Python for Everyone

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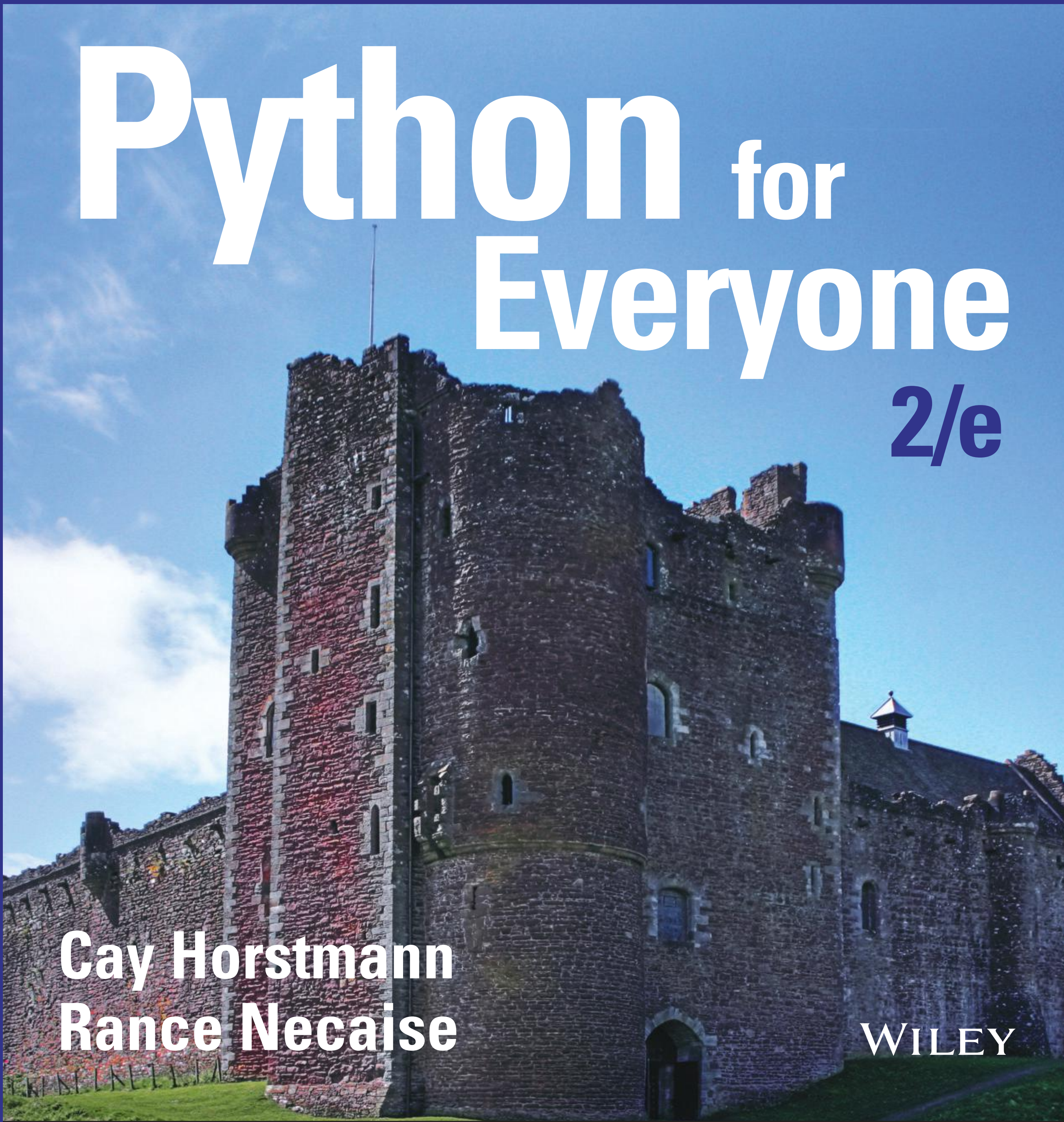

Cay Horstmann
Rance Necaise

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Variable and Constant Definitions

Name — Initial value

```
cansPerPack = 6

CAN_VOLUME = 0.335
```

Use uppercase for constants

Mathematical Functions

`abs(x)`	Absolute value $\lvert x \rvert$
`round(x)`	Rounds to nearest integer
`max(x1, x2, ...)`	Largest of the arguments
`min(x1, x2, ...)`	Smallest of the arguments

From `math` module:

`sqrt(x)`	Square root $\sqrt{x}$
`trunc(x)`	Truncates to an integer
`sin(x), cos(x), tan(x)`	Sine, cosine, tangent of x
`degrees(x), radians(x)`	Converts to degrees or radians
`log(x), log(x, base)`	Natural log, $\log_{base}(x)$

Imports

Module — Imported items

```
from math import sqrt, log
```

Conditional Statement

```
if floor >= 13 :
   actualFloor = floor - 1
elif floor >= 0 :
   actualFloor = floor
else :
   print("Floor negative")
```

- Condition: `floor >= 13`
- Executed when condition is true: `actualFloor = floor - 1`
- Second condition (optional): `elif floor >= 0 :`
- Executed when all conditions are false (optional): `print("Floor negative")`

Loop Statements

```
while balance < TARGET :
   year = year + 1
   balance = balance * (1 + rate / 100)

for value in values :
   sum = sum + value
```

- Condition: `balance < TARGET`
- Executed while condition is true: the two indented lines
- A container (list, str, range, dict, set): `values`

Function Definition

```
def cubeVolume(sideLength) :
   volume = sideLength ** 3
   return volume
```

- Function name: `cubeVolume`
- Parameter name: `sideLength`
- `return`: Exits method and returns result

Selected Operators and Their Precedence

(See Appendix A for the complete list.)

`[]`	Sequence element access
`**`	Raising to a power
`* / // %`	Multiplication, division, floor division, remainder
`+ -`	Addition, subtraction
`< <= > >= != in`	Comparisons and membership
`not` `or` `and`	Boolean operators

Strings

```
s = "Hello"
```

`len(s)`	The length of the string: `5`
`s[1]`	The character with index 1: `"e"`
`s + "!"`	Concatenation: `Hello!`
`s * 2`	Replication: `"HelloHello"`
`s.upper()`	Yields `"HELLO"`
`s.replace("e", "3")`	Yields `"H3llo"`

Lists

```
friends = []
values = [16, 3, 2, 13]

for i in range(len(values)) :
   values[i] = i * i

friends.append("Bob")
friends.insert(0, "Amy")
if "Amy" in friends :
   n = friends.index("Amy")
   friends.pop(n)
else :
   friends.pop()
friends.remove("Bob")

guests = friends + ["Lee", "Zoe"]
scores = [0] * 12
bestFriends = friends[0 : 3]

total = sum(values)
largest = max(values)
values.sort()
```

- `friends = []`: An empty list
- `friends.pop(n)`: Removes nth
- `friends.pop()`: Removes last
- `friends + ["Lee", "Zoe"]`: Concatenation
- `[0] * 12`: Replication
- `friends[0 : 3]`: Slice (0 is included, 3 is excluded)
- `sum(values)`: List must contain numbers
- `max(values)`: Use `min` to get the smallest

Tables

```
table = [[16, 3, 2, 13],
   [5, 10, 11, 8],
   [9, 6, 7, 12],
   [4, 15, 14, 1]]

for row in range(len(table)) :
   for column in range(len(table[row])) :
      sum = sum + table[row][column]
```

- `len(table)`: Number of rows
- `len(table[row])`: Number of columns

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PREFACE

This book is an introduction to computer programming using Python that focuses on the essentials—and on effective learning. Designed to serve a wide range of student interests and abilities, it is suitable for a first course in programming for computer scientists, engineers, and students in other disciplines. No prior programming experience is required, and only a modest amount of high school algebra is needed. For pedagogical reasons, the book uses Python 3, which is more regular than Python 2.

Here are the book's key features:

Present fundamentals first.

The book takes a traditional route, first stressing control structures, functions, procedural decomposition, and the built-in data structures. Objects are used when appropriate in the early chapters. Students start designing and implementing their own classes in Chapter 9.

Guidance and worked examples help students succeed.

Beginning programmers often ask "How do I start? Now what do I do?" Of course, an activity as complex as programming cannot be reduced to cookbook-style instructions. However, step-by-step guidance is immensely helpful for building confidence and providing an outline for the task at hand. "Problem Solving" sections stress the importance of design and planning. "How To" guides help students with common programming tasks. Numerous Worked Examples demonstrate how to apply chapter concepts to interesting problems.

Problem solving strategies are made explicit.

Practical, step-by-step illustrations of techniques help students devise and evaluate solutions to programming problems. Introduced where they are most relevant, these strategies address barriers to success for many students. Strategies included are:

- Algorithm Design (with pseudocode)
- First Do It By Hand (doing sample calculations by hand)
- Flowcharts
- Test Cases
- Hand-Tracing
- Storyboards
- Solve a Simpler Problem First
- Reusable Functions
- Stepwise Refinement
- Adapting Algorithms
- Discovering Algorithms by Manipulating Physical Objects
- Tracing Objects
- Patterns for Object Data
- Thinking Recursively
- Estimating the Running Time of an Algorithm

Practice makes perfect.

Of course, programming students need to be able to implement nontrivial programs, but they first need to have the confidence that they can succeed. This book contains a substantial number of self-check questions at the end of each section. "Practice It" pointers suggest exercises to try after each section. And additional practice opportunities, including automatically-graded programming exercises and skill-oriented multiple-choice questions, are available online.

A visual approach motivates the reader and eases navigation.

Photographs present visual analogies that explain the nature and behavior of computer concepts. Step-by-step figures illustrate complex program operations. Syntax boxes and example tables present a variety of typical and special cases in a compact format. It is easy to get the "lay of the land" by browsing the visuals, before focusing on the textual material.

Visual features help the reader with navigation.

Focus on the essentials while being technically accurate.

An encyclopedic coverage is not helpful for a beginning programmer, but neither is the opposite—reducing the material to a list of simplistic bullet points. In this book, the essentials are presented in digestible chunks, with separate notes that go deeper into good practices or language features when the reader is ready for the additional information.

New to This Edition

Extended Graphics and Image Processing

The use of graphics to reinforce language constructs has been extended to include the use of image processing. Students are introduced to image processing in Chapter 4 as they learn to design and use loops and again in Chapter 5 where they build a toolkit of image processing functions.

Toolbox Sections

Many optional "Toolbox" sections introduce useful packages in the wonderful ecosystem of Python libraries. Students are empowered to perform useful work such as statistical computations, drawing graphs and charts, sending e-mail, processing spreadsheets, and analyzing web pages. The libraries are placed in the context of computer science principles, and students learn how those principles apply to solving real-world problems. Each Toolbox is accompanied by many new end-of-chapter review and programming exercises.

Data Plotting

Several new Worked Examples show students how to create a visual representation of data through graphical plots. These examples use the `pyplot` library to create simple data plots as they show students how to apply the language constructs introduced in the respective chapters.

Interactive Learning

Additional interactive content is available that integrates with this text and immerses students in activities designed to foster in-depth learning. Students don't just watch animations and code traces, they work on generating them. The activities provide instant feedback to show students what they did right and where they need to study more. To find out more about how to make this content available in your course, visit `http://wiley.com/go/pfe2interactivities`.

"CodeCheck" is an innovative online service that students can use to work on programming problems. You can assign exercises that have already been prepared, and you can easily add your own. Visit `http://codecheck.it` to learn more and to try it out.

A Tour of the Book

Figure 1 shows the dependencies between the chapters and how topics are organized. The core material of the book is:

Chapter 1. Introduction
Chapter 2. Programming with Numbers and Strings
Chapter 3. Decisions
Chapter 4. Loops
Chapter 5. Functions
Chapter 6. Lists
Chapter 7. Files and Exceptions
Chapter 8. Sets and Dictionaries

Two chapters cover object-oriented programming:

Chapter 9. Objects and Classes
Chapter 10. Inheritance

Two chapters support a course that goes more deeply into algorithm design and analysis:

Chapter 11. Recursion
Chapter 12. Sorting and Searching

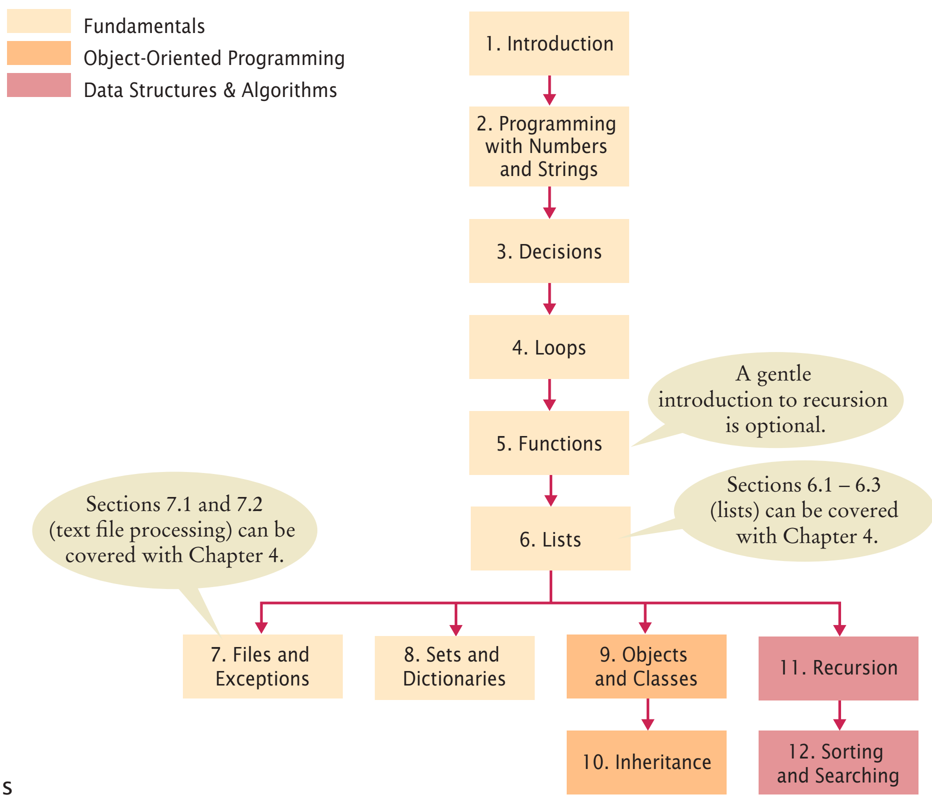

Figure 1
Chapter Dependencies

Appendices Six appendices provide a handy reference for students on operator precedence, reserved words, Unicode, the Python standard library, and more.

Graphics and Image Processing

Writing programs that create drawings or process images can provide students with effective visualizations of complex topics. Chapter 2 introduces the EzGraphics open-source library and how to use it to create basic graphical drawings. The library, which students find easier to use than Python's standard Tkinter library, also supports simple image processing. Graphics Worked Examples and exercises are provided throughout the text, all of which are optional.

Exercises

End-of-chapter exercises contain a broad mix of review and programming questions, with optional questions from graphics, science, and business. Designed to engage students, the exercises illustrate the value of programming in applied fields.

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The interactive edition of *Python For Everyone* adds even more value by integrating a wealth of interactive exercises into the eBook. See `http://wiley.com/go/pfe2interactivities` to find out more about this new format.

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Web Resources

This book is complemented by a complete suite of online resources. Go to `www.wiley.com/college/horstmann` to visit the online companion sites, which include

- Source code for all examples programs and Worked Examples in the book.
- Lecture presentation slides (for instructors only).
- Solutions to all review and programming exercises (for instructors only).
- A test bank that focuses on skills, not just terminology (for instructors only). This extensive set of multiple-choice questions can be used with a word processor or imported into a course management system.
- "CodeCheck" assignments that allow students to work on programming problems presented in an innovative online service and receive immediate feedback. Instructors can assign exercises that have already been prepared, or easily add their own.

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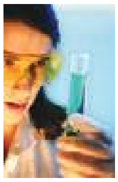
A Walkthrough of the Learning Aids

The pedagogical elements in this book work together to focus on and reinforce key concepts and fundamental principles of programming, with additional tips and detail organized to support and deepen these fundamentals. In addition to traditional features, such as chapter objectives and a wealth of exercises, each chapter contains elements geared to today's visual learner.

1.5 Analyzing Your First Program 11

1.5 Analyzing Your First Program



In this section, we will analyze the first Python program in detail. Here again is the code:

ch01/hello.py

```
# My first Python program.
print("Hello, World!")
```

A Python program contains one or more lines of instructions or **statements** that will be translated and executed by the Python interpreter. The first line

```
# My first Python program.
```

A comment provides information to the programmer.

is a **comment**. Comments begin with # and are not statements. They provide descriptive information to the programmer. Comments will be discussed in more detail in Section 2.1.5.

The second line contains a statement

```
print("Hello, World!")
```

A function is a collection of instructions that perform a particular task.

A function is called by specifying the function name and its arguments.

that prints or displays a line of text, namely "Hello, World!". In this statement, we call a function named `print` and pass it the information to be displayed. A **function** is a collection of programming instructions that carry out a particular task. We do not have to implement this function, it is part of the Python language. We simply want the function to perform its intended task, namely to print a value.

To use, or call, a function in Python, you need to specify

1. The name of the function you want to use (in this case, `print`).
2. Any values the function needs to carry out its task (in this case, `"Hello, World!"`). The technical term for such a value is an **argument**. Arguments are enclosed in parentheses with multiple arguments separated by commas. The number of arguments required depends on the function.

Throughout each chapter, **margin notes** show where new concepts are introduced and provide an outline of key ideas.

Annotated **syntax boxes** provide a quick, visual overview of new language constructs.

Syntax 1.1 `print` Statement

Syntax `print()`
`print(`$value_1$`, `$value_2$`, ..., `$value_n$`)`

```
print("The answer is", 6 + 7, "!")
```

All arguments are optional. If no arguments are given, a blank line is printed.

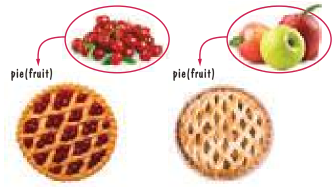
The values to be printed, one after the other, separated by a blank space.

Annotations explain required components and point to more information on common errors or best practices associated with the syntax.

Like a variable in a computer program, a parking space has an identifier and a contents.

Analogies to everyday objects are used to explain the nature and behavior of concepts such as variables, data types, loops, and more.

Memorable photos reinforce analogies and help students remember the concepts.



A recipe for a fruit pie may say to use any kind of fruit. Here, "fruit" is an example of a parameter variable. Apples and cherries are examples of arguments.

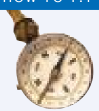
Problem Solving sections teach techniques for generating ideas and evaluating proposed solutions, often using pencil and paper or other artifacts. These sections emphasize that most of the planning and problem solving that makes students successful happens away from the computer.

6.6 Problem Solving: Discovering Algorithms by Manipulating Physical Objects 311

Now how does that help us with our problem, switching the first and the second half of the list?

Let's put the first coin into place, by swapping it with the fifth coin. However, as Python programmers, we will say that we swap the coins in positions 0 and 4:

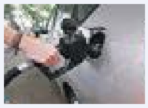
HOW TO 1.1 **Describing an Algorithm with Pseudocode**



This is the first of many "How To" sections in this book that give you step-by-step procedures for carrying out important tasks in developing computer programs.

Before you are ready to write a program in Python, you need to develop an algorithm—a method for arriving at a solution for a particular problem. Describe the algorithm in pseudocode: a sequence of precise steps formulated in English.

Problem Statement You have the choice of buying two cars. One is more fuel efficient than the other, but also more expensive. You know the price and fuel efficiency (in miles per gallon, mpg) of both cars. You plan to keep the car for ten years. Assume a price of $4 per gallon of gas and usage of 15,000 miles per year. You will pay cash for the car and not worry about financing costs. Which car is the better deal?



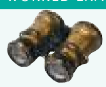
Step 1 Determine the inputs and outputs.

In our sample problem, we have these inputs:

- purchase price1 and fuel efficiency1, the price and fuel efficiency (in mpg) of the first car

How To guides give step-by-step guidance for common programming tasks, emphasizing planning and testing. They answer the beginner's question, "Now what do I do?" and integrate key concepts into a problem-solving sequence.

WORKED EXAMPLE 1.1 **Writing an Algorithm for Tiling a Floor**



Problem Statement Make a plan for tiling a rectangular bathroom floor with alternating black and white tiles measuring 4 × 4 inches. The floor dimensions, measured in inches, are multiples of 4.

Step 1 Determine the inputs and outputs.

The inputs are the floor dimensions (length × width), measured in inches. The output is a tiled floor.

Step 2 Break down the problem into smaller tasks.

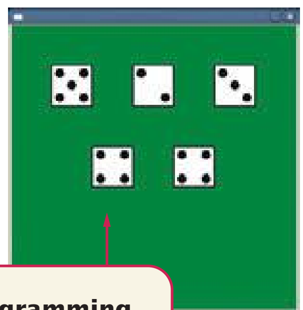
A natural subtask is to lay one row of tiles. If you can solve that task, then you can solve the problem by laying one row next to the other, starting from a wall, until you reach the opposite wall.

Worked Examples apply the steps in the How To to a different example, showing how they can be used to plan, implement, and test a solution to another programming problem.

Table 1 Number Literals in Python

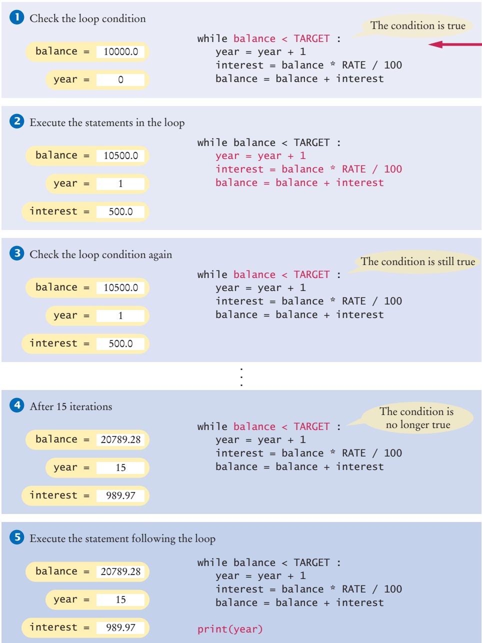
Number	Type	Comment
6	int	An integer has no fractional part.
-6	int	Integers can be negative.
0	int	Zero is an integer.
0.5	float	A number with a fractional part has type float.
1.0	float	An integer with a fractional part .0 has type float.
1E6	float	A number in exponential notation: 1×10^6 or 1000000. Numbers in exponential notation always have type float.
2.96E-2	float	Negative exponent: $2.96 \times 10^{-2} = 2.96 / 100 = 0.0296$
🚫 100,000		**Error:** Do not use a comma as a decimal separator.
🚫 3 1/2		**Error:** Do not use fractions; use decimal notation: 3.5.

Example tables support beginners with multiple, concrete examples. These tables point out common errors and present another quick reference to the section's topic.

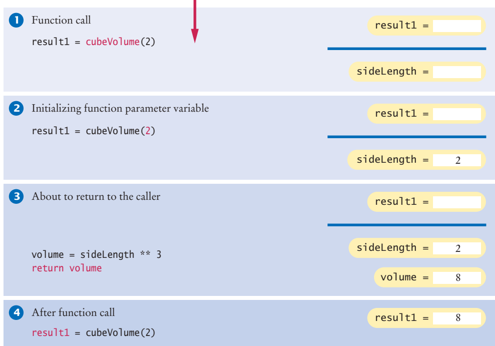


Optional **graphics programming examples** demonstrate constructs with engaging drawings, visually reinforcing programming concepts.

Figure 2 Execution of the doubleinv.py Loop



Progressive figures trace code segments to help students visualize the program flow. Color is used consistently to make variables and other elements easily recognizable.



Consider the function call illustrated in Figure 3:

```
result1 = cubeVolume(2)
```

- The parameter variable `sideLength` of the `cubeVolume` function is created when the function is called. 1
- The parameter variable is initialized with the value of the argument that was passed in the call. In our case, `sideLength` is set to 2. 2
- The function computes the expression `sideLength ** 3`, which has the value 8. That value is stored in the variable `volume`. 3
- The function returns. All of its variables are removed. The return value is trans- ... ller

Self-check exercises at the end of each section are designed to make students think through the new material—and can spark discussion in lecture.

25. Write the `for` loop of the `investment.py` program as a `while` loop.

26. How many numbers does this loop print?

```
for n in range(10, -1, -1) :
   print(n)
```

27. Write a `for` loop that prints all even numbers between 10 and 20 (inclusive).

28. Write a `for` loop that computes the total of the integers from 1 to `n`.

29. How would you modify the loop of the `investment.py` program to print all balances until the investment has doubled?

Practice It Now you can try these exercises at the end of the chapter: R4.18, R4.19, P4.8.

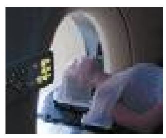
Optional **science, graphics, and business exercises** engage students with realistic applications.

■■ **Business P4.28** *Currency conversion.* Write a program that first asks the user to type today's price for one dollar in Japanese yen, then reads U.S. dollar values and converts each to yen. Use 0 as a sentinel.

■■ **Graphics P2.30** Write a program that displays the Olympic rings. Color the rings in the Olympic colors.

■ **Science P4.37** Radioactive decay of radioactive materials can be modeled by the equation $A = A_0 e^{-t(\log 2 / h)}$, where A is the amount of the material at time t, A_0 is the amount at time 0, and h is the half-life.

Technetium-99 is a radioisotope that is used in imaging of the brain. It has a half-life of 6 hours. Your program should display the relative amount A / A_0 in a patient body every hour for 24 hours after receiving a dose.



ch04/doubleinv.py

```
##
#  This program computes the time required to double an investment.
#

# Create constant variables.
RATE = 5.0
INITIAL_BALANCE = 10000.0
TARGET = 2 * INITIAL_BALANCE

# Initialize variables used with the loop.
balance = INITIAL_BALANCE
year = 0

# Count the years required for the investment to double.
while balance < TARGET :
   year = year + 1
   interest = balance * RATE / 100
   balance = balance + interest

# Print the results.
print("The investment doubled after", year, "years.")
```

Program listings are carefully designed for easy reading, going well beyond simple color coding. Methods and functions are set off by a subtle outline.

Toolbox sections teach students how to use Python libraries for solving real-world problems.

TOOLBOX 7.1

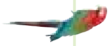
Working with CSV Files

You have seen how to read and write text files and to process data stored in various formats, but what if you need to process data stored in a spreadsheet? For example, suppose you need to print a list of all the movies released in the 1990s from a spreadsheet filled with movie data, such as the one shown below.

Most spreadsheet applications store their data in proprietary file formats that cannot be accessed directly by other programs. Fortunately, most can save a copy of the data in a porta-

Common Errors describe the kinds of errors that students often make, with an explanation of why the errors occur, and what to do about them.

Common Error 3.2



Exact Comparison of Floating-Point Numbers

Floating-point numbers have only a limited precision, and calculations can introduce roundoff errors. You must take these inevitable roundoffs into account when comparing floating-point numbers. For example, the following code multiplies the square root of 2 by itself. Ideally, we expect to get the answer 2:

```
from math import sqrt

r = sqrt(2.0)
if r * r == 2.0 :
   print("sqrt(2.0) squared is 2.0")
else :
   print("sqrt(2.0) squared is not 2.0 but", r * r)
```

Take limited precision into account when comparing floating-point numbers.

nbers exactly. f their differ- nd *y* are close

Programming Tips explain good programming practices, and encourage students to be more productive with tips and techniques such as hand-tracing.

Programming Tip 3.2

Hand-Tracing

A very useful technique for understanding whether a program works correctly is called *hand-tracing*. You simulate the program's activity on a sheet of paper. You can use this method with pseudocode or Python code.

Get an index card, a cocktail napkin, or whatever sheet of paper is within reach. Make a column for each variable. Have the program code ready. Use a marker, such as a paper clip, to mark the current statement. In your mind, execute statements one at a time. Every time the value of a variable changes, cross out the old value and write the new value below the old one.

Let's trace the `taxes.py` program on page 107 with the inputs from the program run that follows it. In lines 12 and 13, `income` and `maritalStatus` are initialized by input statements.

Hand-tracing helps you understand whether a program works correctly.

```
5 # Initialize constant variables for the tax rates and rate limits.
6 RATE1 = 0.10
7 RATE2 = 0.25
8 RATE1_SINGLE_LIMIT = 32000.0
9 RATE1_MARRIED_LIMIT = 64000.0
10
11 # Read income and marital status.
12 income = float(input("Please enter your income: "))
13 maritalStatus = input("Please enter s for single, m for married: ")
```

tax1	tax2	income	marital status
		80000	m

Computing & Society presents social and historical information on computing—for interest and to fulfill the "historical and social context" requirements of the ACM/IEEE curriculum guidelines.

Computing & Society 1.1 Computers Are Everywhere

When computers were first invented in the 1940s, a computer filled an entire room. The photo below shows the ENIAC (*e*lectronic *n*umerical *i*ntegrator *a*nd *c*omputer), completed in 1946 at the University of Pennsylvania. The ENIAC was used by the military to compute the trajectories of projectiles. Nowadays, computing facilities of search engines, Internet shops, and social networks fill huge buildings called data centers. At the other end of the spectrum, computers are all around us. Your cell phone has a computer inside, as do many credit cards and fare cards for public transit. A modern car has several computers—to control the

The advent of ubiquitous computing changed many aspects of our lives. Factories used to employ people to do repetitive assembly tasks that are today carried out by computer-controlled robots, operated by a few people who know how to work with those computers. Books, music, and movies nowadays are often consumed on computers, and computers are almost always involved in their production. The book that not have been written without

This transit card contains a computer.

Special Topics present optional topics and provide additional explanation of others.

Special Topic 3.4

Short-Circuit Evaluation of Boolean Operators

The `and` and `or` operators are computed using **short-circuit evaluation**. In other words, logical expressions are evaluated from left to right, and evaluation stops as soon as the truth value is determined. When an `and` is evaluated and the first condition is false, the second condition is not evaluated, because it does not matter what the outcome of the second test is.

For example, consider the expression

```
quantity > 0 and price / quantity < 10
```

Suppose the value of `quantity` is zero. Then the test `quantity > 0` fails, and the second test is not attempted. That is just as well, because it is illegal to divide by zero.

Similarly, when the first condition of an `or` expression is true, then the remainder is not evaluated because the result must be true.

The `and` and `or` operators are computed using *short-circuit evaluation:* As soon as the truth value is determined, no further conditions are evaluated.

In a short circuit, electricity travels along the path of least resistance. Similarly, short-circuit evaluation takes the fastest path for computing the result of a Boolean expression.

CONTENTS

*On the companion site at www.wiley.com/college/horstmann.

ALPHABETICAL LIST OF SYNTAX BOXES

For Clora, maybe—C.H.

To my parents
Willard and Ella—R.N.

CHAPTER 1

INTRODUCTION

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CHAPTER GOALS

To learn about computers and programming

To write and run your first Python program

To recognize compile-time and run-time errors

To describe an algorithm with pseudocode

CHAPTER CONTENTS


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Just as you gather tools, study a project, and make a plan for tackling it, in this chapter you will gather up the basics you need to start learning to program. After a brief introduction to computer hardware, software, and programming in general, you will learn how to write and run your first Python program. You will also learn how to diagnose and fix programming errors, and how to use pseudocode to describe an *algorithm*—a step-by-step description of how to solve a problem—as you plan your computer programs.

1.1 Computer Programs

Computers execute very basic instructions in rapid succession.

You have probably used a computer for work or fun. Many people use computers for everyday tasks such as electronic banking or writing a term paper. Computers are good for such tasks. They can handle repetitive chores, such as totaling up numbers or placing words on a page, without getting bored or exhausted.

The flexibility of a computer is quite an amazing phenomenon. The same machine can balance your checkbook, lay out your term paper, and play a game. In contrast, other machines carry out a much narrower range of tasks; a car drives and a toaster toasts. Computers can carry out a wide range of tasks because they execute different programs, each of which directs the computer to work on a specific task.

A computer program is a sequence of instructions and decisions.

The computer itself is a machine that stores data (numbers, words, pictures), interacts with devices (the monitor, the sound system, the printer), and executes programs. A **computer program** tells a computer, in minute detail, the sequence of steps that are needed to fulfill a task. The physical computer and peripheral devices are collectively called the **hardware**. The programs the computer executes are called the **software**.

Today's computer programs are so sophisticated that it is hard to believe that they are composed of extremely primitive instructions. A typical instruction may be one of the following:

- Put a red dot at a given screen position.
- Add up two numbers.
- If this value is negative, continue the program at a certain instruction.

The computer user has the illusion of smooth interaction because a program contains a huge number of such instructions, and because the computer can execute them at great speed.

Programming is the act of designing and implementing computer programs.

The act of designing and implementing computer programs is called **programming**. In this book, you will learn how to program a computer—that is, how to direct the computer to execute tasks.

To write a computer game with motion and sound effects or a word processor that supports fancy fonts and pictures is a complex task that requires a team of many highly-skilled programmers. Your first programming efforts will be more mundane. The concepts and skills you learn in this book form an important foundation, and you should not be disappointed if your first programs do not rival the sophisticated software that is familiar to you. Actually, you will find that there is an immense thrill even in simple programming tasks. It is an amazing experience to see the computer precisely and quickly carry out a task that would take you hours of drudgery, to make small changes in a program that lead to immediate improvements, and to see the computer become an extension of your mental powers.

SELF CHECK

1. What is required to play music on a computer?
2. Why is a CD player less flexible than a computer?
3. What does a computer user need to know about programming in order to play a video game?

1.2 The Anatomy of a Computer

To understand the programming process, you need to have a rudimentary understanding of the building blocks that make up a computer. We will look at a personal computer. Larger computers have faster, larger, or more powerful components, but they have fundamentally the same design.

At the heart of the computer lies the **central processing unit (CPU)** (see Figure 1). The inside wiring of the CPU is enormously complicated. The CPUs used for personal computers at the time of this writing are composed of several hundred million structural elements, called *transistors*.

The central processing unit (CPU) performs program control and data processing.

The CPU performs program control and data processing. That is, the CPU locates and executes the program instructions; it carries out arithmetic operations such as addition, subtraction, multiplication, and division; it fetches data from external memory or devices and places processed data into storage.

Storage devices include memory and secondary storage.

There are two kinds of storage. **Primary storage** is made from memory chips: electronic circuits that can store data, provided they are supplied with electric power. **Secondary storage**, usually a **hard disk** (see Figure 2), provides slower and less expensive storage that persists without electricity. A hard disk consists of rotating platters, which are coated with a magnetic material, and read/write heads, which can detect and change the magnetic flux on the platters.

The computer stores both data and programs. They are located in secondary storage and loaded into memory when the program starts. The program then updates the data in memory and writes the modified data back to secondary storage.

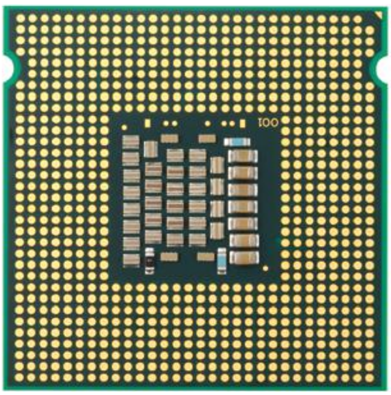

Figure 1 Central Processing Unit

Figure 2 A Hard Disk

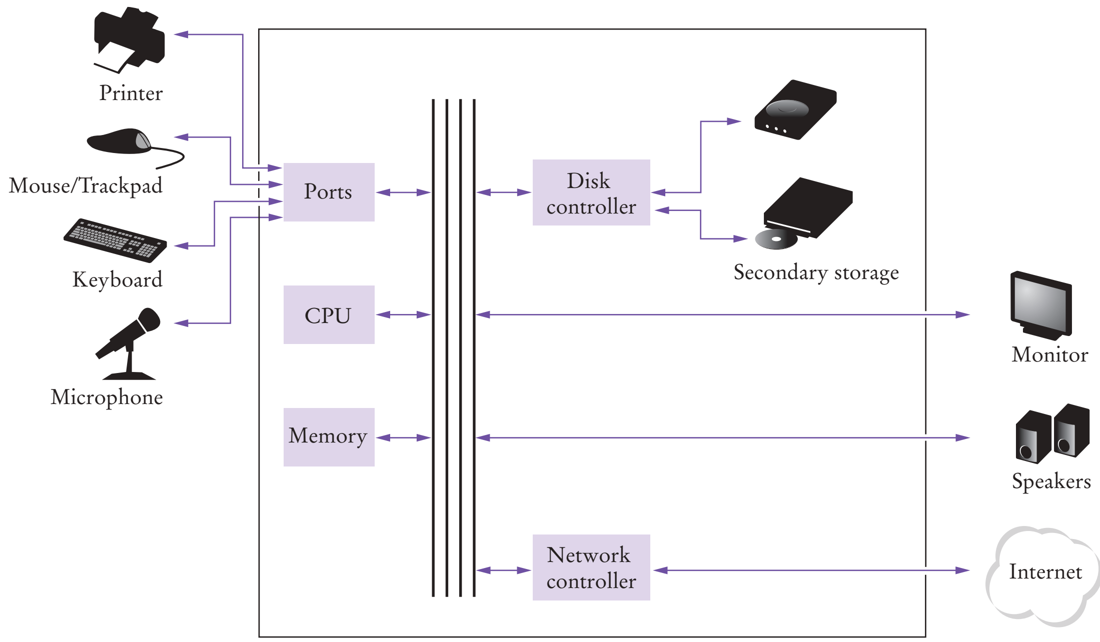

Figure 3 Schematic Design of a Personal Computer

To interact with a human user, a computer requires peripheral devices. The computer transmits information (called *output*) to the user through a display screen, speakers, and printers. The user can enter information (called *input*) for the computer by using a keyboard or a pointing device such as a mouse.

Some computers are self-contained units, whereas others are interconnected through **networks**. Through the network cabling, the computer can read data and programs from central storage locations or send data to other computers. To the user of a networked computer, it may not even be obvious which data reside on the computer itself and which are transmitted through the network.

Figure 3 gives a schematic overview of the architecture of a personal computer. Program instructions and data (such as text, numbers, audio, or video) are stored on the hard disk, on a compact disk (or DVD), or elsewhere on the network. When a program is started, it is brought into memory, where the CPU can read it. The CPU reads the program one instruction at a time. As directed by these instructions, the CPU reads data, modifies it, and writes it back to memory or the hard disk. Some program instructions will cause the CPU to place dots on the display screen or printer or to vibrate the speaker. As these actions happen many times over and at great speed, the human user will perceive images and sound. Some program instructions read user input from the keyboard or mouse. The program analyzes the nature of these inputs and then executes the next appropriate instruction.

4. Where is a program stored when it is not currently running?
5. Which part of the computer carries out arithmetic operations, such as addition and multiplication?

Practice It Now you can try these exercises at the end of the chapter: R1.2, R1.3.

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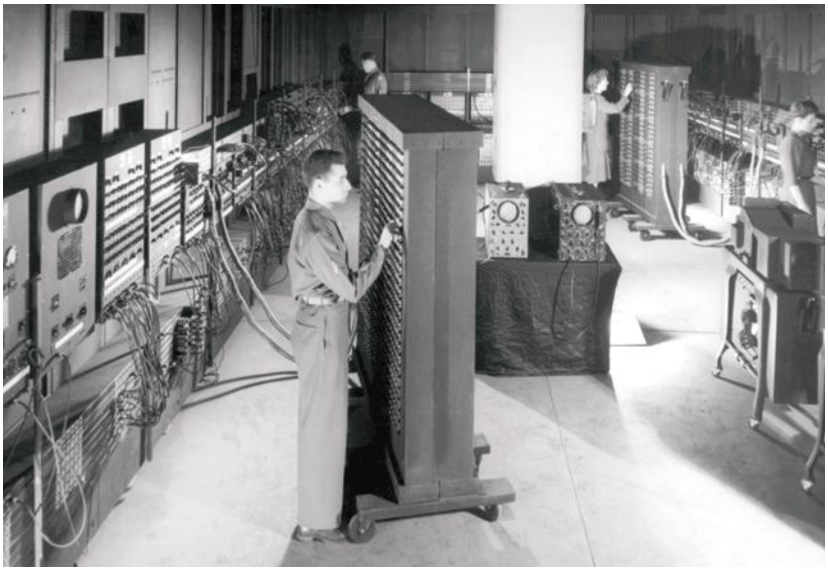
This transit card contains a computer.

The advent of ubiquitous computing changed many aspects of our lives. Factories used to employ people to do repetitive assembly tasks that are today carried out by computer-controlled robots, operated by a few people who know how to work with those computers. Books, music, and movies nowadays are often consumed on computers, and computers are almost always involved in their production. The book that you are reading right now could not have been written without computers.

Knowing about computers and how to program them has become an essential skill in many careers. Engineers design computer-controlled cars and medical equipment that preserve lives. Computer scientists develop programs that help people come together to support social causes. For example, activists used social networks to share videos showing abuse by repressive regimes, and this information was instrumental in changing public opinion.

As computers, large and small, become ever more embedded in our everyday lives, it is increasingly important for everyone to understand how they work, and how to work with them. As you use this book to learn how to program a computer, you will develop a good understanding of computing fundamentals that will make you a more informed citizen and, perhaps, a computing professional.



The ENIAC

1.3 The Python Programming Language

In order to write a computer program, you need to provide a sequence of instructions that the CPU can execute. A computer program consists of a large number of simple CPU instructions, and it is tedious and error-prone to specify them one by one. For that reason, **high-level programming languages** have been created. These languages allow a programmer to specify the desired program actions at a high level. The high-level instructions are then automatically translated into the more detailed instructions required by the CPU.

In this book, we will use a high-level programming language called Python, which was developed in the early 1990s by Guido van Rossum. Van Rossum needed to carry out repetitive tasks for administering computer systems. He was dissatisfied with other available languages that were optimized for writing large and fast programs. He needed to write smaller programs that didn't have to run at optimum speed. It was important to him that he could author the programs quickly and update them quickly as his needs changed. Therefore, he designed a language that made it very easy to work with complex data. Python has evolved considerably since its beginnings. In this book, we use version 3 of the Python language. Van Rossum is still the principal author of the language, but the effort now includes many volunteers.

Sauria Associates, LLC/FlickrVision/Getty Images, Inc.

Python is portable and easy to learn and use.

Python has become popular for business, scientific, and academic applications and is very suitable for the beginning programmer. There are many reasons for the success of Python. Python has a much simpler and cleaner syntax than other popular languages such as Java, C, and C++, which makes it easier to learn. Moreover, you can try out short Python programs in an interactive environment, which encourages experimentation and rapid turnaround. Python is also very portable between computer systems. The same Python program will run, without change, on Windows, UNIX, Linux, and Macintosh.

SELF CHECK

6. Why don't you specify a program directly in CPU instructions?
7. What are the two most important benefits of the Python language?

Practice It Now you can try this exercise at the end of the chapter: R1.5.

1.4 Becoming Familiar with Your Programming Environment

Set aside some time to become familiar with the programming environment that you will use for your class work.

Many students find that the tools they need as programmers are very different from the software with which they are familiar. You should spend some time making yourself familiar with your programming environment. Because computer systems vary widely, this book can only give an outline of the steps you need to follow. It is a good idea to participate in a hands-on lab, or to ask a knowledgeable friend to give you a tour.

Step 1 Install the Python development environment.

Your instructor may have given you installation instructions for the environment that is used in your course. If not, follow the installation instructions that we provide at `http://horstmann.com/python4everyone/install.html`.

Step 2 Start the Python development environment.

Computer systems differ greatly in this regard. On many computers there is an **integrated development environment** in which you can write and test your programs. On other computers you first launch a **text editor**, a program that functions like a word processor, in which you can enter your Python instructions; you then open a **terminal window** and type commands to execute your program. Follow the instructions from your instructor or those at `http://horstmann.com/python4everyone/install.html`.

A text editor is a program for entering and modifying text, such as a Python program.

Step 3 Write a simple program.

The traditional choice for the very first program in a new programming language is a program that displays a simple greeting: "Hello, World!". Let us follow that tradition. Here is the "Hello, World!" program in Python:

```
# My first Python program.
print("Hello, World!")
```

We will examine this program in the next section.

No matter which programming environment you use, you begin your activity by typing the program instructions into an editor window.

Create a new file and call it `hello.py`, using the steps that are appropriate for your environment. (If your environment requires that you supply a project name in addition to the file name, use the name `hello` for the project.) Enter the program instructions *exactly* as they are given above. Alternatively, locate the electronic copy in this book's companion code and paste it into your editor.

As you write this program, pay careful attention to the various symbols, and keep in mind that Python is **case sensitive**. You must enter upper- and lowercase letters exactly as they appear in the program listing. You cannot type `Print` or `PRINT`. If you are not careful, you will run into problems—see Common Error 1.1 on page 15.

Python is case sensitive. You must be careful about distinguishing between upper- and lowercase letters.

Step 4 Run the program.

The process for running a program depends greatly on your programming environment. You may have to click a button or enter some commands. When you run the test program, the message

```
Hello, World!
```

will appear somewhere on the screen (see Figures 4 and 5).

A Python program is executed using the **Python interpreter**. The interpreter reads your program and executes all of its steps. (Special Topic 1.1 on page 10 explains in more detail what the Python interpreter does.) In some programming environments, the Python interpreter is automatically launched when you click on a "Run" button or select the "Run" option from a menu. In other environments, you have to launch the interpreter explicitly.

The Python interpreter reads Python programs and executes the program instructions.

Figure 4 Running the `hello.py` Program in a Terminal Window

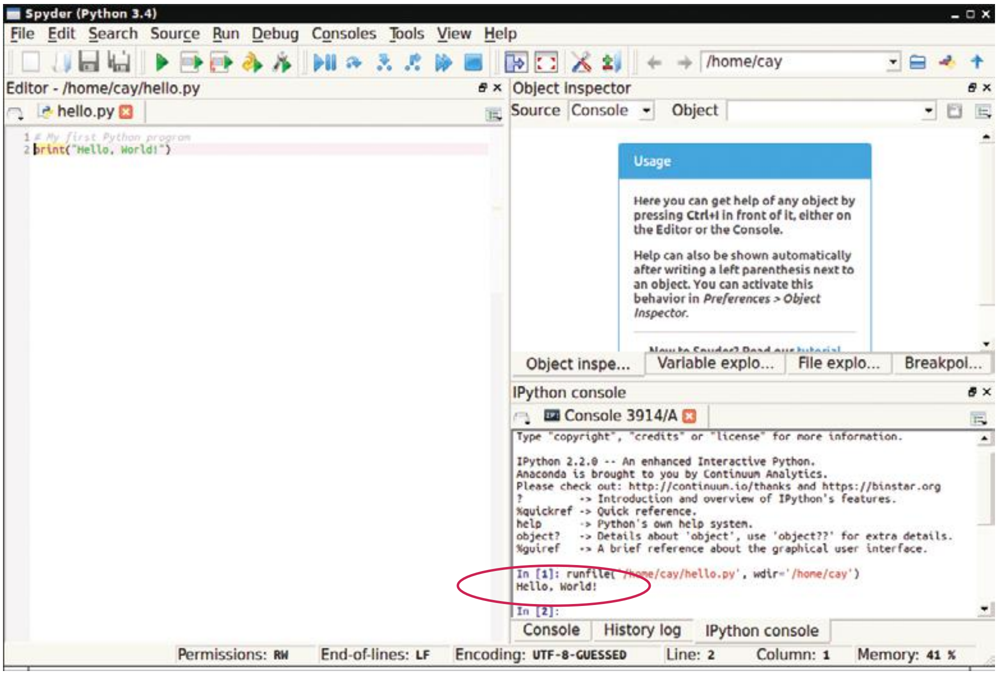


Figure 5 Running the `hello.py` Program in an Integrated Development Environment

Step 5 Organize your work.

As a programmer, you write programs, try them out, and improve them. If you want to keep your programs, or turn them in for grading, you store them in **files**. A Python program can be stored in a file with any name, provided it ends with `.py`. For example, we can store our first program in a file named `hello.py` or `welcome.py`.

Files are stored in **folders** or **directories**. A folder can contain files as well as other folders, which themselves can contain more files and folders (see Figure 6). This hierarchy can be quite large, and you need not be concerned with all of its branches. However, you should create folders for organizing your work. It is a good idea to make a separate folder for your programming class. Inside that folder, make a separate folder for each program.

Some programming environments place your programs into a default location if you don't specify a folder. In that case, you need to find out where those files are located.

Be sure that you understand where your files are located in the folder hierarchy. This information is essential when you submit files for grading, and for making backup copies (see Programming Tip 1.2 on page 9).

Figure 6 A Folder Hierarchy

SELF CHECK

8. Where is the `hello.py` file stored on your computer?
9. What do you do to protect yourself from data loss when you work on programming projects?

Practice It Now you can try this exercise at the end of the chapter: R1.6.

Programming Tip 1.1

Interactive Mode

When you write a complete program, you place the program instructions in a file and let the Python interpreter execute your program file. The interpreter, however, also provides an interactive mode in which Python instructions can be entered one at a time. To launch the Python interactive mode from a terminal window, enter the command

```
python
```

(On systems where multiple versions of Python are installed, use the command `python3` to run version 3 of Python.) Interactive mode can also be started from within most Python integrated development environments.

The interface for working in interactive mode is known as the **Python shell**. First, you will see an informational message similar to the following:

```
Python 3.1.4 (default, Nov 3 2014, 14:38:10)
[GCC 4.9.1 20140930 (Red Hat 4.9.1-11)] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

The `>>>` at the bottom of the output is the **prompt**. It indicates that you can enter Python instructions. (Your prompt may look different, such as `In [1]:`.) After you type an instruction and press the Enter key, the code is immediately executed by the Python interpreter. For example, if you enter

```
print("Hello, World!")
```

the interpreter will respond by executing the `print` function and displaying the output, followed by another prompt:

```
>>> print("Hello, World!")
Hello World
>>>
```

Interactive mode is very useful when you are first learning to program. It allows you to experiment and test individual Python instructions to see what happens. You can also use interactive mode as a simple calculator. Just enter mathematical expressions using Python syntax:

```
>>> 7035 * 0.15
1055.25
>>>
```

Make it a habit to use interactive mode as you experiment with new language constructs.

Programming Tip 1.2

Backup Copies

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You will spend many hours creating and improving Python programs. It is easy to delete a file by accident, and occasionally files are lost because of a computer malfunction. Retyping the contents of lost files is frustrating and time-consuming. It is therefore crucially important that you learn how to safeguard files and get in the habit of doing so *before* disaster strikes. Backing up files on a memory stick is an easy and convenient storage method for many people. Another increasingly popular form of backup is Internet file storage. Here are a few pointers to keep in mind:

Develop a strategy for keeping backup copies of your work before disaster strikes.

- *Back up often.* Backing up a file takes only a few seconds, and you will hate yourself if you have to spend many hours recreating work that you could have saved easily. We recommend that you back up your work once every thirty minutes.
- *Rotate backups.* Use more than one directory for backups, and rotate them. That is, first back up onto the first directory. Then back up onto the second directory. Then use the