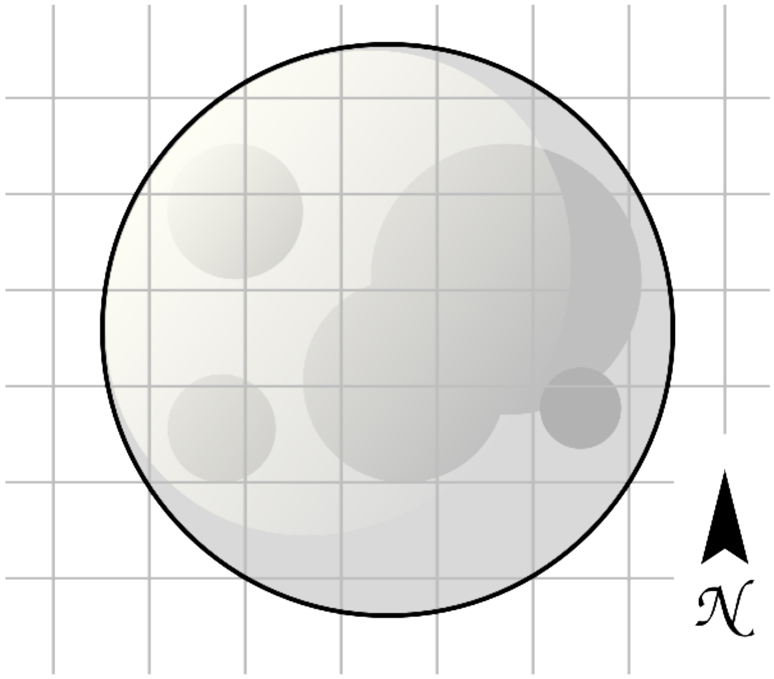
Covers Lua 5.4, 5.3, 5.2, and 5.1!

Lua Quick Reference

A small, fast, powerful, and embeddable language



Second Edition

Mitchell

Lua Quick Reference

Lua is a small, fast, powerful, and embeddable scripting language. It is well-suited for use in video games, application scripting, embedded devices, and nearly anywhere else a scripting language is needed. This quick reference contains a wealth of knowledge on how to program in and embed Lua, whether it is Lua 5.4, 5.3, 5.2, or 5.1. It groups the language's features and C API in a convenient and easy-to-use manner, while clearly marking the differences between Lua versions.

This book covers:

- Lua syntax, expressions, and statements
- Metatables and metamethods
- Object-oriented programming with Lua
- Creating and working with Lua and C Modules
- Lua's standard library and its C API
- Collaborative multi-threading in Lua and C
- How to embed and use Lua within a host
- And much more

Mitchell commands more than 15 years of experience programming and embedding Lua in both the corporate and open-source realms.

Triple Quasar Books

SECOND EDITION

Lua
Quick Reference

Mitchell

Lua Quick Reference
by Mitchell

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Editor: Ana Balan
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Indexer: Mitchell

Printing history:
July 2017: First Edition
May 2020: Second Edition

ISBN: 978-0-9912379-5-1

Preface to the Second Edition

This book is an updated version of *Lua Quick Reference* and covers many of the features, changes, and incompatibilities introduced in Lua 5.4. Among the new content contained in this edition:

- Local variable attributes, including const and to-be-closed variables.
- Defining to-be-closed variable behavior.
- Lua's new warning system.
- The improved random number generator.
- Changes to Lua's string and thread facilities.
- Compiling Lua programs.
- More details about user values in the Lua C API.
- Various Lua C API additions and changes, including incompatible changes to the threading API.

The book's code examples have also been updated to use Lua 5.4 where applicable.

Contents

Introduction

Lua[1] is a small, fast, powerful, and embeddable scripting language. It is well-suited for use in video games, application scripting, embedded devices, and nearly anywhere else a scripting language is needed.

Weighing in at just 400KB in compiled size and comprising less than 15,000 lines of highly portable ISO (ANSI) C source code, Lua is a very small language that compiles unmodified on nearly any platform with a C compiler. Many independent benchmarks recognize Lua as one of the fastest scripting languages available. Not only is Lua small and fast, but it is also powerful. With dynamic typing, lexical scoping, first-class functions, collaborative multi-threading, automatic memory management, and an incredibly flexible data structure, Lua is a truly effective object-oriented language, functional language, and data-driven language.

In addition to its assets of size, speed, and power, Lua's primary strength is that it is an embedded language. Lua is implemented as a C library, so a host program can use Lua's C Application Programming Interface (C API) to initialize and interact with a Lua interpreter, define global variables, register C functions that Lua can call, call user-defined Lua functions, and execute arbitrary Lua code. (In fact, Lua's stand-alone interpreter is just a C application that makes use of the Lua library and its C API.) This tight coupling between Lua and its host allows each language to leverage its own strengths: C's raw speed and ability to interact with third-party software, and Lua's flexibility, rapid prototyping, and ease of use.

Lua Quick Reference is designed to help the software developer "get things done" when it comes to programming in and embedding Lua, whether it is Lua 5.4, 5.3, 5.2, or 5.1. This book can even be used with LuaJIT,[2] a Just-In-Time compiler for Lua based on Lua 5.1. *Lua Quick Reference*'s pragmatic approach assumes the developer has a basic understanding of programming concepts. While familiarity with Lua is helpful, it is not a requirement—this book is suitable for helping seasoned developers quickly get up to speed with the language.

1 *http://www.lua.org*

2 *http://luajit.org/luajit.html*

This quick reference is broken up into two parts: Part I covers the Lua language itself and Part II covers Lua's C API. Each part has a number of descriptive sections with conveniently grouped tasks that cover nearly every aspect of Lua and its C API, with differences between versions clearly marked. For the most part, the contents of each task are not listed in conceptual order. They are listed in procedural order, an order the developer would likely follow when programming in or embedding Lua.

While this book aims to be a complete reference, it does omit some of the lesser-known parts of Lua. For example, this reference does not cover Lua's debug interface, weak tables, or some of the finer details of how external modules are loaded. *Lua Quick Reference* serves as a complement to each Lua version's Reference Manual.

Finally, all code examples in this book are based on Lua 5.4, so adaptating them for Lua 5.1, 5.2, and Lua 5.3 may be necessary.

Download

Lua is free software and is available in source format from its website: *http://www.lua.org/download.html*. Links to platform-specific binaries are also available from that page. Lua is highly extensible and can be configured by modifying its *lua conf.h* file prior to compiling the library. For example, on more restricted platforms and embedded devices, the flag "`LUA_32BITS`" can be defined in order to force Lua to use 32-bit integers and 32-bit floating point numbers.

Code Editors

Programming in Lua does not require an Integrated Development Environment (IDE). A simple text editor is sufficient. The author recommends Textadept,[3] a fast, minimalist, and remarkably extensible cross-platform text editor that has fantastic support for Lua. Not only is Textadept free and open-source, but it is also one of the few cross-platform editors that have both a graphical and terminal user interface, the latter being helpful for working on remote machines.

3 *https://orbitalquark.github.io/textadept*

Fundamentals

Lua is a free-form language with whitespace being significant only between identifiers and keywords. Lua source code files typically have the extension "*.lua*".

Comments

Lua has both line comments and block comments. Line comments start with "`--`" and apply until the end of the line they occur on. Block comments start with "`--[[`" and end with "`]]`". Block comment delimiters can contain an optional, equal number of '`=`' characters between the brackets:

```
-- Line comment.
i = 1 -- another line comment

--[[Multi-line
block comment.]]
t = {1, 2, --[[in-line block comment]] 3}

--[=[ Block comment that contains "]]". ]=]
```

Identifiers and Reserved Words

Identifiers are names of variables, table fields, and labels[†]. They are case-sensitive, and can be any combination of ASCII letters, digits, and underscores, though they cannot start with a digit or be a reserved word. Table 1 lists Lua's reserved words.

Some examples of valid identifiers are "`a`", "`_`", "`A_i`", "`a1`", and "`END`". Some examples of invalid identifiers are "`1a`", "`µ`", "`function`", and "`$amount`".

NOTE

By convention, identifiers comprising an underscore followed by one or more upper-case letters (e.g. "`_M`" and "`_VERSION`") are reserved for use by Lua itself.

[†] Except for Lua 5.1, which does not have labels.

Table 1. Reserved words

`and`	`break`	`do`	`else`	`elseif`
`end`	`false`	`for`	`function`	`goto`[a]
`if`	`in`	`local`	`nil`	`not`
`or`	`repeat`	`return`	`then`	`true`
`until`	`while`			

[a] Not in Lua 5.1.

Variables and Scopes

Lua has both global and local variables. Global variables do not need to be declared; they can simply be used. Local variables must be declared with the keyword "`local`" (unless they are function arguments or `for` loop iterator variables, in which case they are implicitly local). Local variable declarations do not have to specify an initial value.

CAUTION

Variables in Lua are global by default. Lua will never raise an error if an attempt is made to reference a global variable with no previously defined value. Instead, the result will always be the value `nil`. Example 10 on page 46 gives an example of how to catch these cases.

It is better practice to use local variables wherever possible. Not only does this avoid potential name clashes between different parts of a program, but also local variable access is faster than global variable access.

Local variables are *lexically scoped*, meaning they are available only from within their current *block* starting after their point of declaration, and within any sub-blocks. Blocks are entities such as function bodies, control structure body parts, and Lua files. Local variables of the same name declared in different scopes are completely independent of one another. The following example and its accompanying call-outs exhibit the availability of local variables in various scopes:

```
-- Scoping example.
x = 1 ❶
local function y(z) ❷
  if condition then
    local x = x ❸
    block
  else
    block
    local z = x ❹
    block
  end
end
```

❶ `x` is a global variable. It is available anywhere a local variable `x` is not in scope.

❷ `y` is a local function and `z` is an implicit local argument variable. `y` is available inside itself (including its sub-blocks) and after its complete definition. `z` is available only inside `y` and its sub-blocks.

❸ `x` is a local variable whose initial value is the one assigned to global variable `x`. (This statement is a common idiom in Lua.) Any reassignments to local `x` do not affect global `x`. Local `x` is available only in the subsequent block below it. Outside that block (including within the `else` block), `x` refers to global `x`.

❹ `z` is a local variable whose initial value is global `x` (not local `x` in the `if` block). `z` is available only in the subsequent block below it (and not in the block above). Outside the lower block, `z` refers to local argument `z`.

Local Variable Attributes

Lua 5.4 introduced the ability to append the attributes "const" and "close" to local variable declarations:

```
local PI_2 <const> = math.pi / 2
local f <close> = io.open(filename)
```

`<const>` prevents the variable from being assigned a new value after its initial value assignment. `<close>` closes the variable's value when the variable goes out of scope (e.g. via `break`, `return`, loop end, error, etc.). This *to-be-closed variable* is particularly useful for automatic resource management, as demonstrated by Example 6 on page 35. Any other attribute is considered a syntax error.

Types

Lua is a *dynamically typed* scripting language. Lua variables have no defined type, and can be assigned and reassigned any Lua value. Lua values are *first-class values*, meaning they can be assigned to variables, passed as function arguments, returned as results, and so on. The following example illustrates these concepts:

```
a = nil
a = true
a = 0
a = "string"
a = function(x, y) return x + y, x - y end
a = {1, 2, 3}
a = coroutine.create(function(x)
  coroutine.yield(x^2)
end) -- note the function that is an argument
a = io.open("filename")
```

Lua has eight basic value types: *nil*, *boolean*, *number*, *string*, *function*, *table*, *thread*, and *userdata*. Each of these types is described in the following sections.

Nil

The nil type has a single value: `nil`. It typically indicates the absence of a useful value. The default value for variables and table keys is `nil`. Assigning `nil` to a variable or table key effectively deletes it.

Booleans

Booleans have one of two values: `true` or `false`. Other than `false` and `nil`, any other value is considered to be true in a boolean sense, including the number zero, the empty string, and an empty table.

Numbers

Numbers comprise both integer numbers and floating point numbers, or *floats*. Floats are typically double-precision floating point numbers, though this is configurable when compiling Lua. This book uses the term "float" in place of whatever type of float Lua is configured to use, which is not necessarily C's single-precision float.

Numbers can be written in decimal, exponential, or hexadecimal[†] notation. Integer numbers include "`0`" and "`-10`". Decimal floats include "`-1.0`" and "`3.14`". Exponential floats include "`6.67e-11`" and "`3E8`". Hexadecimal numbers include "`0xFF`", "`0x1P+8`", and "`0X0.a`".

NOTE

Lua 5.3 and 5.4 represent numbers internally as either integers or floats and seamlessly convert between the two types as needed. The range of integers that can be represented exactly is `math.mininteger` (typically -2^{63}) to `math.maxinteger` (typically 2^{63}). Integers wrap on overflow or underflow. The function `math.type()` returns whether a given number is represented as an integer or float internally.

Lua 5.1 and 5.2 represent all numbers (including integers) internally as floats. As a result, the range of integers that can be represented exactly is typically -2^{53} to 2^{53} (for a double-precision float). Any integer outside that range loses precision.

Lua can perform arithmetic with numbers, which is described in the section "Arithmetic Operators" on page 17. Its other numeric capabilities are listed in the section "Numeric Facilities" on page 51.

Strings

Strings are immutable, arbitrary sequences of bytes. They can contain embedded zeros and have no specific encoding attached to them. Strings can be constructed using double quotes, single quotes, or brackets:

```
dq = "double-quoted string"
sq = 'single-quoted string'
ms = [[multi-line
string]]
```

† Except for Lua 5.1, which cannot express hexadecimal floats.

Quoted strings can contain any of the escape sequences listed in Table 2.

Bracketed strings cannot contain escape sequences, but can span multiple lines without the need for an escape sequence. If a bracketed string immediately starts with a newline, that initial newline is ignored. Similarly to block comments, bracketed string delimiters can contain an optional, equal number of '=' characters between the brackets.

Table 2. Quoted string escape sequences

Sequence	Meaning	Sequence	Meaning
\a	Bell	\"	Double quote
\b	Backspace	\'	Single quote
\f	Form feed	\(newline)	Literal newline
\n	Newline	\z[a]	Ignore subsequent whitespace
\r	Carriage return	\ddd	Decimal byte
\t	Horizontal tab	\x*hh*[a]	Hexadecimal byte
\v	Vertical tab	\u{*uuuu*}[b]	Hexadecimal UTF-8 codepoint
\\	Literal '\'		

[a] Not in Lua 5.1.

[b] Not in Lua 5.1 or 5.2.

Lua can concatenate strings, and this operation is covered in the section "Other Operators" on page 21. Its facilities for creating strings, querying and transforming strings, and searching and replacing within strings are described in the section "String Facilities" on page 54.

Functions

Functions consist of both Lua functions and C functions. (Lua does not distinguish between the two.) As first-class values, functions are anonymous (they do not have names). The sections "Functions" on page 27 and "C Functions" on page 114 describe Lua and C functions, respectively.

Tables

Tables are Lua's primary data type and implement *associative arrays*. An associative array is a set of key-value pairs where keys can be any value except `nil` and NaN,[4] and values can be any value except `nil`. (Therefore, if a table key is assigned `nil`, that key will no longer exist in the table.) Tables can be constructed using brace characters:

```
empty = {}
list  = {1, 2, 3}
dict  = {["a"] = 1, ["b"] = 2, ["c"] = 3}
mix   = {[0] = 0, 1, 2, 3, a = 1, b = 2, c = 3}
```

When keys are omitted in a table constructor, they implicitly become the integer values 1, 2, ..., *n* for the *n* values given without keys. (This kind of table with successive integer keys is considered a *list* and its values are considered *elements*.) Otherwise, keys are enclosed between brackets and are explicitly assigned values. (Both keys and values can be the results of expressions.) As a shortcut, an identifier may be used for a key. In this case, that *field* becomes a string key (e.g. the assignment "`a = 1`" is equivalent to "`["a"] = 1`"). If the last (or only) expression in a table constructor is a function call, all of the values returned by the called function are added as trailing list elements.

NOTE

Lua's list indices start at 1, unlike C's array indices, which start at 0.

Tables are mutable and can be altered using the various operators, statements, and functions covered throughout this book. Lua always assigns, passes, and returns references to tables instead of copies of tables. Tables automatically grow in size as needed, and Lua handles all of the memory management associated with them.

Threads

Threads are separate, independent lines of execution. Instead

4 Not a Number is a special value for undefined numbers like `0/0`.

of true multi-threading (asynchronous threads), Lua supports collaborative threads, or *coroutines*. Coroutines work together by resuming one another and then yielding to one another (a coroutine cannot be interrupted from the outside). Despite the fact that they run independently from one another, coroutines share the same global environment, and only one can be active at a time. Lua's main thread is a coroutine. The sections "Thread Facilities" and "Threading in C" on pages 68 and 133, respectively, describe Lua threads in more detail.

Userdata

Userdata act in place of C data types that cannot be represented by any other Lua value. As userdata, those C types can be treated like any other Lua value. (For example, Lua's file input and output objects are userdata.) Userdata values cannot be modified by Lua itself. The section "Push a userdata" on page 98 describes userdata in more detail.

Perform Basic Value Operations

Lua provides the means to retrieve the type of an arbitrary value, obtain the string representation of a value, and convert a string value to a number value.

`type(`*`value`*`)`
: Returns the string type of value ***`value`***. The returned string is either `"nil"`, `"boolean"`, `"number"`, `"string"`, `"table"`, `"function"`, `"thread"`, or `"userdata"`.

`tostring(`*`value`*`)`
: Returns the string representation of value ***`value`***, invoking the metamethod `__tostring()` if it exists. The section "Metatables and Metamethods" on page 32 describes metamethods.

`tonumber(`*`value`*`[, `*`base`*`])`
: Returns string ***`value`*** converted to a number in base number ***`base`***, or `nil` if the conversion fails. ***`base`*** must be an integer between `2` and `36`, inclusive, and its default value is `10`.

C API Introduction

Lua itself is just a C library. Its three header files provide the host application with a simple API for creating an embedded Lua interpreter, interacting with it, and then closing it. Example 23 demonstrates a very basic stand-alone Lua interpreter whose command line accepts only a Lua script to run.

NOTE

The C examples in this book make use of some C99-specific features, so adapting those examples on a platform without a C99-compliant compiler will likely be necessary. However, Lua itself is written in ISO (ANSI) C, and will compile without modification.

Example 23. Simple stand-alone Lua interpreter

```
#include "lua.h"
#include "lauxlib.h"
#include "lualib.h"

int main(int argc, char **argv) {
  int status = 0;
  // Create a new embedded Lua interpreter.
  lua_State *L = luaL_newstate();
  // Load all of Lua's standard library modules.
  luaL_openlibs(L);
  // Execute the Lua script specified on the command
  // line. If there is an error, report it.
  if (argc > 1 && luaL_dofile(L, argv[1]) != LUA_OK†) {
    const char *errmsg = lua_tostring(L, -1);
    fprintf(stderr, "Lua error: %s\n", errmsg);
    status = 1;
  }
  // Close the Lua interpreter.
  lua_close(L);
  return status;
}
```

The header file *lua.h* provides Lua's basic C API. All functions and macros in that file start with the prefix "`lua_`". The file *lauxlib.h* provides a higher-level API with convenience func-

† `LUA_OK` does not exist in Lua 5.1, which uses the constant 0 instead.

tions for common tasks that involve the basic API. All functions and macros in that file start with the prefix "`luaL_`". The file *lualib.h* provides Lua's standard library module API. Table 13 lists the contents of *lualib.h* for hosts that prefer to load only specific Lua standard library modules rather than all of them at once.

This book refers to Lua's API functions and macros as "API functions" for the sake of simplicity.

CAUTION

Programming with Lua in C does not make programming in C any easier. Type-checking is mandatory, memory allocation errors are possible, and segmentation faults are nearly a given when passing improper arguments to Lua's API functions. Also, any unexpected errors raised by Lua will likely cause the host program to abort. (The section "Error and Warning Handling" on page 129 describes how to avoid that unhappy scenario.)

Table 13. Standard library module API (lualib.h)

Standard Library Module Name	C Function
`""`	luaopen_base
`LUA_BITLIBNAME` ("bit32")[a]	luaopen_bit32[a]
`LUA_LOADLIBNAME` ("package")	luaopen_package
`LUA_MATHLIBNAME` ("math")	luaopen_math
`LUA_STRLIBNAME` ("string")	luaopen_string
`LUA_UTF8LIBNAME` ("utf8")[b]	luaopen_utf8[b]
`LUA_TABLIBNAME` ("table")	luaopen_table
`LUA_COLIBNAME` ("coroutine")	luaopen_coroutine[c]
`LUA_IOLIBNAME` ("io")	luaopen_io
`LUA_OSLIBNAME` ("os")	luaopen_os
`LUA_DBLIBNAME` ("debug")	luaopen_debug

[a] Only in Lua 5.2.

[b] Not in Lua 5.1 or 5.2.

[c] Not in Lua 5.1, whose coroutine library module is included in luaopen_base.

`lua_State`
: A C `struct` that represents both a thread in a Lua interpreter and the interpreter itself. Data can be shared between Lua threads but not between Lua interpreters.

TIP

Lua is fully re-entrant and can be used in multi-threaded code provided the macros `lua_lock` and `lua_unlock` are defined when compiling Lua.

`lua_State *luaL_newstate();`
: Returns a newly created Lua interpreter, which is also that interpreter's main thread.

`void luaL_openlibs(lua_State *`*`L`*`);`
: Loads all of Luas standard library modules into Lua interpreter *`L`*.

`luaL_requiref(`*`L`*`, `*`name`*`, `*`f`*`, 1), lua_pop(`*`L`*`, 1);` **Lua 5.2, 5.3, 5.4**
`lua_pushcfunction(`*`L`*`, `*`f`*`), lua_pushstring(`*`L`*`, `*`name`*`),`
`lua_call(`*`L`*`, 1, 0);` **Lua 5.1**
: Loads one of Lua's standard library modules into Lua interpreter *`L`*. *`name`* is the string name of the module to load and *`f`* is that module's C function. Table 13 lists Lua's standard library module names and their associated C functions.

  Using this in place of `luaL_openlibs()` is useful for hosts that want control over which of Lua's standard library modules are available. For example, a host can prevent Lua code from interacting with the underlying operating system via the `os` module by simply not loading that module.

`void lua_close(lua_State *`*`L`*`);`
: Destroys, garbage-collects, and frees the memory used by all values in Lua interpreter *`L`*. In Lua 5.4, also closes any to-be-closed variables.

Compiling Lua Programs

While a comprehensive guide to compiling Lua programs is beyond the scope of this book, the general idea is to provide a C compiler with the path to Lua's include files, and either

Concept Index