Lexical analysis

A Python program is read by a *parser*. Input to the parser is a stream of *tokens*, generated by the *lexical analyzer*. This chapter describes how the lexical analyzer breaks a file into tokens.

Python uses the 7-bit ASCII character set for program text.

For compatibility with older versions, Python only warns if it finds 8-bit characters; those warnings should be corrected by either declaring an explicit encoding, or using escape sequences if those bytes are binary data, instead of characters.

The run-time character set depends on the I/O devices connected to the program but is generally a superset of ASCII.

Future compatibility note: It may be tempting to assume that the character set for 8-bit characters is ISO Latin-1 (an ASCII superset that covers most western languages that use the Latin alphabet), but it is possible that in the future Unicode text editors will become common. These generally use the UTF-8 encoding, which is also an ASCII superset, but with very different use for the characters with ordinals 128-255. While there is no consensus on this subject yet, it is unwise to assume either Latin-1 or UTF-8, even though the current implementation appears to favor Latin-1. This applies both to the source character set and the run-time character set.

Line structure

A Python program is divided into a number of *logical lines*.

Logical lines

The end of a logical line is represented by the token NEWLINE. Statements cannot cross logical line boundaries except where NEWLINE is allowed by the syntax (e.g., between statements in compound statements). A logical line is constructed from one or more *physical lines* by following the explicit or implicit *line joining* rules.

Physical lines

A physical line is a sequence of characters terminated by an end-of-line sequence. In source files, any of the standard platform line termination sequences can be used - the Unix form using ASCII LF (linefeed), the Windows form using the ASCII sequence CR LF (return followed by linefeed), or the old Macintosh form using the ASCII CR (return) character. All of these forms can be used equally, regardless of platform.

When embedding Python, source code strings should be passed to Python APIs using the standard C conventions for newline characters (the `\n` character, representing ASCII LF, is the line terminator).

Comments

A comment starts with a hash character (`#`) that is not part of a string literal, and ends at the end of the physical line. A comment signifies the end of the logical line unless the implicit line joining rules are invoked. Comments are ignored by the syntax; they are not tokens.

Encoding declarations

If a comment in the first or second line of the Python script matches the regular expression `coding[=:]\s*([-\w.]+)`, this comment is processed as an encoding declaration; the first group of this expression names the encoding of the source code file. The recommended forms of this expression are

```
# -*- coding: <encoding-name> -*-
```

which is recognized also by GNU Emacs, and

```
# vim:fileencoding=<encoding-name>
```

which is recognized by Bram Moolenaar's VIM. In addition, if the first bytes of the file are the UTF-8 byte-order mark (`'\xef\xbb\xbf'`), the declared file encoding is UTF-8 (this is supported, among others, by Microsoft's :program:`notepad`).

If an encoding is declared, the encoding name must be recognized by Python. The encoding is used for all lexical analysis, in particular to find the end of a string, and to interpret the contents of Unicode literals. String literals are converted to Unicode for syntactical analysis, then converted back to their original encoding before interpretation starts. The encoding declaration must appear on a line of its own.

Explicit line joining

Two or more physical lines may be joined into logical lines using backslash characters (`\`), as follows: when a physical line ends in a backslash that is not part of a string literal or comment, it is joined with the following forming a single logical line, deleting the backslash and the following end-of-line character. For example:

```
if 1900 < year < 2100 and 1 <= month <= 12 \
   and 1 <= day <= 31 and 0 <= hour < 24 \
   and 0 <= minute < 60 and 0 <= second < 60:   # Looks like a valid date
        return 1
```

A line ending in a backslash cannot carry a comment. A backslash does not continue a comment. A backslash does not continue a token except for string literals (i.e., tokens other than string literals cannot be split across physical lines using a backslash). A backslash is illegal elsewhere on a line outside a string literal.

Implicit line joining

Expressions in parentheses, square brackets or curly braces can be split over more than one physical line without using backslashes. For example:

```
month_names = ['Januari', 'Februari', 'Maart',      # These are the
               'April',   'Mei',      'Juni',       # Dutch names
               'Juli',    'Augustus', 'September',  # for the months
               'Oktober', 'November', 'December']   # of the year
```

Implicitly continued lines can carry comments. The indentation of the continuation lines is not important. Blank continuation lines are allowed. There is no NEWLINE token between implicit continuation lines. Implicitly continued lines can also occur within triple-quoted strings (see below); in that case they cannot carry comments.

Blank lines

A logical line that contains only spaces, tabs, formfeeds and possibly a comment, is ignored (i.e., no NEWLINE token is generated). During interactive input of statements, handling of a blank line may differ depending on the implementation of the read-eval-print loop. In the standard implementation, an entirely blank logical line (i.e. one containing not even whitespace or a comment) terminates a multi-line statement.

Indentation

Leading whitespace (spaces and tabs) at the beginning of a logical line is used to compute the indentation level of the line, which in turn is used to determine the grouping of statements.

First, tabs are replaced (from left to right) by one to eight spaces such that the total number of characters up to and including the replacement is a multiple of eight (this is intended to be the same rule as used by Unix). The total number of spaces preceding the first non-blank character then determines the line's indentation. Indentation cannot be split over multiple physical lines using backslashes; the whitespace up to the first backslash determines the indentation.

Cross-platform compatibility note: because of the nature of text editors on non-UNIX platforms, it is unwise to use a mixture of spaces and tabs for the indentation in a single source file. It should also be noted that different platforms may explicitly limit the maximum indentation level.

A formfeed character may be present at the start of the line; it will be ignored for the indentation calculations above. Formfeed characters occurring elsewhere in the leading whitespace have an undefined effect (for instance, they may reset the space count to zero).

The indentation levels of consecutive lines are used to generate INDENT and DEDENT tokens, using a stack, as follows.

Before the first line of the file is read, a single zero is pushed on the stack; this will never be popped off again. The numbers pushed on the stack will always be strictly increasing from bottom to top. At the beginning of each logical line, the line's indentation level is compared to the top of the stack. If it is equal, nothing happens. If it is larger, it is pushed on the stack, and one INDENT token is generated. If it is smaller, it *must* be one of the numbers occurring on the stack; all numbers on the stack that are larger are popped off, and for each number popped off a DEDENT token is generated. At the end of the file, a DEDENT token is generated for each number remaining on the stack that is larger than zero.

Here is an example of a correctly (though confusingly) indented piece of Python code:

```
def perm(l):
        # Compute the list of all permutations of l
    if len(l) <= 1:
                  return [l]
    r = []
    for i in range(len(l)):
             s = l[:i] + l[i+1:]
             p = perm(s)
             for x in p:
              r.append(l[i:i+1] + x)
    return r
```

The following example shows various indentation errors:

```
 def perm(l):                       # error: first line indented
for i in range(len(l)):             # error: not indented
    s = l[:i] + l[i+1:]
        p = perm(l[:i] + l[i+1:])   # error: unexpected indent
        for x in p:
                r.append(l[i:i+1] + x)
            return r                # error: inconsistent dedent
```

(Actually, the first three errors are detected by the parser; only the last error is found by the lexical analyzer --- the indentation of `return r` does not match a level popped off the stack.)

Whitespace between tokens

Except at the beginning of a logical line or in string literals, the whitespace characters space, tab and formfeed can be used interchangeably to separate tokens. Whitespace is needed between two tokens only if their concatenation could otherwise be interpreted as a different token (e.g., ab is one token, but a b is two tokens).

Other tokens

Besides NEWLINE, INDENT and DEDENT, the following categories of tokens exist: *identifiers*, *keywords*, *literals*, *operators*, and *delimiters*. Whitespace characters (other than line terminators, discussed earlier) are not tokens, but serve to delimit tokens. Where ambiguity exists, a token comprises the longest possible string that forms a legal token, when read from left to right.

Identifiers and keywords

Identifiers (also referred to as *names*) are described by the following lexical definitions:

Identifiers are unlimited in length. Case is significant.

Keywords

The following identifiers are used as reserved words, or *keywords* of the language, and cannot be used as ordinary identifiers. They must be spelled exactly as written here:

```
and       del       from      not       while
as        elif      global    or        with
assert    else      if        pass      yield
break     except    import    print
class     exec      in        raise
continue  finally   is        return
def       for       lambda    try
```

Reserved classes of identifiers

Certain classes of identifiers (besides keywords) have special meanings. These classes are identified by the patterns of leading and trailing underscore characters:

`_*`
Not imported by `from module import *`. The special identifier `_` is used in the interactive interpreter to store the result of the last evaluation; it is stored in the :mod:`__builtin__` module. When not in interactive mode, `_` has no special meaning and is not defined. See section :ref:`import`.

Note

The name `_` is often used in conjunction with internationalization; refer to the documentation for the :mod:`gettext` module for more information on this convention.

`__*__`
System-defined names. These names are defined by the interpreter and its implementation (including the standard library); applications should not expect to define additional names using this convention. The set of names of this class defined by Python may be extended in future versions. See section :ref:`specialnames`.

`__*`
Class-private names. Names in this category, when used within the context of a class definition, are re-written to use a mangled form to help avoid name clashes between "private" attributes of base and derived classes. See section :ref:`atom-identifiers`.

Literals

Literals are notations for constant values of some built-in types.

String literals

String literals are described by the following lexical definitions:

One syntactic restriction not indicated by these productions is that whitespace is not allowed between the :token:`stringprefix` and the rest of the string literal. The source character set is defined by the encoding declaration; it is ASCII if no encoding declaration is given in the source file; see section :ref:`encodings`.

In plain English: String literals can be enclosed in matching single quotes (`'`) or double quotes (`"`). They can also be enclosed in matching groups of three single or double quotes (these are generally referred to as *triple-quoted strings*). The backslash (`\`) character is used to escape characters that otherwise have a special meaning, such as newline, backslash itself, or the quote character. String literals may optionally be prefixed with a letter `'r'` or `'R'`; such strings are called :dfn:`raw strings` and use different rules for interpreting backslash escape sequences. A prefix of `'u'` or `'U'` makes the string a Unicode string. Unicode strings use the Unicode character set as defined by the Unicode Consortium and ISO 10646. Some additional escape sequences, described below, are available in Unicode strings. The two prefix characters may be combined; in this case, `'u'` must appear before `'r'`.

In triple-quoted strings, unescaped newlines and quotes are allowed (and are retained), except that three unescaped quotes in a row terminate the string. (A "quote" is the character used to open the string, i.e. either `'` or `"`.)

Unless an `'r'` or `'R'` prefix is present, escape sequences in strings are interpreted according to rules similar to those used by Standard C. The recognized escape sequences are:

Escape Sequence	Meaning	Notes
`\newline`	Ignored	
`\\`	Backslash (`\`)	
`\'`	Single quote (`'`)	
`\"`	Double quote (`"`)	

Escape Sequence	Meaning	Notes
`\a`	ASCII Bell (BEL)	
`\b`	ASCII Backspace (BS)	
`\f`	ASCII Formfeed (FF)	
`\n`	ASCII Linefeed (LF)	
`\N{name}`	Character named *name* in the Unicode database (Unicode only)	
`\r`	ASCII Carriage Return (CR)	
`\t`	ASCII Horizontal Tab (TAB)	
`\uxxxx`	Character with 16-bit hex value *xxxx* (Unicode only)	(1)
`\Uxxxxxxxx`	Character with 32-bit hex value *xxxxxxxx* (Unicode only)	(2)
`\v`	ASCII Vertical Tab (VT)	
`\ooo`	Character with octal value *ooo*	(3,5)
`\xhh`	Character with hex value *hh*	(4,5)

Notes:

1. Individual code units which form parts of a surrogate pair can be encoded using this escape sequence.
2. Any Unicode character can be encoded this way, but characters outside the Basic Multilingual Plane (BMP) will be encoded using a surrogate pair if Python is compiled to use 16-bit code units (the default). Individual code units which form parts of a surrogate pair can be encoded using this escape sequence.
3. As in Standard C, up to three octal digits are accepted.
4. Unlike in Standard C, exactly two hex digits are required.
5. In a string literal, hexadecimal and octal escapes denote the byte with the given value; it is not necessary that the byte encodes a character in the source character set. In a Unicode literal, these escapes denote a Unicode character with the given value.

Unlike Standard C, all unrecognized escape sequences are left in the string unchanged, i.e., *the backslash is left in the string*. (This behavior is useful when debugging: if an escape sequence is mistyped, the resulting output is more easily recognized as broken.) It is also important to note that the escape sequences marked as "(Unicode only)" in the table above fall into the category of unrecognized escapes for non-Unicode string literals.

When an `'r'` or `'R'` prefix is present, a character following a backslash is included in the string without change, and *all backslashes are left in the string*. For example, the string literal `r"\n"` consists of two characters: a backslash and a lowercase `'n'`. String quotes can be escaped with a backslash, but the backslash remains in the string; for example, `r"\""` is a valid string literal consisting of two characters: a backslash and a double quote; `r"\"` is not a valid string literal (even a raw string cannot end in an odd number of backslashes). Specifically, *a raw string cannot end in a single backslash* (since the backslash would escape the following quote character). Note also that a single backslash followed by a newline is interpreted as those two characters as part of the string, *not* as a line continuation.

When an `'r'` or `'R'` prefix is used in conjunction with a `'u'` or `'U'` prefix, then the `\uxxxx` and `\Uxxxxxxxx` escape sequences are processed while *all other backslashes are left in the string*. For example, the string literal `ur"\u0062\n"` consists of three Unicode characters: 'LATIN SMALL LETTER B', 'REVERSE SOLIDUS', and 'LATIN SMALL LETTER N'. Backslashes can be escaped with a preceding backslash; however, both remain in the string. As a result, `\uxxxx` escape sequences are only recognized when there are an odd number of backslashes.

String literal concatenation

Multiple adjacent string literals (delimited by whitespace), possibly using different quoting conventions, are allowed, and their meaning is the same as their concatenation. Thus, `"hello" 'world'` is equivalent to `"helloworld"`. This feature can be used to reduce the number of backslashes needed, to split long strings conveniently across long lines, or even to add comments to parts of strings, for example:

```
re.compile("[A-Za-z_]"       # letter or underscore
           "[A-Za-z0-9_]*"   # letter, digit or underscore
          )
```

Note that this feature is defined at the syntactical level, but implemented at compile time. The '+' operator must be used to concatenate string expressions at run time. Also note that literal concatenation can use different quoting styles for each component (even mixing raw strings and triple quoted strings).

Numeric literals

There are four types of numeric literals: plain integers, long integers, floating point numbers, and imaginary numbers. There are no complex literals (complex numbers can be formed by adding a real number and an imaginary number).

Note that numeric literals do not include a sign; a phrase like `-1` is actually an expression composed of the unary operator ' `-` ' and the literal `1`.

Integer and long integer literals

Integer and long integer literals are described by the following lexical definitions:

Although both lower case `'l'` and upper case `'L'` are allowed as suffix for long integers, it is strongly recommended to always use `'L'`, since the letter `'l'` looks too much like the digit `'1'`.

Plain integer literals that are above the largest representable plain integer (e.g., 2147483647 when using 32-bit arithmetic) are accepted as if they were long integers instead. [1] There is no limit for long integer literals apart from what can be stored in available memory.

Some examples of plain integer literals (first row) and long integer literals (second and third rows):

```
7     2147483647                        0177
3L    79228162514264337593543950336L    0377L   0x100000000L
      79228162514264337593543950336             0xdeadbeef
```

Floating point literals

Floating point literals are described by the following lexical definitions:

Note that the integer and exponent parts of floating point numbers can look like octal integers, but are interpreted using radix 10. For example, `077e010` is legal, and denotes the same number as `77e10`. The allowed range of floating point literals is implementation-dependent. Some examples of floating point literals:

```
3.14    10.    .001    1e100    3.14e-10    0e0
```

Note that numeric literals do not include a sign; a phrase like `-1` is actually an expression composed of the unary operator `-` and the literal `1`.

Imaginary literals

Imaginary literals are described by the following lexical definitions:

An imaginary literal yields a complex number with a real part of 0.0. Complex numbers are represented as a pair of floating point numbers and have the same restrictions on their range. To create a complex number with a nonzero real part, add a floating point number to it, e.g., `(3+4j)`. Some examples of imaginary literals:

```
3.14j   10.j    10j     .001j   1e100j  3.14e-10j
```

Operators

The following tokens are operators:

```
+       -       *       **      /       //      %
<<      >>      &       |       ^       ~
<       >       <=      >=      ==      !=      <>
```

The comparison operators `<>` and `!=` are alternate spellings of the same operator. `!=` is the preferred spelling; `<>` is obsolescent.

Delimiters

The following tokens serve as delimiters in the grammar:

```
(       )       [       ]       {       }       @
,       :       .       `       =       ;
+=      -=      *=      /=      //=     %=
&=      |=      ^=      >>=     <<=     **=
```

The period can also occur in floating-point and imaginary literals. A sequence of three periods has a special meaning as an ellipsis in slices. The second half of the list, the augmented assignment operators, serve lexically as delimiters, but also perform an operation.

The following printing ASCII characters have special meaning as part of other tokens or are otherwise significant to the lexical analyzer:

```
'       "       #       \
```

The following printing ASCII characters are not used in Python. Their occurrence outside string literals and comments is an unconditional error:

```
$       ?
```

Footnotes

[1]	In versions of Python prior to 2.4, octal and hexadecimal literals in the range just above the largest representable plain integer but below the largest unsigned 32-bit number (on a machine using 32-bit arithmetic), 4294967296, were taken as the negative plain integer obtained by subtracting 4294967296 from their unsigned value.