ignored if the `+` flag is also given. The `+` or `'` flag could be useful if conversions might include positive and negative results, and you wanted to align the decimal points in exponential notation. The `#` flag causes the output value to contain a decimal point in all cases; by default, the output contains a decimal point only if there are digits (which can be trailing zeros) to the right of the point. With the `g` or `G` types, the `#` flag also prevents the suppression of trailing zeros. The digit-grouping flag `'` shows a thousands separator in digits to the left of the decimal point. This can be useful when displaying large numbers in fixed-point decimal; for example, with the format `‘%f’`,

You have: mile
You want: microfurlong
* 8000000.000000
/ 0.000000

the magnitude of the first result may not be immediately obvious without counting the digits to the left of the decimal point. If the thousands separator is the comma (`‘,’`), the output with the format `‘%f’` might be

You have: mile
You want: microfurlong
* 8,000,000.000000
Units Conversion

making the magnitude readily apparent. Unfortunately, few compilers support the digit-grouping flag.

With the ‘-’ flag, the output value is left aligned within the specified field width. If a field width greater than needed to show the output value is specified, the ‘0’ (zero) flag causes the output value to be left padded with zeros until the specified field width is reached; for example, with the format ‘%011.6f’,

You have: troy pound
You want: grain
* 5760.000000
/ 0000.000174

The ‘0’ flag has no effect if the ‘-’ (left align) flag is given.

11.3 Field Width

By default, the output value is left aligned and shown with the minimum width necessary for the specified (or default) precision. If a field width greater than this is specified, the value shown is right aligned, and padded on the left with enough spaces to provide the specified field width. A width specification is typically used with fixed-point decimal to have columns of numbers align at the decimal point; this arguably is less useful with units than with long columnar output, but it may nonetheless assist in quickly assessing the relative magnitudes of results. For example, with the format ‘%12.6f’,

You have: km
You want: in
* 39370.078740
/ 0.000025

You have: km
You want: rod
* 198.838782
/ 0.005029

You have: km
You want: furlong
* 4.970970
/ 0.201168

11.4 Precision

The meaning of “precision” depends on the format type. With ‘g’ or ‘G’, it specifies the number of significant digits (like the --digits option); with ‘e’, ‘E’, ‘f’, or ‘F’, it specifies the maximum number of digits to be shown after the decimal point.

With the ‘g’ and ‘G’ format types, trailing zeros are suppressed, so the results may sometimes have fewer digits than the specified precision (as indicated above, the ‘#’ flag causes trailing zeros to be displayed).

The default precision is 6, so ‘%g’ is equivalent to ‘%.6g’, and would show the output to six significant digits. Similarly, ‘%e’ or ‘%f’ would show the output with six digits after the decimal point.
The C \texttt{printf()} function allows a precision of arbitrary size, whether or not all of the digits are meaningful. With most compilers, the maximum internal precision with \texttt{units} is 15 decimal digits (or 13 hexadecimal digits). With the \texttt{--digits} option, you are limited to the maximum internal precision; with the \texttt{--output-format} option, you may specify a precision greater than this, but it may not be meaningful. In some cases, specifying excess precision can result in rounding artifacts. For example, a pound is exactly 7000 grains, but with the format ‘%.18g’, the output might be

You have: pound
You want: grain
* 6999.9999999999991
/ 0.00014285714285714287

With the format ‘%.25g’ you might get the following:

You have: 1/3
You want:
\texttt{Definition: 0.333333333333333314829616256247}

In this case the displayed value includes a series of digits that represent the underlying binary floating-point approximation to 1/3 but are not meaningful for the desired computation. In general, the result with excess precision is system dependent. The precision affects only the \textit{display} of numbers; if a result relies on physical constants that are not known to the specified precision, the number of physically meaningful digits may be less than the number of digits shown.

See the documentation for \texttt{printf()} for more detailed descriptions of the format specification.

The \texttt{--output-format} option is incompatible with the \texttt{--exponential} or \texttt{--digits} options; if the former is given in combination with either of the latter, the format is controlled by the last option given.

\section{12 Localization}

Some units have different values in different locations. The localization feature accommodates this by allowing a units data file to specify definitions that depend on the user’s locale.

\subsection*{12.1 Locale}

A locale is a subset of a user’s environment that indicates the user’s language and country, and some attendant preferences, such as the formatting of dates. The \texttt{units} program attempts to determine the locale from the POSIX setlocale function; if this cannot be done, \texttt{units} examines the environment variables \texttt{LC\_CTYPE} and \texttt{LANG}. On POSIX systems, a locale is of the form \texttt{language\_country}, where \texttt{language} is the two-character code from ISO 639-1 and \texttt{country} is the two-character code from ISO 3166-1; \texttt{language} is lower case and \texttt{country} is upper case. For example, the POSIX locale for the United Kingdom is \texttt{en\_GB}.

On systems running Microsoft Windows, the value returned by \texttt{setlocale()} is different from that on POSIX systems; \texttt{units} attempts to map the Windows value to a POSIX value by means of a table in the file \texttt{locale.map.txt} in the same directory as the other
data files. The file includes entries for many combinations of language and country, and can be extended to include other combinations. The \texttt{locale.map.txt} file comprises two tab-separated columns; each entry is of the form

\begin{verbatim}
Windows-locale   POSIX-locale
\end{verbatim}

where \texttt{POSIX-locale} is as described above, and \texttt{Windows-locale} typically spells out both the language and country. For example, the entry for the United States is

\begin{verbatim}
English_United States   en_US
\end{verbatim}

You can force \texttt{units} to run in a desired locale by using the \texttt{-l} option.

In order to create unit definitions for a particular locale you begin a block of definitions in a unit datafile with ‘\texttt{!locale}’ followed by a locale name. The ‘!’ must be the first character on the line. The \texttt{units} program reads the following definitions only if the current locale matches. You end the block of localized units with ‘\texttt{!endlocale}’. Here is an example, which defines the British gallon.

\begin{verbatim}
!locale en_GB
gallon  4.54609 liter 
!endlocale
\end{verbatim}

\subsection*{12.2 Additional Localization}

Sometimes the locale isn’t sufficient to determine unit preferences. There could be regional preferences, or a company could have specific preferences. Though probably uncommon, such differences could arise with the choice of English customary units outside of English-speaking countries. To address this, \texttt{units} allows specifying definitions that depend on environment variable settings. The environment variables can be controled based on the current locale, or the user can set them to force a particular group of definitions.

A conditional block of definitions in a units data file begins with either ‘\texttt{!var}’ or ‘\texttt{!varnot}’ following by an environment variable name and then a space separated list of values. The leading ‘!’ must appear in the first column of a units data file, and the conditional block is terminated by ‘\texttt{!endvar}’. Definitions in blocks beginning with ‘\texttt{!var}’ are executed only if the environment variable is exactly equal to one of the listed values. Definitions in blocks beginning with ‘\texttt{!varnot}’ are executed only if the environment variable does not equal any of the list values.

The inch has long been a customary measure of length in many places. The word comes from the latin \textit{uncia} meaning “one twelfth,” referring to its relationship with the foot. By the 20th century, the inch was officially defined in English-speaking countries relative to the yard, but until 1959, the yard differed slightly among those countries. In France the customary inch, which was displaced in 1799 by the meter, had a different length based on a french foot. These customary definitions could be accommodated as follows:

\begin{verbatim}
!var INCH_UNIT usa
yard  3600|3937 m
!endvar
!var INCH_UNIT canada
yard  0.9144 meter
!endvar
\end{verbatim}
![var] INCH_UNIT uk
yard 0.91439841 meter
!endvar
![var] INCH_UNIT canada uk usa
foot 1|3 yard
inch 1|12 foot
!endvar
![var] INCH_UNIT france
foot 144|443.296 m
inch 1|12 foot
line 1|12 inch
!endvar
![varnot] INCH_UNIT usa uk france canada
!message Unknown value for INCH_UNIT
!endvar

When units reads the above definitions it will check the environment variable INCH_UNIT and load only the definitions for the appropriate section. If INCH_UNIT is unset or is not set to one of the four values listed then units will run the last block. In this case that block uses the 'message' command to display a warning message. Alternatively that block could set default values.

In order to create default values that are overridden by user settings the data file can use the 'set' command, which sets an environment variable only if it is not already set; these settings are only for the current units invocation and do not persist. So if the example above were preceded by '!set INCH_UNIT france' then this would make 'france' the default value for INCH_UNIT. If the user had set the variable in the environment before invoking units, then units would use the user's value.

To link these settings to the user's locale you combine the 'set' command with the 'locale' command. If you wanted to combine the above example with suitable locales you could do by preceding the above definition with the following:

![locale] en_US
!set INCH_UNIT usa
!endlocale
![locale] en_GB
!set INCH_UNIT uk
!endlocale
![locale] en_CA
!set INCH_UNIT canada
!endlocale
![locale] fr_FR
!set INCH_UNIT france
!endlocale
!set INCH_UNIT france

These definitions set the overall default for INCH_UNIT to 'france' and set default values for four locales appropriately. The overall default setting comes last so that it only applies when INCH_UNIT was not set by one of the other commands or by the user.
If the variable given after ‘!var’ or ‘!varnot’ is undefined then units prints an error message and ignores the definitions that follow. Use ‘!set’ to create defaults to prevent this situation from arising. The -c option only checks the definitions that are active for the current environment and locale, so when adding new definitions take care to check that all cases give rise to a well defined set of definitions.

13 Environment Variables

The units program uses the following environment variables:

**HOME**
Specifies the location of your home directory; it is used by units to find a personal units data file ‘.units’. On systems running Microsoft Windows, the file is ‘unitdef.units’, and if HOME does not exist, units tries to determine your home directory from the HOMEDRIVE and HOMEPATH environment variables; if these variables do not exist, units finally tries USERPROFILE—typically C:\Users\username (Windows Vista and Windows 7) or C:\Documents and Settings\username (Windows XP).

**LC_CTYPE, LANG**
Checked to determine the locale if units cannot obtain it from the operating system. Sections of the standard units data file are specific to certain locales.

**MYUNITSFILE**
Specifies your personal units data file. If this variable exists, units uses its value rather than searching your home directory for ‘.units’. The personal units file will not be loaded if any data files are given using the -f option.

**PAGER**
Specifies the pager to use for help and for displaying the conformable units. The help function browses the units database and calls the pager using the ‘+n’ n syntax for specifying a line number. The default pager is more; PAGER can be used to specify alternatives such as less, pg, emacs, or vi.

**UNITS_ENGLISH**
Set to either ‘US’ or ‘GB’ to choose United States or British volume definitions, overriding the default from your locale.

**UNITSFILE**
Specifies the units data file to use (instead of the default). You can only specify a single units data file using this environment variable. If units data files are given using the -f option, the file specified by UNITSFILE will be not be loaded unless the -f option is given with the empty string (‘units -f ””’).

**UNITSLOCALEMAP**
Windows only; this variable has no effect on Unix-like systems. Specifies the units locale map file to use (instead of the default). This variable seldom needs to be set, but you can use it to ensure that the locale map file will be found if you specify a location for the units data file using either the -f option or the UNITSFILE environment variable, and that location does not also contain the locale map file.
14 Data Files

The `units` program uses two default data files: `definitions.units` and `currency.units`. The program can also use an optional personal units data file `.units (unitdef.units under Windows) located in the user's home directory. The personal units data file is described in more detail in Section 10.1 [Units Data Files], page 25.

On Unix-like systems, the data files are typically located in `/usr/share/units` if `units` is provided with the operating system, or in `/usr/local/share/units` if `units` is compiled from the source distribution.

On systems running Microsoft Windows, the files may be in the same locations if Unix-like commands are available, a Unix-like file structure is present (e.g., `C:/usr/local`), and `units` is compiled from the source distribution. If Unix-like commands are not available, a more common location is `C:\Program Files (x86)\GNU\units` (for 64-bit Windows installations) or `C:\Program Files\GNU\units` (for 32-bit installations).

If `units` is obtained from the GNU Win32 Project (http://gnuwin32.sourceforge.net/), the files are commonly in `C:\Program Files\GnuWin32\share\units`.

If the default units data file is not an absolute pathname, `units` will look for the file in the directory that contains the `units` program; if the file is not found there, `units` will look in a directory `../share/units` relative to the directory with the `units` program.

You can determine the location of the files by running `units --version`. Running `units --info` will give you additional information about the files, how `units` will attempt to find them, and the status of the related environment variables.

15 Unicode Support

The standard units data file is in Unicode, using UTF-8 encoding. Most definitions use only ASCII characters (i.e., code points U+0000 through U+007F); definitions using non-ASCII characters appear in blocks beginning with `!utf8` and ending with `!endutf8`.

When `units` starts, it checks the locale to determine the character set. If `units` is compiled with Unicode support and definitions; otherwise these definitions are ignored. When Unicode support is active, `units` will check every line of all of the units data files for invalid or non-printing UTF-8 sequences; if such sequences occur, `units` ignores the entire line. In addition to checking validity, `units` determines the display width of non-ASCII characters to ensure proper positioning of the pointer in some error messages and to align columns for the `search` and `?` commands.

At present, `units` does not support Unicode under Microsoft Windows. The UTF-16 and UTF-32 encodings are not supported on any systems.

If definitions that contain non-ASCII characters are added to a units data file, those definitions should be enclosed within `!utf8` ... `!endutf8` to ensure that they are only loaded when Unicode support is available. As usual, the `!` must appear as the first character on the line. As discussed in Section 10.1 [Units Data Files], page 25, it's usually best to put such definitions in supplemental data files linked by an `!include` command or in a personal units data file.
When Unicode support is not active, `units` makes no assumptions about character encoding, except that characters in the range 00–7F hexadecimal correspond to ASCII encoding. Non-ASCII characters are simply sequences of bytes, and have no special meanings; for definitions in supplementary units data files, you can use any encoding consistent with this assumption. For example, if you wish to use non-ASCII characters in definitions when running `units` under Windows, you can use a character set such as Windows “ANSI” (code page 1252 in the US and Western Europe). You can even use UTF-8, though some messages may be improperly aligned, and `units` will not detect invalid UTF-8 sequences. If you use UTF-8 encoding when Unicode support is not active, you should place any definitions with non-ASCII characters outside `!utf8` . . . `!endutf8` blocks—otherwise, they will be ignored.

Typeset material other than code examples usually uses the Unicode minus (U+2212) rather than the ASCII hyphen-minus operator (U+002D) used in `units`; the figure dash (U+002D) and en dash (U+2013) are also occasionally used. To allow such material to be copied and pasted for interactive use or in units data files, `units` converts these characters to U+002D before further processing. Because of this, none of these characters can appear in unit names.

## 16 Readline Support

If the `readline` package has been compiled in, then when `units` is used interactively, numerous command line editing features are available. To check if your version of `units` includes `readline`, invoke the program with the `--version` option.

For complete information about `readline`, consult the documentation for the `readline` package. Without any configuration, `units` will allow editing in the style of `emacs`. Of particular use with `units` are the completion commands.

If you type a few characters and then hit `ESC` followed by `?` then `units` will display a list of all the units that start with the characters typed. For example, if you type `metr` and then request completion, you will see something like this:

```
You have: metr
metre  metriccup  metrichorsepower  metrictenth
metretes  metricfifth  metricounce  metricton
metriccarat  metricgrain  metricquart  metricyarncount
You have: metr
```

If there is a unique way to complete a unitname, you can hit the `TAB` key and `units` will provide the rest of the unit name. If `units` beeps, it means that there is no unique completion. Pressing the `TAB` key a second time will print the list of all completions.

The readline library also keeps a history of the values you enter. You can move through this history using the up and down arrows. The history is saved to the file `.units_history` in your home directory so that it will persist across multiple `units` invocations. If you wish to keep work for a certain project separate you can change the history filename using the `--history` option. You could, for example, make an alias for `units` to `units --history .units_history` so that `units` would save separate history in the current directory. The length of each history file is limited to 5000 lines. Note also that if you run several concurrent copies of `units` each one will save its new history to the history file upon exit.
17 Updating Currency Exchange Rates

The units program includes currency exchange rates and prices for some precious
metals in the database. Of course, these values change over time, sometimes very
rapidly, and units cannot provide real time values. To update the exchange rates
run the units_cur, which rewrites the files containing the currency rates, typically
/usr/share/units/currency.units. This program requires python and the unidecode
package, and must be run with suitable permissions to write the file. To keep the
rates updated automatically, run it using a cron job on a Unix-like system, or a similar
scheduling program on a different system. Currency exchange rates are taken from Time
Genie (http://www.timegenie.com) and precious metals pricing from Packetizer (www.
packetizer.com). These sites update once per day, so there is no benefit in running the
update script more often than daily. You can run units_cur with a filename specified on
the command line and it will write the data to that file. If you give ‘-’ for the file it will
write to standard output.

18 Database Command Syntax

unit definition
   Define a regular unit.

prefix- definition
   Define a prefix.

funcname(var) noerror units=[in-units,out-units] domain=[x1,x2]
range=[y1,y2] definition(var) ; inverse(funcname)
   Define a nonlinear unit or unit function. The four optional keywords noerror,
   units=, range= and domain= can appear in any order. The definition of the
   inverse is optional.

tabname[out-units] noerror pair-list
   Define a piecewise linear unit. The pair list gives the points on the table listed
   in ascending order. The noerror keyword is optional.

!endlocale
   End a block of definitions beginning with ‘!locale’

!endutf8
   End a block of definitions begun with ‘!utf8’

!endvar
   End a block of definitions begun with ‘!var’ or ‘!varnot’

!include file
   Include the specified file.

!locale value
   Load the following definitions only of the locale is set to value.

!message text
   Display text when the database is read unless the quiet option (-q) is enabled.

!set variable value
   Sets the environment variable, variable, to the specified value only if it is not
   already set.
!unitlist alias definition
  Define a unit list alias.

!utf8
  Load the following definitions only if units is running with UTF-8 enabled.

!var envar value-list
  Load the block of definitions that follows only if the environment variable envar
  is set to one of the values listed in the space-separated value list. If envar is
  not set, units prints an error message and ignores the block of definitions.

!varnot envar value-list
  Load the block of definitions that follows only if the environment variable envar
  is set to value that is not listed in the space-separated value list. If envar is not
  set, units prints an error message and ignores the block of definitions.

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Index

! 13
    ‘!’ to indicate primitive units ................. 26
    ‘-’ as multiplication operator .................. 12
    ‘-’ as subtraction operator ...................... 8
    ‘--check (option for units)’ ..................... 8
    ‘--check-verbose (option for units)’ ............ 21
    ‘--compact (option for units)’ .................. 23
    ‘--digits (option for units)’ .................... 21
    ‘--exponential (option for units)’ .......... 22
    ‘--file (option for units)’ ...................... 22, 23
    ‘--help (option for units)’ ..................... 23
    ‘--info (option for units)’ ..................... 25
    ‘--locale (option for units)’ .................... 25
    ‘--log (option for units)’ ....................... 23
    ‘--minus (option for units)’ .................... 23
    ‘--newstar (option for units)’ ................ 23
    ‘--oldstar (option for units)’ .................. 23
    ‘--one-line (option for units)’ ............... 24
    ‘--output-format (option for units)’ .......... 22
    ‘--product (option for units)’ ................. 23
    ‘--quiet (option for units)’ .................... 23
    ‘--silent (option for units)’ ................. 23
    ‘--strict (option for units)’ ................. 24
    ‘--terse (option for units)’ ................... 24
    ‘--unitsfile (option for units)’ ............. 24
    ‘--verbose (option for units)’ ............... 24
    ‘--verbose-check (option for units)’ ........ 21
    ‘--version (option for units)’ ............... 24
    ‘-1 (option for units)’ ......................... 24

*  8
    ‘*’ operator ...................................... 6
    ‘**’ operator .................................... 7

+ 12
    ‘+’ operator ...................................... 8

-  8
    ‘-’ operator ...................................... 8
-c (option for units) .......................... 21
-d (option for units) .......................... 21
-e (option for units) .......................... 22
-f (option for units) .......................... 22, 23
-h (option for units) .......................... 23
-I (option for units) .......................... 25
-l (option for units) .......................... 25
-L (option for units) .......................... 23
-m (option for units) .......................... 23
-o (option for units) .......................... 22
-p (option for units) .......................... 23
-q (option for units) .......................... 23
-s (option for units) .......................... 24
-t (option for units) .......................... 24
-U (option for units) .......................... 25
-v (option for units) .......................... 24
-V (option for units) .......................... 24

? ............................. 39
? for unit completion with readline ............................. 39
? to show conformable units ............................. 3

- ............................. 10
- to use result of previous conversion ............................. 10

| ............................. 7
| 'I' operator ............................. 7

A
abrasive grit size ............................. 14
addition of units ............................. 8
additional units data files ............................. 25

B
backwards compatibility ............................. 12
British Imperial measure ............................. 5

circle, area of ............................. 14
cmd, '!' to indicate primitive units ............................. 26
cmd, '!endlocale' ............................. 34
cmd, '!endutf8' ............................. 38
cmd, '!endvar' ............................. 34
cmd, '!include' ............................. 25
cmd, '!locale' ............................. 34
cmd, '!message' ............................. 34
cmd, '!set' ............................. 34
cmd, '!unitlist' ............................. 31
cmd, '!utf8' ............................. 38
cmd, '!var' ............................. 34
cmd, '!varnot' ............................. 34
cmd-line options ............................. 20
cmd-line unit conversion ............................. 4
commands in units database ............................. 40
compatibility ............................. 12
compatibility with earlier versions ............................. 12
completion, unit, using '?' (readline only) ............................. 39
conformable units, '?' to show ............................. 3
currency, updating ............................. 40

D
Darcy–Weisbach equation ............................. 11
data files ............................. 38
data files, additional ............................. 25
database syntax summary ............................. 40
defining nonlinear units ............................. 27
defining piecewise linear units ............................. 29
defining prefixes ............................. 26
defining unit list aliases ............................. 31
defining units ............................. 26
defining units with '-1' ............................. 12
differences of units ............................. 8
dimensionless units ............................. 3
dimensionless units, defining ............................. 26
division of numbers ............................. 7
division of units ............................. 6
domain, nonlinear unit definitions ............................. 28

e
environment dependent definitions ............................. 34
environment variable, HOME ............................. 37
environment variable, LANG ............................. 37
environment variable, LC_CTYPE ............................. 37
environment variable, MYUNITSFILE ............................. 26, 37
environment variable, PAGER ............................. 37
environment variable, UNITS_ENGLISH ............................. 37
environment variable, UNITSFILE ............................. 37
environment variable, UNITSLOCALEMAP ............................. 37
environment variables ............................. 37
exchange rates, updating ............................. 40
exponent operator ............................. 7

F
files, data ............................. 38
flags, output format ............................. 32
format specification, output ............................. 32
fractions, numerical ............................. 7
functions of units ............................. 29
functions, built in ............................. 9

H
help ............................. 3, 37
HOME environment variable ............................. 37
hyphen as multiplication operator ............................. 12
I
Imperial measure ........................................... 5
include files ............................................. 26
including additional units data files ............... 25
incompatible units ......................................... 3
interactive use ........................................... 1
international mile ......................................... 5
international yard ......................................... 5
invoking units ............................................ 20

M
measure, Imperial .......................................... 5
mile, international ......................................... 5
minus (’-’) operator, subtraction ....................... 8
multiplication of units .................................... 6
multiplication, hyphen ..................................... 12
MYUNITSFILE environment variable ................. 26, 37

N
non-conformable units ....................................... 3
non-interactive unit conversion ......................... 4
nonlinear unit conversions ................................ 12, 27
nonlinear units, defining .................................. 27
nonlinear units, other ....................................... 14
numbers as units ............................................ 9
numeric output format ..................................... 31
numerical fractions ......................................... 7

O
operator precedence ........................................ 6
operator, (’**’) ........................................... 7
operator, caret (’^’) ....................................... 7
operator, hyphen (’-’) as multiplication ............. 12
operator, hyphen (’-’) as subtraction .................. 8
operator, minus (’-’) ...................................... 8
operator, ‘per’ ........................................... 6
operator, plus (+) .......................................... 8
operator, slash (’/’) ........................................ 6
operator, solidus (’/’) ...................................... 6
operator, space ............................................ 6
operator, star (*) .......................................... 6
operator, vertical bar (’|’) ............................... 7
operators .................................................... 6
output field width ........................................ 33
output format ............................................. 31
output format flags ........................................ 32
output format specification ............................. 32
output precision .......................................... 33

P
PAGER environment variable ......................... 37
parentheses ................................................. 6, 7, 8, 11, 26, 27
‘per’ operator .............................................. 6
personal units data file .................................. 25
piecewise linear units .................................... 29
plus (’+’) operator ........................................ 8
powers ....................................................... 7
precision, output .......................................... 33
prefixes ...................................................... 5
prefixes and exponents ................................... 7
prefixes, definition ....................................... 26
previous result ............................................ 10
primitive units ............................................ 26
products of units .......................................... 6
quotients of units ......................................... 6
range, nonlinear unit definitions ....................... 28
readline, use with units .................................. 39
reciprocal conversion .................................... 2
roots .......................................................... 9
setlocale function ......................................... 34
slash (’/’) operator ........................................ 6
solidus (’/’) operator ..................................... 6
sphere, volume of ......................................... 14
square roots ............................................... 9
star (’*’) operator ......................................... 6
State Plane Coordinate System, US .................... 5
strict conversion .......................................... 2
subtraction of units ....................................... 8
sums and differences of units ......................... 8
sums of units .............................................. 8, 15
survey foot, US ............................................ 5
survey measure, US ....................................... 5
survey mile, US ............................................ 5
syntax of units database .................................. 40
temperature conversions .................................. 13

S
setlocale function ......................................... 34
slash (’/’) operator ........................................ 6
solidus (’/’) operator ..................................... 6
sphere, volume of ......................................... 14
square roots ............................................... 9
star (’*’) operator ......................................... 6
State Plane Coordinate System, US .................... 5
strict conversion .......................................... 2
subtraction of units ....................................... 8
sums and differences of units ......................... 8
sums of units .............................................. 8, 15
survey foot, US ............................................ 5
survey measure, US ....................................... 5
survey mile, US ............................................ 5
syntax of units database .................................. 40

temperature conversions .................................. 13
U
Unicode support ..................................... 38
unit completion using ‘?’ (readline only) ...... 39
unit definitions...................................... 4
unit expressions.................................... 6
unit expressions, complicated..................... 11
unit list aliases, defining.......................... 31
unit lists............................................. 15
unit name completion................................. 39
units data file, personal............................ 25
units data files, additional......................... 25
units definitions, adding............................ 26
units definitions, changing......................... 26
units functions..................................... 29
units quotients...................................... 6
units, definition of................................ 26
units, lookup method................................. 5
units, piecewise linear............................... 29
units, primitive..................................... 26
units, sums and differences......................... 8
units, sums of..................................... 15
UNITS_ENGLISH environment variable......... 37
UNITSFILE environment variable............... 37
UNITSLOCALEMAP environment variable..... 37
US State Plane Coordinate System.............. 5
US survey foot.................................... 5
US survey measure................................ 5
US survey mile.................................... 5
UTF-8................................................ 38
V
verbose output..................................... 2
vertical bar (‘|’) operator......................... 7
volume measure, English customary............. 5
W
wire gauge........................................ 14
Y
yard, international................................. 5