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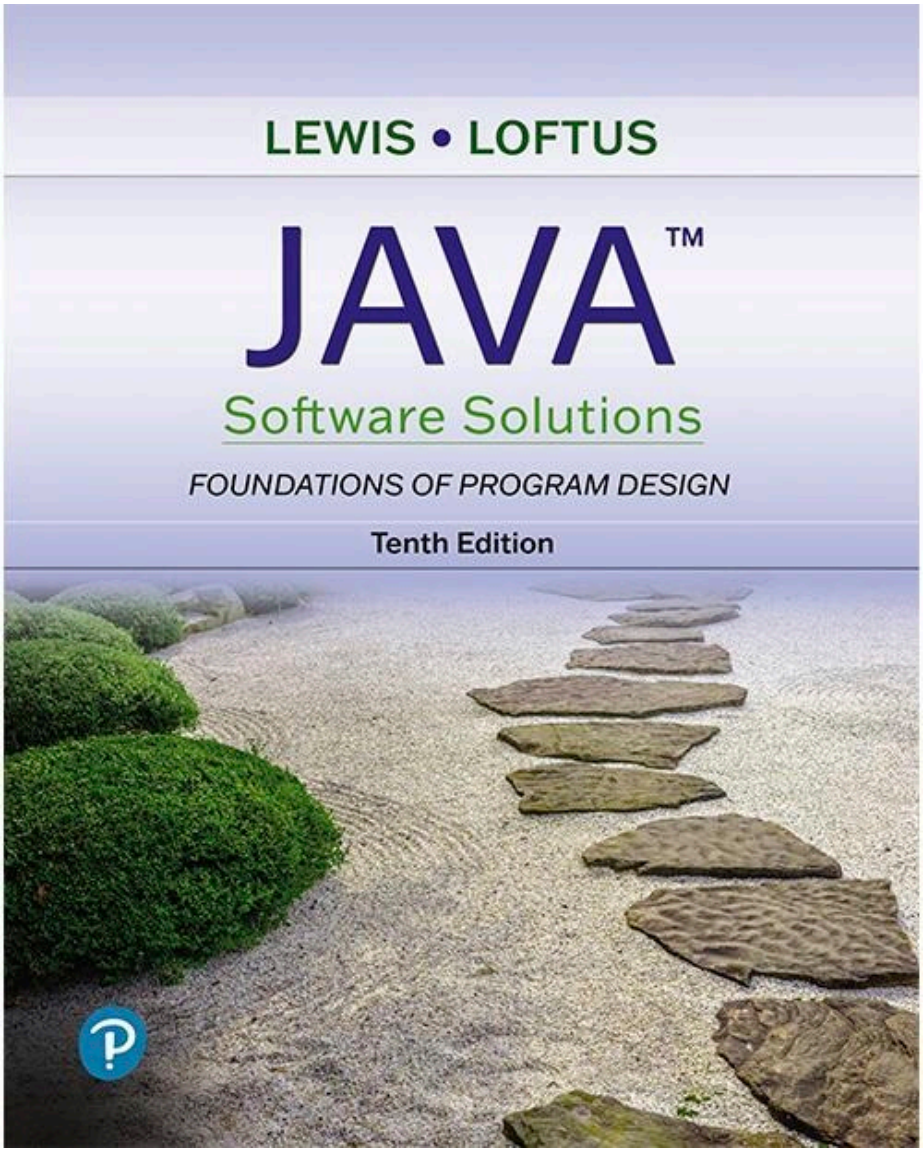
JAVA™

Software Solutions

FOUNDATIONS OF PROGRAM DESIGN

Tenth Edition



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Java™ Software Solutions

Foundations of Program Design

Tenth Edition

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This book is dedicated to our families.
Sharon, Justin, Kayla, Nathan, and Samantha Lewis
and
Veena, Isaac, and Dévi Loftus

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Preface

Welcome to the Tenth Edition of *Java Software Solutions: Foundations of Program Design*. We are pleased that this book has served the needs of so many students and faculty over the years. This edition has been tailored further to improve the coverage of topics key to introductory computing.

New to This Edition

The biggest change in the 10th edition of Java Software Solutions is the migration to digital format and inclusion of interactive coding activities and scored programming assessments (available in Revel Courseware and Pearson+ ebook) that provide immediate and personalized feedback to students on what they got wrong. The immediate feedback coaches students to the correct answer which increases persistence. This change reflects the need to make textbooks, especially computer science books, interactive and engaging. The tested and refined presentation of core material is now integrated with dynamic features and assessments.

- 21 Coding Animations to help students understand what is going on in the program and in the computer.
- 42 NEW Videonotes. Engaging video tutorials that take students from design to code completion.
- LiveCodeExamples interspersed throughout the chapters that provide coding practice.
- Over 388 Checkpoint self-check questions for students to test understanding of what they just read.
- Over 238 scored quiz assessment questions.
- Over 27 Summative end-of-chapter Programming Projects.

In addition to the digital/interactive transformation, several content changes were made for the tenth edition to stay on top of the ever-evolving Java language as it impacts introductory programmer, as well as updates to keep the examples fresh and improve the discussion of individual topics. These changes include:

- A new example demonstrating an Array of Objects in **Chapter 8**.
- A new section covering Maps and their implementation in the Java API.
- Coverage of the use of the `var` keyword to simplify complex variable declarations.
- A new section on lambda expressions, especially as they relate to the management of collections, in **Chapter 13**.

We're excited about the opportunities this new edition of Java Software Solutions provides for both students and instructors. Questions and comments are always welcome.

Cornerstones of the Text

This text is based on the following basic ideas that we believe make for a sound introductory text:

- *True object-orientation***.** A text that really teaches a solid object-oriented approach must use what we call object-speak. That is, all processing should be discussed in object-oriented terms. That does not mean, however, that the first program a student sees must discuss the writing of multiple classes and methods. A student should learn to use objects before learning to write them. This text uses a natural progression that culminates in the ability to design real object-oriented solutions.

- *Sound programming practices*. Students should not be taught how to program; they should be taught how to write good software. There's a difference. Writing software is not a set of cookbook actions, and a good program is more than a collection of statements. This text integrates practices that serve as the foundation of good programming skills. These practices are used in all examples and are reinforced in the discussions. Students learn how to solve problems as well as how to implement solutions. We introduce and integrate basic software engineering techniques throughout the text. The **Software Failure** vignettes reiterate these lessons by demonstrating the perils of not following these sound practices.
- *Examples*. Students learn by example. This text is filled with fully implemented examples that demonstrate specific concepts. We have intertwined small, readily understandable examples with larger, more realistic ones. There is a balance between graphics and nongraphics programs. The **VideoNotes** provide additional examples in a live presentation format.
- *Graphics and GUIs*. Graphics can be a great motivator for students, and their use can serve as excellent examples of object-orientation. As such, we use them throughout the text in a well-defined set of sections that we call the Graphics Track. The book fully embraces the JavaFX API, the preferred and fully-supported approach to Java graphics and GUIs. Students learn to build GUIs in the appropriate way by using a natural progression of topics. The Graphics Track can be avoided entirely for those who do not choose to use graphics.

Chapter Breakdown

Chapter 1 (Introduction) introduces computer systems in general, including basic architecture and hardware, networking, programming, and language translation. Java is introduced in this chapter, and the basics of general program development, as well as object-oriented programming, are discussed. This chapter contains broad introductory material that can be covered while students become familiar with their development environment.

Chapter 2 (Data and Expressions) explores some of the basic types of data used in a Java program and the use of expressions to perform calculations. It discusses the conversion of data from one type to another and how to read input interactively from the user with the help of the standard **`Scanner`** class.

Chapter 3 (Using Classes and Objects) explores the use of predefined classes and the objects that can be created from them. Classes and objects are used to manipulate character strings, produce random numbers, perform complex calculations, and format output. Enumerated types are also discussed.

Chapter 4 (Writing Classes) explores the basic issues related to writing classes and methods. Topics include instance data, visibility, scope, method parameters, and return types. Encapsulation and constructors are covered as well. Some of the more involved topics are deferred to or revisited in **Chapter 6**.

Chapter 5 (Conditionals and Loops) covers the use of boolean expressions to make decisions. Then the **`if`** statement and **`while`** loop are explored in detail. Once loops are established, the concept of an iterator is introduced and the **`Scanner`** class is revisited for additional input parsing and the reading of text files. Finally, the **`ArrayList`** class introduced, which provides the option for managing a large number of objects.

Chapter 6 (More Conditionals and Loops) examines the rest of Java's conditional (**`switch`**) and loop (**`do`**, **`for`**) statements. All related statements for conditionals and loops are discussed, including the enhanced version of the **`for`** loop. The for-each loop is also used to process iterators and **`ArrayList`** objects.

Chapter 7 (Object-Oriented Design) reinforces and extends the coverage of issues related to the design of classes. Techniques for identifying the classes and objects needed for a problem and the relationships among them are discussed. This chapter also covers static class members, interfaces, and the design of enumerated type classes. Method design issues and method overloading are also discussed.

Chapter 8 (Arrays) contains extensive coverage of arrays and array processing. The nature of an array as a low-level programming structure is contrasted to the higher-level object management approach. Additional topics include command-line arguments, variable length parameter lists, and multidimensional arrays.

Chapter 9 (Inheritance) covers class derivations and associated concepts such as class hierarchies, overriding, and visibility. Strong emphasis is put on the proper use of inheritance and its role in software design.

Chapter 10 (Polymorphism) explores the concept of binding and how it relates to polymorphism. Then we examine how polymorphic references can be accomplished using either inheritance or interfaces. Sorting is used as an example of polymorphism. Design issues related to polymorphism are examined as well.

Chapter 11 (Exceptions) explores the class hierarchy from the Java standard library used to define exceptions, as well as the ability to define our own exception objects. We also discuss the use of exceptions when dealing with input and output and examine an example that writes a text file.

Chapter 12 (Recursion) covers the concept, implementation, and proper use of recursion. Several examples from various domains are used to demonstrate how recursive techniques make certain types of processing elegant.

Chapter 13 (Collections) introduces the idea of a collection and its underlying data structure. Abstraction is revisited in this context and the classic data structures are explored. Generic types, map collections, the use of the **`var`** keyword, and lambda expressions are also introduced. This chapter serves as an introduction to a CS2 course.

Supplements

Student Online Resources

These student resources can be accessed at the book's Companion Website, "**https://media.pearsoncmg.com/ph/esm/ecs_lewis_java10e/cw/**"

- Source Code for all the programs in the text
- Links to Java development environments
- VideoNotes: short step-by-step videos demonstrating how to solve problems from design through coding. VideoNotes allow for self-paced instruction with easy navigation including the ability to select, play, rewind, fast-forward, and stop within each VideoNote exercise. Margin icons in your textbook let you know when a VideoNote video is available for a particular concept or homework problem.

Instructor Resources

The following supplements are available to qualified instructors only. Visit the Pearson Education Instructor Resource Center (**www.pearsonhighered.com/irc**) for information on how to access them:

- Presentation Slides—in PowerPoint.
- Solutions to end-of-chapter Exercises.
- Solutions to end-of-chapter Programming Projects.

- Lab Manual Solutions
- Solutions for the Revel

Features of the Text

Key Concepts

Throughout the text, the Key Concept boxes highlight fundamental ideas and important guidelines. These concepts are summarized at the end of each chapter.

Listings

All programming examples are presented in clearly labeled listings, followed by the program output, a sample run, or screen shot display as appropriate. The code is colored to visually distinguish comments and reserved words.

Syntax Diagrams

At appropriate points in the text, syntactic elements of the Java language are discussed in special highlighted sections with diagrams that clearly identify the valid forms for a statement or construct. Syntax diagrams for the entire Java language are presented in **Appendix J**.

Graphics Track

All processing that involves graphics and graphical user interfaces is discussed in one or two sections at the end of each chapter that we collectively refer to as the Graphics Track. This material can be skipped without loss of continuity, or focused on specifically as desired. The material in any Graphics Track section relates to the main topics of the chapter in which it is found. Graphics Track sections are indicated by a brown border on the edge of the page.

Summary of Key Concepts

The Key Concepts presented throughout a chapter are summarized at the end of the chapter.

Self-Review Questions and Answers

These short-answer questions review the fundamental ideas and terms established in the preceding section. They are designed to allow students to assess their own basic grasp of the material. The answers to these questions can be found at the end of the book in **Appendix K**.

Exercises

These intermediate problems require computations, the analysis or writing of code fragments, and a thorough grasp of the chapter content. While the exercises may deal with code, they generally do not require any online activity.

Programming Projects

These problems require the design and implementation of Java programs. They vary widely in level of difficulty.

VideoNotes

VideoNotes are narrated step-by-step video tutorials that show how to solve problems completely, from design through coding.

Software Failures

These between-chapter vignettes discuss real-world flaws in software design, encouraging students to adopt sound design practices from the beginning.

Acknowledgments

I am most grateful to the faculty and students from around the world who have provided their feedback on previous editions of this book. I am pleased to see the depth of the faculty's concern for their students and the students' thirst for knowledge. Your comments and questions are always welcome.

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The ACM Special Interest Group on Computer Science Education (SIGCSE) is a tremendous resource. Their conferences provide an opportunity for educators from all levels and all types of schools to share ideas and materials. If you are an educator in any area of computing and are not involved with SIGCSE, you're missing out.

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Chapter 1

Introduction

Learning Objectives

1. Describe the relationship between hardware and software.
2. Define various types of software and how they are used.
3. Identify the core hardware components of a computer and explain their roles.
4. Explain how the hardware components interact to execute programs and manage data.
5. Describe how computers are connected into networks to share information.
6. Introduce the Java programming language.
7. Describe the steps involved in program compilation and execution.
8. Present an overview of object-oriented principles.

This book is about writing well-designed software. To understand software, we must first have a fundamental understanding of its role in a computer system. Hardware and software cooperate in a computer system to accomplish complex tasks. The purpose of various hardware components and the way those components are connected into networks are important prerequisites to the study of software development. This chapter first discusses basic computer processing and then begins our exploration of software development by introducing the Java programming language and the principles of object-oriented programming.

1.1: Computer Processing

All computer systems, whether it's a desktop, laptop, tablet, smartphone, gaming console, or a special-purpose device such as a car's navigation system, share certain characteristics. The details vary, but they all process data in similar ways. While the majority of this book deals with the development of software, we'll begin with an overview of computer processing to set the context. It's important to establish some fundamental terminology and see how key pieces of a computer system interact.

A computer system is made up of hardware and software. The **hardware** components of a computer system are the physical, tangible pieces that support the computing effort. They include chips, boxes, wires, keyboards, speakers, disks, memory cards, universal serial bus (USB) flash drives (also called jump drives), cables, plugs, printers, mice, monitors, routers, and so on. If you can physically touch it and it can be considered part of a computer system, then it is computer hardware.

KEY CONCEPT

A computer system consists of hardware and software that work in concert to help us solve problems.

The hardware components of a computer are essentially useless without instructions to tell them what to do. A **program** is a series of instructions that the hardware executes one after another. **Software** consists of programs and the data that programs use. Software is the intangible counterpart to the physical hardware components. Together they form a tool that we can use to help solve problems.

The key hardware components in a computer system are

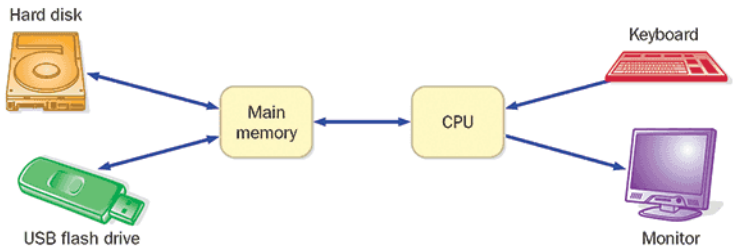
- central processing unit (CPU)
- input/output (I/O) devices
- main memory
- secondary memory devices

Each of these hardware components is described in detail in the next section. For now, let's simply examine their basic roles. The **central processing unit (CPU)** is a device that executes the individual commands of a program. **Input/output (I/O) devices**, such as the keyboard, mouse, trackpad, and **monitor**, allow a human being to interact with the computer.

Programs and data are held in storage devices called memory, which fall into two categories: main memory and secondary memory. **Main memory** is the storage device that holds the software while it is being processed by the **CPU**. **Secondary memory** devices store software in a relatively permanent manner. The most important secondary memory device of a typical computer system is the hard disk that resides inside the main computer box. A USB flash drive is also an important secondary memory device. A typical USB flash drive cannot store nearly as much information as a hard disk. USB flash drives have the advantage of **portability**; they can be removed temporarily or moved from computer to computer as needed.

Figure 1.1 shows how information moves among the basic hardware components of a computer. Suppose you have an executable program you wish to run. The program is stored on some secondary memory device, such as a hard disk. When you instruct the computer to execute your program, a copy of the program is brought in from secondary memory and stored in main memory. The CPU reads the individual program instructions from main memory. The CPU then executes the instructions one at a time until the program ends. The data that the instructions use, such as two numbers that will be added together, also are stored in main memory. They are either brought in from secondary memory or read from an input device such as the keyboard. During execution, the program may display information to an output device such as a monitor.

FIGURE 1.1
A simplified view of a computer system



KEY CONCEPT

The CPU reads the program instructions from main memory, executing them one at a time until the program ends.

The process of executing a program is fundamental to the operation of a computer. All computer systems basically work in the same way.

Software Categories

Software can be classified into many categories using various criteria. At this point, we will simply differentiate between system programs and application programs.

The **operating system** is the core software of a computer. It performs two important functions. First, it provides a **user interface** that allows the user to interact with the machine. Second, the operating system manages computer resources such as the CPU and main memory. It determines when programs are allowed to run, where they are loaded into memory, and how hardware devices communicate. It is the operating system's job to make the computer easy to use and to ensure that it runs efficiently.

KEY CONCEPT

The operating system provides a user interface and manages computer resources.

Several popular operating systems are in use today. The Windows operating system was developed for personal computers by Microsoft, which has captured the lion's share of the operating systems market. Various versions of the Unix operating system are also quite popular, especially in larger computer systems. A version of Unix called Linux was developed as an open-source project, which means that many people contributed to its development and its code is freely available. Because of that Linux has become a particular favorite among some users. Mac OS is an operating system used for computing systems developed by Apple Computers.

Operating systems are often specialized for mobile devices such as smartphones and tablets. The iOS operating system from Apple is used on the iPhone, iPad, and iPod. It is similar in functionality and appearance to the desktop Mac OS, but tailored for the smaller devices. The Android operating system developed by Google currently dominates the smartphone market.

An **application** (often shortened in conversation to "app") is a generic term for just about any software other than the operating system. Word processors, missile control systems, database managers, Web browsers, and games all can be considered application programs. Each application program has its own user interface that allows the user to interact with that particular program.

The user interface for most modern operating systems and applications is a **graphical user interface** (*GUI*, pronounced "gooey"), which, as the name implies, makes use of graphical screen elements. Among many others, these elements include

- **windows**, which are used to separate the screen into distinct work areas
- **icons**, which are small images that represent computer resources, such as a **file**
- **menus, checkboxes, and radio buttons**, which provide the user with selectable options
- **sliders**, which allow the user to select from a range of values
- **buttons**, which can be "pushed" with a mouse click to indicate a user selection

A mouse or trackpad is the primary input device used with GUIs; thus, GUIs are sometimes called *point-and-click interfaces*. The screenshot in **Figure 1.2** shows an example of a GUI.

FIGURE 1.2
An example of a graphical user interface (GUI)