

# Computing Concepts with Java Essentials

Third Edition

Advanced Placement\*  
Computer Science Study Guide

**FRANCES P. TREES**

*Drew University*

**CAY HORSTMANN**

*San Jose State University*



**JOHN WILEY & SONS, INC**

*New York / Chichester / Weinheim / Brisbane / Singapore / Toronto*

\* AP and Advanced Placement are registered trademarks of the College Entrance Examination Board, which was not involved in the production of and does not endorse this product.

ACQUISITIONS EDITOR  
MARKETING MANAGER  
PROJECT MANAGER  
EDITORIAL ASSISTANT  
COVER DESIGN

Paul Crockett  
Katherine Hepburn  
Cindy Johnson  
Simon Durkin  
Susan Cyr / Harry Nolan

This book was set in Times New Roman and printed and bound by J&M Reproductions. The cover was printed by J&M Reproductions.

This book is printed on acid-free paper.

The paper in this book was manufactured by a mill whose forest management programs include sustained-yield harvesting of its timberlands. Sustained-yield harvesting principles ensure that the numbers of trees cut each year does not exceed the amount of new growth.

\* AP and Advanced Placement are registered trademarks of the College Entrance Examination Board, which was not involved in the production of and does not endorse this product.

Copyright 2004 © John Wiley & Sons, Inc. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, E-Mail: PERMREQ@WILEY.COM. To order books or for customer service, please call 1-800-CALL-WILEY (225-5945)

ISBN 0-471-44939-3

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

# **PREFACE**

This Study Guide is designed to assist high school students preparing for the AP Computer Science Examination. It is organized and designed to accompany *Computing Concepts with Java Essentials, 3rd. ed.*, and *Big Java*, both by Cay Horstmann and published by John Wiley & Sons, Inc.

## **To the Student**

Advanced Placement Computer Science is a college level course. As a student in an AP course, you are expected to understand college level material and to read college level textbooks. Because these texts may be used in multiple college courses, they contain material that is not tested on the AP Computer Science (CS) Examinations. This guide identifies and stresses the content that is tested on the AP CS Exams. This does not imply that you should skip the additional material in the text. Your teacher may include the additional material in your course and hold you responsible for that material. Some of the material that is not tested on the exam is extremely useful and may be included in your course. By following this guide, you will be able to focus on the topics included in the AP CS 2003-2004 Topic Outline and the elements of the AP Java subset that will be tested on the exam. Because the guide is designed for students taking either the A or the AB Computer Science exam, topics covered on the AB Exam are marked “AB only.” If you are participating in an AP CS A course, this should not discourage you from reading these sections; it merely indicates that those topics will be tested on the AB exam and not the A Exam.

## **Features of the Study Guide**

This guide is organized to help students recognize and master those topics that will be tested on both the A and AB examinations. Where applicable, each chapter includes:

### ***Topic Summary***

This section parallels the material in the textbook, adding additional examples and explanation of topics presented in the text. Students will find special emphasis here on topics that are likely to be tested.

### ***Expanded Coverage of Topics not Found in the Text***

Any topics in the AP CS Topic Outline or the AP Java subsets that are not covered in the text are presented in this section. In addition, Appendix A includes two additional textbook chapters that expand the coverage of data structures and algorithms needed for the AP exam.

### ***Topics That are Useful but not Tested***

This section alerts students to sections of the textbook that present useful features of the Java language. Although these sections are not required for the AP exam, they address features of Java programs that students are likely to encounter, or that they will need to progress in their programming ability.

### ***Things to Remember When Taking the Exam***

Each chapter restates important concepts and provides specific suggestions for avoiding common errors.

### ***Key Words***

Vocabulary used in the chapter is listed alphabetically here for student review and reference. Each key word is accompanied by the page number(s) where it is defined and/or discussed in the text.

### ***Connecting the Detailed Topic Outline with the Text***

This listing links the topics presented in the guide to the pages in the text where the same topics are covered.

### ***Practice Questions (Multiple Choice and Free Response)***

A large number of practice questions, modeled after those on the AP exam, are included in each chapter. The questions use the multiple-choice and free-response formats that students will encounter on the exam. Answers to the practice questions are provided in Appendix D.

### ***AB Examination Topics***

Any sections (and practice questions) that cover topics that will not be tested on the Computer Science A exam are clearly marked “AB only.” Students who are preparing for the AB exam should be sure to complete these sections.

## **Web Resources**

The AP Computer Science Topic Outline and Quick Reference Guides that students may use during the AP exam are available from the College Board’s Web site at <http://www.collegeboard.com/ap/students/compsci/>. The Quick Reference Guides list the classes, interfaces, and methods contained in the Java subset covered by the AP exam. The AP Computer Science Topic Outline and the AP testable Java subsets may be revised from time to time, so you are encouraged to check for the most current version of these documents in the AP Computer Science Course Description on the College Board site.

Web sites associated with this guide and with *Computing Concepts with Java Essentials, 3rd. ed.*, and *Big Java* are another important resource for users of this guide. Cay Horstmann’s site, <http://www.horstmann.com>, contains an expansion of Chapter 19, Help with Common Compilers, that provides installation tips and getting started instructions for the most commonly used Java compilers and environments. You will also find source code for programs in the text(s) and Appendix A, solutions to selected exercises in the text(s), frequently asked questions, a programming style guide, and more.

Many of these same items are also available from the Wiley Web site at <http://www.wiley.com/college/horstmann>, plus instructor resources not available to students.

## **Acknowledgments**

It has been a sincere pleasure working with Cay Horstmann, master computer scientist and teacher, in the creation of this guide. I will always value this experience.

Many thanks to Paul Crockett for providing the opportunity for me to be involved in this project and to Cindy Johnson and her staff at Publishing Services for their hard work, support, and patience throughout. I am extremely grateful to Joe Kmoch, *Washington High School*, whose review offered many valuable comments and suggestions. I also am grateful to Judy Hromcik, *Arlington High School*, and David Levine, *St. Bonaventure University*, for their suggestions and encouragement.

My energy and enthusiasm for AP Computer Science is constantly renewed by the many AP CS teachers that I work with at AP CS workshops and, of course, by my AP CS students, some of whom are now AP CS teachers!

Finally, thanks to Eli for his patience, encouragement and support.

*This work is dedicated to my mother.  
F.T.*



# **CONTENTS IN BRIEF**

1. Introduction	<b>1</b>
2. Hardware and Software (1)*	<b>9</b>
3. Introduction to Objects and Classes (2)	<b>17</b>
4. Fundamental Data Types (3)	<b>35</b>
5. Decisions (5)	<b>55</b>
6. Iteration (6)	<b>73</b>
7. Designing Classes (7)	<b>93</b>
8. Testing and Debugging (8)	<b>113</b>
9. Interfaces and Polymorphism (9)	<b>121</b>
10. Inheritance (11)	<b>137</b>
11. Array Lists and Arrays (13)	<b>163</b>
12. Exception Handling (14)	<b>195</b>
13. System Design (16)	<b>207</b>
14. Recursion (17)	<b>221</b>
15. Introduction to Sorting and Searching (18)	<b>235</b>
16. Introduction to Data Structures (AB) (19)	<b>263</b>
17. Advanced Data Structures (AB) (20, A-20, and A-20A)	<b>303</b>
18. Information about the Case Study	<b>355</b>
19. Help with Common Compilers	<b>359</b>
A. Advanced Data Structures and Algorithms (Expanded Coverage)	<b>368</b>
B. Exercise Solutions	<b>437</b>

\* Parenthesis indicates the corresponding chapter in *Computing Concepts with Java Essentials, 3rd ed.*, and *Big Java*.

# CONTENTS

- 1. Introduction 1**
  - 1.1 What is Advanced Placement? 1
    - 1.1.1 Computer Science as an AP Subject
  - 1.2 Who Takes AP Courses? 2
    - 1.2.1 Who Takes AP CS?
  - 1.3 What is the Difference between AP Computer Science A and AB? 3
    - 1.3.1 AP CS Course Organization
  - 1.4 Which Elements of Computer Science Are on the AP Exam? 4
    - 1.4.1 Format of the AP CS Exam
  - 1.5 Strategies for Taking the AP CS Exam 4
    - 1.5.1 Strategies for Part 1
    - 1.5.2 Strategies for Part 2
    - 1.5.3 Materials
    - 1.5.4 Last Minute Reminders
  - 1.6 How are the Exams Graded? 6
    - 1.6.1 Special Recognition for Doing Well
  - 1.7 How Should this Guide be Used to Prepare for the AP CS Exam? 7
  - 1.8 Where Can I Get More Information? 7
    - 1.8.1 Where Can I Get the Text Ancillaries?
  - 1.9 Are There Other Suggestions for Success in AP CS? 8
- 2. Hardware and Software 9**
  - 2.1 Hardware Components 9
    - 2.1.1 The Anatomy of a Computer
  - 2.2 System Software 10
  - 2.3 Types of Systems 10
  - 2.4 A Simple Program 10
    - 2.4.1 Escape Sequences
    - 2.4.2 Java Comments
  - 2.5 Errors 11
- 3. Introduction to Objects and Classes 17**
  - 3.1 Using and Constructing Objects 17
  - 3.2 Object Variables 18
    - 3.2.1 Importing Classes
  - 3.3 Defining a Class 20
  - 3.4 Testing a Class 21
  - 3.5 Instance Fields 21
  - 3.6 Constructors 22
  - 3.7 Designing the Public Interface of a Class 22
    - 3.7.1 Overloading
  - 3.8 Commenting the Public Interface 23
  - 3.9 Specifying the Implementation of a Class 23
  - 3.10 Variable Types 25
  - 3.11 Explicit and Implicit Method Parameters 26
- 4. Fundamental Data Types 35**
  - 4.1 Number Types 35
  - 4.2 Assignment 36
  - 4.3 Constants 37
  - 4.4 Arithmetic and Mathematical Functions 38
    - 4.4.1 Calling Static Methods
    - 4.4.2 Type Conversion
  - 4.5 Strings 42
  - 4.6 Comparing Primitive Types and Objects 44
- 5. Decisions 55**
  - 5.1 The `if` Statement 55
  - 5.2 Comparing Values 56
    - 5.2.1 The `null` Reference
    - 5.2.2 Dangling `else`
  - 5.3 Using Boolean Expressions 61
    - 5.3.1 Short Circuit Evaluation
    - 5.3.2 Using Boolean Variables



- 6. Iteration 73**
  - 6.1 while Loops 73
  - 6.2 for Loops 74
  - 6.3 Nested Loops 76
  - 6.4 Off-by-1 Errors 77
  - 6.5 Random Numbers and Simulations 78
  - 6.6 Loop Invariants (AB only) 79
- 7. Designing Classes 93**
  - 7.1 Choosing Classes 93
  - 7.2 Cohesion and Coupling 94
  - 7.3 Accessor and Mutator Methods 95
  - 7.4 Parameter Passing 95
  - 7.5 Side Effects 98
  - 7.6 Preconditions and Postconditions 98
    - 7.6.1 Class Invariants (AB)
  - 7.7 Static Methods 100
  - 7.8 Static Fields 100
  - 7.9 Scope 101
    - 7.9.1 Scope of Local Variables
    - 7.9.2 Scope of Class Members
  - 7.10 Initializing Variables 101
  - 7.11 Packages 102
- 8. Testing and Debugging 113**
  - 8.1 Unit Tests 113
  - 8.2 Test Case Evaluation 114
  - 8.3 Program Traces and Assertions 114
  - 8.4 The Debugger 115
- 9. Interfaces and Polymorphism 121**
  - 9.1 Developing Reusable Solutions 121
  - 9.2 Converting Between Types 127
    - 9.2.1 Constants in Interfaces
  - 9.3 Polymorphism 128
- 10. Inheritance 137**
  - 10.1 Introduction to Inheritance 137
  - 10.2 Inheritance Hierarchies 141
  - 10.3 Inheriting Instance Fields and Methods 143
  - 10.4 Subclass Construction 143
  - 10.5 Converting from Subclasses to Superclasses 144
  - 10.6 Abstract Classes 147
  - 10.7 Access Control 148
  - 10.8 Object: The Cosmic Superclass 148
    - 10.8.1 Overriding the toString Method
    - 10.8.2 Overriding the equals Method
- 11. Array Lists and Arrays 163**
  - 11.1 Array Lists 163
    - 11.1.1 A Word about Efficiency
    - 11.1.2 Wrapper Classes
  - 11.2 Arrays 169
    - 11.2.1 One-Dimensional Arrays
    - 11.2.2 Another Word about Efficiency
    - 11.2.3 Two-Dimensional Arrays (AB)
- 12. Exception Handling 195**
  - 12.1 Introduction to Exceptions 195
  - 12.2 Understanding Unchecked Exceptions 196
  - 12.3 Throwing Exceptions (AB only) 199
- 13. System Design 207**
  - 13.1 Designing Software Systems 207
  - 13.2 The Software Life Cycle 208
  - 13.3 Discovering Classes 208
  - 13.4 Relationships between Classes 208
  - 13.5 Responsibilities of a Class 209
- 14. Recursion 221**
  - 14.1 Thinking Recursively 221
  - 14.2 Permutations 223
  - 14.3 Tracing Through Recursive Methods 225
  - 14.4 Recursive Helper Methods and Mutual Recursion 226
  - 14.5 A Word About Efficiency 226
- 15. Introduction to Sorting and Searching 235**
  - 15.1 Selection Sort 235
    - 15.1.1 Analyzing the Performance of the Selection Sort Algorithm
  - 15.2 Insertion Sort 238
    - 15.2.1 Analyzing the Performance of the Insertion Sort Algorithm

- 15.3 Merge Sort 241
  - 15.3.1 Analyzing the Performance of the Merge Sort Algorithm
- 15.4 Quicksort (AB only) 243
  - 15.4.1 Analyzing the Performance of the Quicksort Algorithm
- 15.5 Comparing  $O(n^2)$  and  $O(n \log(n))$  (AB only) 245
- 15.6 Sequential Search 246
  - 15.6.1 Analyzing the Performance of the Sequential Search Algorithm (AB only)
- 15.7 Binary Search 247
  - 15.7.1 Analyzing the Performance of the Binary Search Algorithm
- 15.8 Comparing  $O(n)$  and  $O(\log(n))$  (AB only) 248

## **16. Introduction to Data Structures (AB) 263**

- 16.1 Using Linked Lists 263
- 16.2 Implementing Linked Lists 268
  - 16.2.1 Doubly Linked Lists
  - 16.2.2 Circularly Linked Lists
  - 16.2.3 Header and Trailer Nodes
- 16.3 Abstract and Concrete Data Types 280
- 16.4 Stacks 281
- 16.5 Queues 284

## **17. Advanced Data Structures (AB) 303**

- 17.1 Sets 303
- 17.2 Maps 304
- 17.3 Hash Tables 306
  - 17.3.1 Using HashSet
  - 17.3.2 Implementing HashSet
  - 17.3.3 Using HashMap
  - 17.3.4 Implementing HashMap
- 17.4 Computing Hash Codes 314
- 17.5 Binary Search Trees 314
  - 17.5.1 Binary Tree Traversals
  - 17.5.2 Searching a Binary Search Tree
  - 17.5.3 Removing a Node from a Binary Search Tree
- 17.6 Using Tree Sets and Tree Maps 322
- 17.7 Priority Queues 330
- 17.8 Heaps 333
  - 17.8.1 Implementing a Heap
  - 17.8.2 The Heapsort Algorithm
- 17.9 Choosing a Container 335

## **18. Information about the Case Study 355**

- 18.1 What Is a Case Study? 355
- 18.2 Why Are Case Studies Included in AP CS? 356
- 18.3 How Do I Use the Case Study During the School Year? 356
- 18.4 How Do I Prepare for the Case Study Questions on the AP Exam? 356
- 18.5 Where Do I Get the Case Study? 357

## **19. Help with Common Compilers 359**

- 19.1 Java™ 2 Platform 359
- 19.2 Command Line Programming 360
- 19.3 Common Integrated Development Environments 361
  - 19.3.1 BlueJ
  - 19.3.2 Eclipse
  - 19.3.3 JCreator
  - 19.3.4 JJ
  - 19.3.5 Metrowerks CodeWarrior
  - 19.3.6 NetBeans

## **Appendices**

### **A. Advanced Data Structures and Algorithms (Expanded Coverage) 368**

### **B. Exercise Solutions 437**