

INTRODUCTION TO
JAVATM
PROGRAMMING

COMPREHENSIVE VERSION



9TH EDITION



Volume 2

Y. Daniel Liang

CONTENTS

Chapter 1	Introduction to Computers, Programs, and Java	1
1.1	Introduction	2
1.2	What Is a Computer?	2
1.3	Programming Languages	9
1.4	Operating Systems	12
1.5	Java, the World Wide Web, and Beyond	13
1.6	The Java Language Specification, API, JDK, and IDE	16
1.7	A Simple Java Program	16
	Creating, Compiling, and Executing a Java Program	19
	Displaying Text in a Message Dialog Box	22
	Programming Style and Documentation	24
1.11	Programming Errors	26
Chapter 2	Elementary Programming	33
2.1	Introduction	34
2.2	Writing a Simple Program	34
2.3	Reading Input from the Console	37
2.4	Identifiers	40
2.5	Variables	40
2.6	Assignment Statements and Assignment Expressions	42
2.7	Named Constants	43
2.8	Naming Conventions	44
2.9	Numeric Data Types and Operations	44
2.10	Numeric Literals	48
2.11	Evaluating Expressions and Operator Precedence	50
2.12	Case Study: Displaying the Current Time	51
2.13	Augmented Assignment Operators	53
2.14	Increment and Decrement Operators	54
2.15	Numeric Type Conversions	56
2.16	Software Development Process	58
2.17	Character Data Type and Operations	62
2.18	The String Type	68
2.19	Getting Input from Input Dialogs	70
Chapter 3	Selections	81
3.1	Introduction	82
3.2	boolean Data Type	82

30.3	Representing Graphs	1051
30.4	Modeling Graphs	1056
30.5	Graph Visualization	1066
30.6	Graph Traversals	1069
30.7	Depth-First Search (DFS)	1070
30.8	Case Study: The Connected Circles Problem	1074
30.9	Breadth-First Search (BFS)	1077
30.10	Case Study: The Nine Tails Problem	1080
Chapter 31	Weighted Graphs and Applications	1093
31.1	Introduction	1094
31.2	Representing Weighted Graphs	1095
31.3	The <code>WeightedGraph</code> Class	1097
31.4	Minimum Spanning Trees	1105
31.5	Finding Shortest Paths	1111
31.6	Case Study: The Weighted Nine Tails Problem	1119
Chapter 32	Multithreading and Parallel Programming	1129
32.1	Introduction	1130
32.2	Thread Concepts	1130
32.3	Creating Tasks and Threads	1130
32.4	The <code>Thread</code> Class	1134
32.5	Case Study: Flashing Text	1137
32.6	GUI Event Dispatch Thread	1138
32.7	Case Study: Clock with Audio	1139
32.8	Thread Pools	1142
32.9	Thread Synchronization	1144
32.10	Synchronization Using Locks	1148
32.11	Cooperation among Threads	1150
32.12	Case Study: Producer/Consumer	1155
32.13	Blocking Queues	1158
32.14	Semaphores	1160
32.15	Avoiding Deadlocks	1162
32.16	Thread States	1163
32.17	Synchronized Collections	1163
32.18	Parallel Programming	1165
Chapter 33	Networking	1175
33.1	Introduction	1176
33.2	Client/Server Computing	1176

33.3	The InetAddress Class	1183
33.4	Serving Multiple Clients	1184
33.5	Applet Clients	1187
33.6	Sending and Receiving Objects	1190
33.7	Case Study: Distributed Tic-Tac-Toe Games	1195

Chapter 34	Java Database Programming	1211
34.1	Introduction	1212
34.2	Relational Database Systems	1212
34.3	SQL	1216
34.4	JDBC	1227
34.5	PreparedStatement	1235
34.6	CallableStatement	1238
34.7	Retrieving Metadata	1241

Bonus Chapters 35–50 are available from the companion Website at www.pearsonhighered.com/liang:

Chapter 35	Internationalization	35-1
Chapter 36	JavaBeans	36-1
Chapter 37	Containers, Layout Managers, and Borders	37-1
Chapter 38	Menus, Toolbars, and Dialogs	38-1
Chapter 39	MVC and Swing Models	39-1
Chapter 40	JTable and JTree	40-1
Chapter 41	Advanced Database Programming	41-1
Chapter 42	Servlets	42-1
Chapter 43	JavaServer Pages	43-1
Chapter 44	JavaServer Faces	44-1
Chapter 45	Web Services	45-1
Chapter 46	Remote Method Invocation	46-1

3.3	if Statements	84
3.4	Case Study: Guessing Birthdays	86
3.5	Two-Way if-else Statements	89
3.6	Nested if and Multi-Way if-else Statements	91
3.7	Common Errors in Selection Statements	93
3.8	Generating Random Numbers	96
3.9	Case Study: Computing Body Mass Index	97
3.10	Case Study: Computing Taxes	99
3.11	Logical Operators	101
3.12	Case Study: Determining Leap Year	105
3.13	Case Study: Lottery	106
3.14	switch Statements	108
3.15	Conditional Expressions	111
3.16	Formatting Console Output	112
3.17	Operator Precedence and Associativity	115
3.18	Confirmation Dialogs	117
3.19	Debugging	119
Chapter 4	Loops	133
4.1	Introduction	134
4.2	The while Loop	134
4.3	The do-while Loop	144
4.4	The for Loop	146
4.5	Which Loop to Use?	150
4.6	Nested Loops	152
4.7	Minimizing Numeric Errors	154
4.8	Case Studies	155
4.9	Keywords <i>break</i> and <i>continue</i>	159
4.10	Case Study: Displaying Prime Numbers	162
4.11	Controlling a Loop with a Confirmation Dialog	164
Chapter 5	Methods	177
5.1	Introduction	178
5.2	Defining a Method	178
5.3	Calling a Method	180
5.4	void Method Example	183
5.5	Passing Parameters by Values	186
5.6	Modularizing Code	189
5.7	Case Study: Converting Decimals to Hexadecimals	191
5.8	Overloading Methods	193
5.9	The Scope of Variables	196
5.10	The Math Class	197

5.11	Case Study: Generating Random Characters	201
5.12	Method Abstraction and Stepwise Refinement	203

Chapter 6 Single-Dimensional Arrays 223

6.1	Introduction	224
6.2	Array Basics	224
6.3	Case Study: Lotto Numbers	231
6.4	Case Study: Deck of Cards	234
6.5	Copying Arrays	236
6.6	Passing Arrays to Methods	237
6.7	Returning an Array from a Method	240
6.8	Case Study: Counting the Occurrences of Each Letter	241
6.9	Variable-Length Argument Lists	244
6.10	Searching Arrays	245
6.11	Sorting Arrays	248
6.12	The Arrays Class	252

Chapter 7 Multidimensional Arrays 263

7.1	Introduction	264
7.2	Two-Dimensional Array Basics	264
7.3	Processing Two-Dimensional Arrays	267
7.4	Passing Two-Dimensional Arrays to Methods	269
7.5	Case Study: Grading a Multiple-Choice Test	270
7.6	Case Study: Finding the Closest Pair	272
7.7	Case Study: Sudoku	274
7.8	Multidimensional Arrays	277

Chapter 8 Objects and Classes 295

8.1	Introduction	296
8.2	Defining Classes for Objects	296
8.3	Example: Defining Classes and Creating Objects	298
8.4	Constructing Objects Using Constructors	303
8.5	Accessing Objects via Reference Variables	304
8.6	Using Classes from the Java Library	308
8.7	Static Variables, Constants, and Methods	312
8.8	Visibility Modifiers	317
8.9	Data Field Encapsulation	319
8.10	Passing Objects to Methods	322
8.11	Array of Objects	326

Chapter 9 Strings 335

9.1	Introduction	336
9.2	The String Class	336

5.11	Case Study: Generating Random Characters	201
5.12	Method Abstraction and Stepwise Refinement	203

Chapter 6 Single-Dimensional Arrays 223

6.1	Introduction	224
6.2	Array Basics	224
6.3	Case Study: Lotto Numbers	231
6.4	Case Study: Deck of Cards	234
6.5	Copying Arrays	236
6.6	Passing Arrays to Methods	237
6.7	Returning an Array from a Method	240
6.8	Case Study: Counting the Occurrences of Each Letter	241
6.9	Variable-Length Argument Lists	244
6.10	Searching Arrays	245
6.11	Sorting Arrays	248
6.12	The Arrays Class	252

Chapter 7 Multidimensional Arrays 263

7.1	Introduction	264
7.2	Two-Dimensional Array Basics	264
7.3	Processing Two-Dimensional Arrays	267
7.4	Passing Two-Dimensional Arrays to Methods	269
7.5	Case Study: Grading a Multiple-Choice Test	270
7.6	Case Study: Finding the Closest Pair	272
7.7	Case Study: Sudoku	274
7.8	Multidimensional Arrays	277

Chapter 8 Objects and Classes 295

8.1	Introduction	296
8.2	Defining Classes for Objects	296
8.3	Example: Defining Classes and Creating Objects	298
8.4	Constructing Objects Using Constructors	303
8.5	Accessing Objects via Reference Variables	304
8.6	Using Classes from the Java Library	308
8.7	Static Variables, Constants, and Methods	312
8.8	Visibility Modifiers	317
8.9	Data Field Encapsulation	319
8.10	Passing Objects to Methods	322
8.11	Array of Objects	326

Chapter 9 Strings 335

9.1	Introduction	336
9.2	The String Class	336

9.3	Case Study: Checking Palindromes	347
9.4	Case Study: Converting Hexadecimals to Decimals	348
9.5	The Character Class	350
9.6	The StringBuilder and StringBuffer	353
9.7	Command-Line Arguments	358
Chapter 10	Thinking in Objects	369
10.1	Introduction	370
10.2	Immutable Objects and Classes	370
10.3	The Scope of Variables	371
10.4	The this Reference	373
10.5	Class Abstraction and Encapsulation	375
10.6	Object-Oriented Thinking	379
10.7	Object Composition	382
10.8	Case Study: Designing the Course Class	384
10.9	Case Study: Designing a Class for Stacks	386
10.10	Case Study: Designing the GuessDate Class	388
10.11	Class Design Guidelines	391
10.12	Processing Primitive Data Type Values as Objects	393
10.13	Automatic Conversion between Primitive Types and Wrapper Class Types	396
10.14	The BigInteger and BigDecimal	397
Chapter 11	Inheritance and Polymorphism	407
11.1	Introduction	408
11.2	Superclasses and Subclasses	408
11.3	Using the super Keyword	414
11.4	Overriding Methods	418
11.5	Overriding vs. Overloading	418
11.6	The Object Class and Its toString()	420
11.7	Polymorphism	421
11.8	Dynamic Binding	422
11.9	Casting Objects and the instanceof Operator	425
11.10	The Object's equals method	429
11.11	The ArrayList Class	430
11.12	Case Study: A Custom Stack Class	436
11.13	The protected Data and Methods	437
11.14	Preventing Extending and Overriding	439
Chapter 12	GUI Basics	445
12.1	Introduction	446
12.2	Swing vs. AWT	446

12.3	The Java GUI API	446
12.4	Frames	449
12.5	Layout Managers	451
12.6	Using Panels as Subcontainers	458
12.7	The Color Class	460
12.8	The Font Class	461
12.9	Common Features of Swing GUI Components	462
12.10	Image Icons	465
12.11	JButton	467
12.12	JCheckBox	471
12.13	JRadioButton	472
12.14	Labels	473
12.15	Text Fields	474

Chapter 13 Graphics 479

13.1	Introduction	480
13.2	The Graphics Class	480
13.3	Drawing Strings, Lines, Rectangles, and Ovals	483
13.4	Case Study: The FigurePanel Class	485
13.5	Drawing Arcs	488
13.6	Drawing Polygons and Polylines	490
13.7	Centering a String Using the FontMetrics Class	493
13.8	Case Study: The MessagePanel Class	495
13.9	Case Study: The StillClock Class	500
13.10	Displaying Images	504
13.11	Case Study: The ImageViewer Class	506

Chapter 14 Exception Handling and Text I/O 517

14.1	Introduction	518
14.2	Exception-Handling Overview	518
14.3	Exception Types	523
14.4	More on Exception Handling	526
14.5	The finally Clause	534
14.6	When to Use Exceptions	535
14.7	Rethrowing Exceptions	536
14.8	Chained Exceptions	537
14.9	Defining Custom Exception Classes	538
14.10	The File Class	541
14.11	File Input and Output	544
14.12	File Dialogs	549
14.13	Reading Data from the Web	551

Chapter 15	Abstract Classes and Interfaces	559
15.1	Introduction	560
15.2	Abstract Classes	560
15.3	Case Study: the Abstract Number Class	565
15.4	Case Study: Calendar and GregorianCalendar	567
15.5	Interfaces	570
15.6	The Comparable Interface	573
15.7	The Cloneable Interface	577
15.8	Interfaces vs. Abstract Classes	581
15.9	Case Study: The Rational Class	584
Chapter 16	Event-Driven Programming	599
16.1	Introduction	600
16.2	Events and Event Sources	602
16.3	Listeners, Registrations, and Handling Events	603
16.4	Inner Classes	608
16.5	Anonymous Class Listeners	609
16.6	Alternative Ways of Defining Listener Classes	612
16.7	Case Study: Loan Calculator	615
16.8	Mouse Events	617
16.9	Listener Interface Adapters	620
16.10	Key Events	621
16.11	Animation Using the Timer Class	625
Chapter 17	GUI Components	639
17.1	Introduction	640
17.2	Events for JCheckBox, JRadioButton and JTextField	640
17.3	Text Areas	644
17.4	Combo Boxes	647
17.5	Lists	650
17.6	Scroll Bars	654
17.7	Sliders	657
17.8	Creating Multiple Windows	660
Chapter 18	Applets and Multimedia	671
18.1	Introduction	672
18.2	Developing Applets	672
18.3	The HTML File and the <applet>Tag	673
18.4	Applet Security Restrictions	675

18.5	Enabling Applets to Run as Applications	676
18.6	Applet Life-Cycle Methods	677
18.7	Passing Strings to Applets	679
18.8	Case Study: Bouncing Ball	683
18.9	Case Study: Developing a Tic-Tac-Toe Game	686
18.10	Locating Resources Using the URL Class	691
18.11	Playing Audio in Any Java Program	693
18.12	Case Study: National Flags and Anthems	695

Chapter 19 Binary I/O 709

19.1	Introduction	710
19.2	How Is Text I/O Handled in Java?	710
19.3	Text I/O vs. Binary I/O	711
19.4	Binary I/O Classes	712
19.5	Case Study: Copying Files	722
19.6	Object I/O	724
19.7	Random-Access Files	729

Chapter 20 Recursion 737

20.1	Introduction	738
20.2	Case Study: Computing Factorials	738
20.3	Case Study: Computing Fibonacci Numbers	741
20.4	Problem Solving Using Recursion	744
20.5	Recursive Helper Methods	746
20.6	Case Study: Finding the Directory Size	749
20.7	Case Study: Towers of Hanoi	750
20.8	Case Study: Fractals	754
20.9	Recursion vs. Iteration	757
20.10	Tail Recursion	758

Chapter 21 Generics 769

21.1	Introduction	770
21.2	Motivations and Benefits	770
21.3	Defining Generic Classes and Interfaces	772
21.4	Generic Methods	774
21.5	Case Study: Sorting an Array of Objects	776
21.6	Raw Types and Backward Compatibility	778
21.7	Wildcard Generic Types	779
21.8	Erasure and Restrictions on Generics	782
21.9	Case Study: Generic Matrix Class	784

Chapter 22	Lists, Stacks, Queues, and Priority Queues	793
22.1	Introduction	794
22.2	Collections	794
22.3	Iterators	798
22.4	Lists	799
22.5	The Comparator Interface	803
22.6	Static Methods for Lists and Collections	805
22.7	Case Study: Bouncing Balls	809
22.8	The Vector and Stack Classes	813
22.9	Queues and Priority Queues	814
22.10	Case Study: Evaluating Expressions	817
Chapter 23	Sets and Maps	829
23.1	Introduction	830
23.2	Sets	830
23.3	Comparing the Performance of Sets and Lists	838
23.4	Case Study: Counting Keywords	841
23.5	Maps	842
23.6	Case Study: Occurrences of Words	847
23.7	Singleton and Unmodifiable Collections and Maps	848
Chapter 24	Developing Efficient Algorithms	853
24.1	Introduction	854
24.2	Measuring Algorithm Efficiency Using Big O Notation	854
24.3	Examples: Determining Big O	856
24.4	Analyzing Algorithm Time Complexity	859
24.5	Finding Fibonacci Numbers Using Dynamic Programming	862
24.6	Finding Greatest Common Divisors Using Euclid's Algorithm	864
24.7	Efficient Algorithms for Finding Prime Numbers	869
24.8	Finding the Closest Pair of Points Using Divide-and-Conquer	875
24.9	Solving the Eight Queens Problem Using Backtracking	877
24.10	Computational Geometry: Finding a Convex Hull	880
Chapter 25	Sorting	893
25.1	Introduction	894
25.2	Bubble Sort	894
25.3	Merge Sort	896
25.4	Quick Sort	900
25.5	Heap Sort	904
25.6	Bucket Sort and Radix Sort	911
25.7	External Sort	913

Chapter 26 Implementing Lists, Stacks, Queues, and Priority Queues	927
26.1 Introduction	928
26.2 Common Features for Lists	928
26.3 Array Lists	932
26.4 Linked Lists	938
26.5 Stacks and Queues	952
26.6 Priority Queues	955
 Chapter 27 Binary Search Trees	 961
27.1 Introduction	962
27.2 Binary Search Trees	962
27.3 Deleting Elements from a BST	975
27.4 Tree Visualization	981
27.5 Iterators	984
27.6 Case Study: Data Compression	986
 Chapter 28 Hashing	 997
28.1 Introduction	998
28.2 What Is Hashing?	998
28.3 Hash Functions and Hash Codes	999
28.4 Handling Collisions Using Open Addressing	1001
28.5 Handling Collisions Using Separate Chaining	1005
28.6 Load Factor and Rehashing	1005
28.7 Implementing a Map Using Hashing	1007
28.8 Implementing Set Using Hashing	1016
 Chapter 29 AVL Trees	 1027
29.1 Introduction	1028
29.2 Rebalancing Trees	1028
29.3 Designing Classes for AVL Trees	1031
29.4 Overriding the insert Method	1032
29.5 Implementing Rotations	1033
29.6 Implementing the delete Method	1034
29.7 The AVLTree Class	1034
29.8 Testing the AVLTree Class	1040
29.9 AVL Tree Time Complexity Analysis	1043
 Chapter 30 Graphs and Applications	 1047
30.1 Introduction	1048
30.2 Basic Graph Terminologies	1049