JAVA PROGRAMMING

FROM PROBLEM ANALYSIS TO PROGRAM DESIGN

5 EDITION

D.S. Malik

Java Programming

From Problem Analysis to Program Design

Fifth Edition

D.S. Malik

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D.S. Malik

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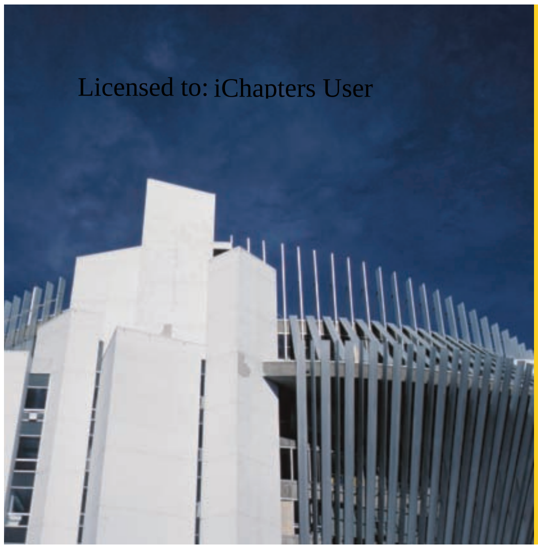
TO

My Daughter

Shelly Malik



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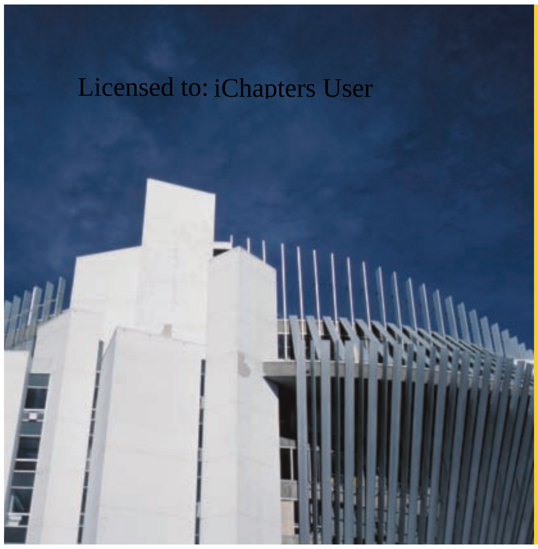

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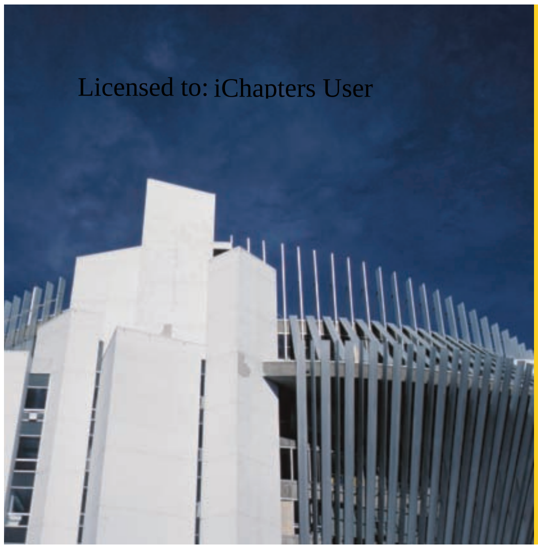


PREFACE TO THE FIFTH EDITION

Welcome to *Java Programming: From Problem Analysis to Program Design, Fifth Edition*. Designed for a first Computer Science (CS1) Java course, this text will provide a breath of fresh air to you and your students. The CS1 course serves as the cornerstone of the Computer Science curriculum. My primary goal is to motivate and excite all programming students, regardless of their level. Motivation breeds excitement for learning. Motivation and excitement are critical factors that lead to the success of the programming student. This text is the culmination and development of my classroom notes throughout more than fifty semesters of teaching successful programming.

Warning: This text can be expected to create a serious reduction in the demand for programming help during your office hours. Other side effects include significantly diminished student dependency on others while learning to program.

The primary focus in writing this text is on student learning. Therefore, in addition to clear explanations, we address the key issues that otherwise impede student learning. For example, a common question that arises naturally during an early programming assignment is: "How many variables and what kinds are needed in this program?" We illustrate this important and crucial step by helping students learn why variables are needed and how data in a variable is manipulated. Next students learn that the analysis of the problem will spill the number and types of the variables. Once students grasp this key concept, control structures (selection and loops) become easier to learn. The second major impediment in learning programming is parameter passing. We pay special attention to this topic. First students learn how to use predefined methods and how actual and formal parameters relate. Next students learn about user-defined methods. They see visual diagrams that help them learn how methods are called and how formal parameters affect actual parameters. Once students have a clear understanding of these two key concepts, they readily assimilate advanced topics.

The topics are introduced at a pace that is conducive to learning. The writing style is friendly, engaging, and straightforward. It parallels the learning style of the contemporary CS1 student. Before introducing a key concept, the student learns why the concept is needed, and then sees examples illustrating the concept. Special attention is paid to topics that are essential in mastering the Java programming language and in acquiring a foundation for further study of computer science.

Other important topics include debugging techniques and techniques for avoiding programming bugs. When a beginner compiles his/her first program and sees that the number of errors exceeds the length of this first program, he/she becomes frustrated by the plethora of errors, only some of which can be interpreted. To ease this frustration and help students learn to produce correct programs, debugging and bug avoidance techniques are presented systematically throughout the text.

Changes in the Fifth Edition

The main changes are:

- In the fifth edition, new debugging sections have been added and some of the old ones have been rewritten. These sections are indicated with a debugging icon.
- The fifth edition contains more than 125 new exercises, 27 new programming exercises, and numerous new examples spread throughout the book.
- In Chapters 6 and 12 the GUI figures have been captured and replaced in Windows 7 Professional environment.
- Appendix D contains screen images illustrating how to compile and execute a Java program using the command-line statements as well as how to set the path in Windows 7 Professional environment.

These changes were implemented based on comments from the text reviewers of the fifth edition. The source code and the programming exercises are developed and tested using Java 6.0 and the version of Java 7.0 available at the time this book was being typeset.

Approach

Once conceived as a Web programming language, Java slowly but surely found its way into classrooms where it now serves as a first programming language in computer science curricula (CS1). Java is a combination of traditional style programming—programming with a non-graphical user interface—and modern style programming with a graphical user interface (GUI). This book introduces you to both styles of programming. After giving a brief description of each chapter, we discuss how to read this book.

Chapter 1 briefly reviews the history of computers and programming languages. The reader can quickly skim and become familiar with some of the hardware and software components of the computer. This chapter also gives an example of a Java program and describes how a Java program is processed. The two basic problem-solving techniques, structured programming and object-oriented design, are also presented.

After completing Chapter 2, students become familiar with the basics of Java and are ready to write programs that are complicated enough to do some computations. The debugging section in this chapter illustrates how to interpret and correct syntax errors.

The three terms that you will encounter throughout the book are—primitive type variables, reference variables, and objects. Chapter 3 makes clear distinctions between these terms and sets the tone for the rest of the book. An object is a fundamental entity in an object-oriented programming language. This chapter further explains how an object works. The **class** `String` is one of the most important classes in Java. This chapter introduces this class and explains how various methods of this class can be used to manipulate strings. Because input/output is fundamental to any programming language, it is introduced early, and is covered in detail in Chapter 3. The debugging section in this chapter illustrates how to find and correct logical errors.

Chapters 4 and 5 introduce control structures used to alter the sequential flow of execution. The debugging sections in these chapters discuss and illustrate logical errors associated with selection and looping structures.

Java is equipped with powerful yet easy-to-use graphical user interface (GUI) components to create user-friendly graphical programs. Chapter 6 introduces various GUI components and gives examples of how to use these components in Java application programs. Because Java is an object-oriented programming language, the second part of Chapter 6 discusses and gives examples of how to solve various problems using object-oriented design methodology.

Chapter 7 discusses user-defined methods. Parameter passing is a fundamental concept in any programming language. Several examples, including visual diagrams, help readers understand this concept. It is recommended that readers with no prior programming background spend extra time on this concept. The debugging section in this chapter discuss how to debug a program using stubs and drivers.

Chapter 8 discusses user-defined classes. In Java, a class is an important and widely used element. It is used to create Java programs, group related operations, and it allows users to create their own data types. This chapter uses extensive visual diagrams to illustrate how objects of classes manipulate data.

Chapter 9 describes arrays. This chapter also introduces variable length formal parameter lists. In addition, this chapter introduces foreach loops and explains how this loop can be used to process the elements of an array. This chapter also discusses the sequential searching algorithm and the **class** `Vector`.

Inheritance is an important principle of object-oriented design. It encourages code reuse. Chapter 10 discusses inheritance and gives various examples to illustrate how classes are derived from existing classes. In addition, this chapter also discusses polymorphism, abstract classes, inner classes, and composition.

An occurrence of an undesirable situation that can be detected during program execution is called an exception. For example, division by zero is an exception. Java provides extensive support for handing exceptions. Chapter 11 shows how to handle exceptions in a program. Chapter 11 also discusses event handling, which was introduced in Chapter 6. Chapter 12 picks up the discussion of GUI components started in Chapter 6. This chapter introduces additional GUI components and discusses how to create applets.

Chapter 13 introduces recursion. Several examples illustrate how recursive methods execute.

Chapter 14 discusses a binary search algorithm as well as bubble sort, selection sort, insertion sort, and quick sort algorithms. Additional content covering the sorting algorithms bubble sort and quick sort is provided online at *www.cengagebrain.com*.

Appendix A lists the reserved words in Java. Appendix B shows the precedence and associativity of the Java operators. Appendix C lists the ASCII (American Standard Code for Information Interchange) portion of the Unicode character set as well as the EBCDIC (Extended Binary Code Decimal Interchange) character set.

Appendix D contains additional topics in Java. The topics covered are converting a base 10 number to binary (base 2) number and vice versa, converting a number from base 2 to base 8 (base 16) and vice versa, how to compile and execute a Java program using command line statements, how to create Java style documentation of the user-defined classes, how to create packages, how to use user-defined classes in a Java program, and `enum` type. Appendix E gives answers to the odd-numbered exercises in the text. Those odd-numbered exercises with very long solutions will not be in the text, but will be provided to students online at *www.cengagebrain.com*.

How To Use This Book

Java is a complex and very powerful language. In addition to traditional (non-GUI) programming, Java provides extensive support for creating programs that use a graphical user interface (GUI). Chapter 3 introduces graphical input and output dialog boxes. Chapter 6 introduces the most commonly used GUI components such as labels, buttons, and text fields. More extensive coverage of GUI components is provided in Chapter 12.

This book can be used in two ways. One way is an integrated approach in which readers learn how to write both non-GUI and GUI programs as they learn basic programming concepts and skills. The other approach focuses on illustrating fundamental programming concepts with non-GUI programming first, and later incorporating GUI components. The recommended chapter sequence for each of these approaches is as follows:

- **Integrated approach:** Study all chapters in sequence.
- **Non-GUI first, then GUI:** Study Chapters 1–5 in sequence. Then study Chapters 7–11 and Chapters 13 and 14. This approach initially skips Chapters 6 and 12, the primary GUI chapters. After studying Chapters 1–5, 7–11, 13, and 14, the reader can come back to study Chapters 6 and 12, the GUI chapters. Also note that Chapter 14 can be studied after Chapter 9.

If you choose the second approach, it should also be noted that the Programming Examples in Chapters 8 and 10 are developed first without any GUI components, and then the programs are extended to incorporate GUI components. Also, if Chapter 6 is skipped, the reader can skip the event handling part of Chapter 11. Chapter 13 (recursion) contains two Programming Examples: one creates a non-GUI application program, while the other creates a program that uses GUI. If you skip Chapters 6 and 12, you can skip the GUI part of the Programming Examples in Chapters 8, 10, 11, and 13. Once you have studied Chapter 6 and 12, you can study the GUI part of the Programming Examples of Chapters 8, 10, 11, and 13.

Figure 1 shows a chapter dependency diagram for this book. Solid arrows indicate that the chapter at the beginning of the arrow is required before studying the chapter at the end of the arrow. A dotted arrow indicates that the chapter at the beginning of the arrow is not essential to studying the chapter at the end of the dotted arrow.

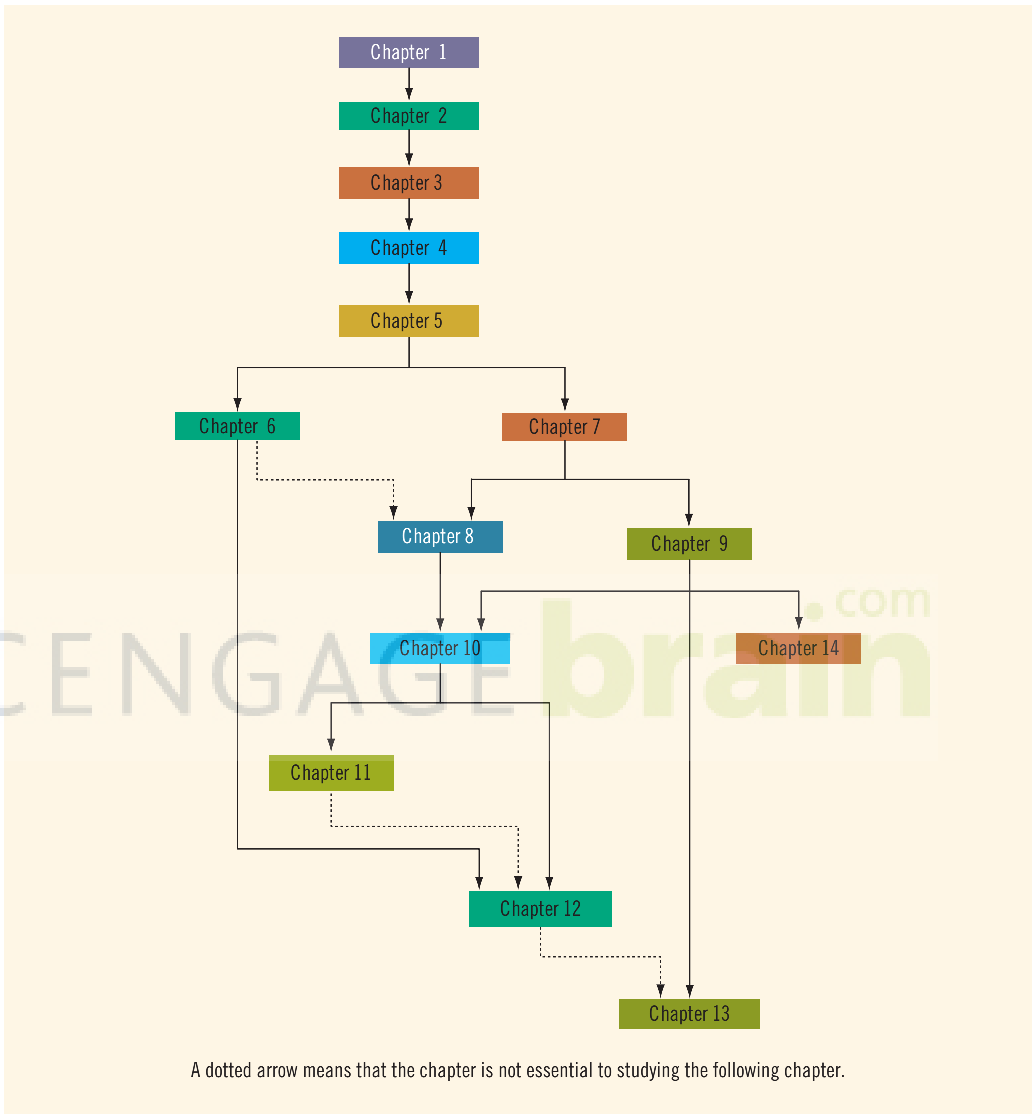
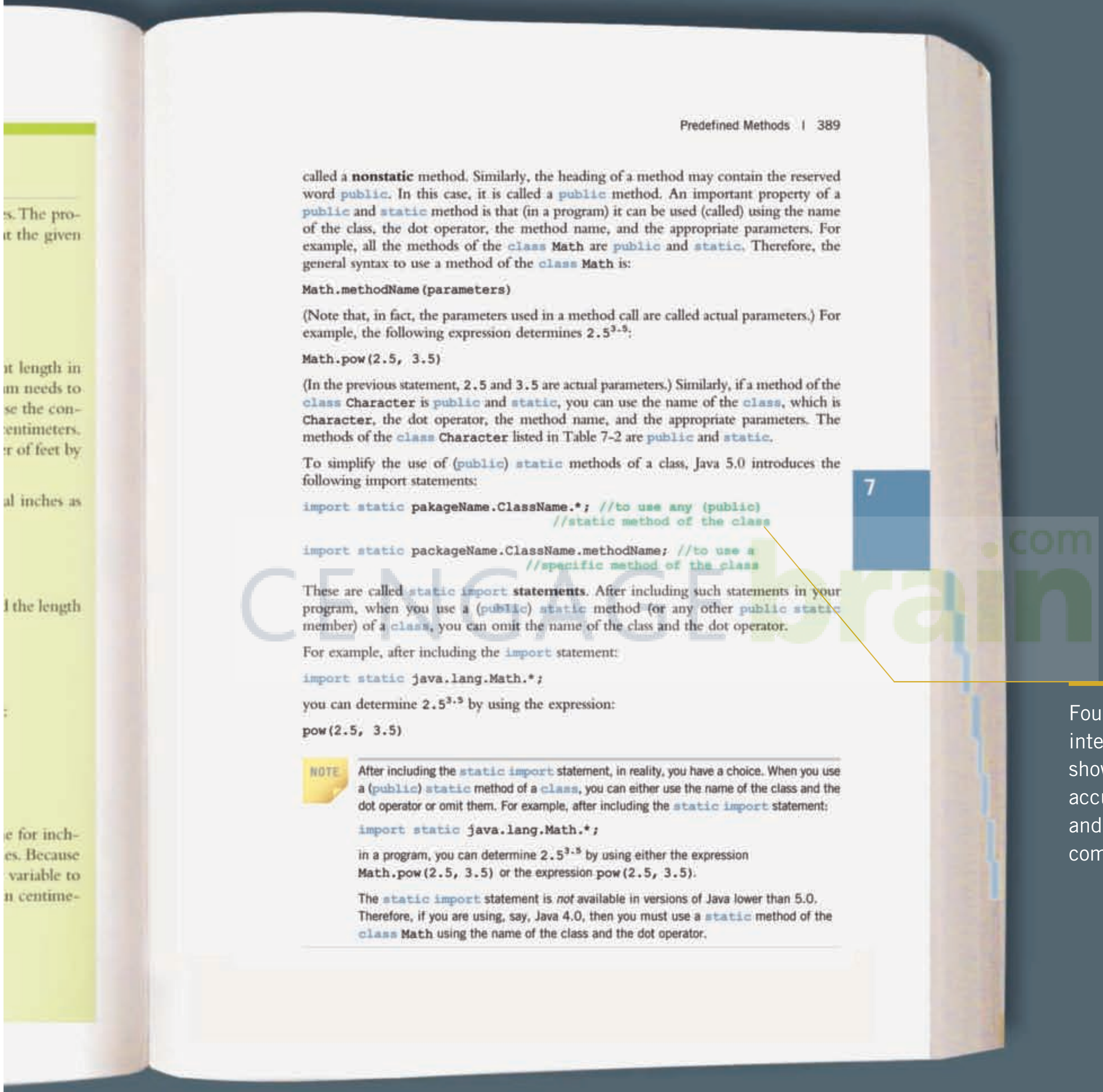


FIGURE 1 Chapter dependency diagram

All source code and solutions have been written, compiled, and quality assurance tested with Java 6.0 and the version of Java 7.0 available at the time this book was being typeset.

Features of the Book



called a **nonstatic** method. Similarly, the heading of a method may contain the reserved word `public`. In this case, it is called a `public` method. An important property of a `public` and `static` method is that (in a program) it can be used (called) using the name of the class, the dot operator, the method name, and the appropriate parameters. For example, all the methods of the `class Math` are `public` and `static`. Therefore, the general syntax to use a method of the `class Math` is:

```
Math.methodName(parameters)
```

(Note that, in fact, the parameters used in a method call are called actual parameters.) For example, the following expression determines $2.5^{3.5}$:

```
Math.pow(2.5, 3.5)
```

(In the previous statement, `2.5` and `3.5` are actual parameters.) Similarly, if a method of the `class Character` is `public` and `static`, you can use the name of the `class`, which is `Character`, the dot operator, the method name, and the appropriate parameters. The methods of the `class Character` listed in Table 7-2 are `public` and `static`.

To simplify the use of (`public`) `static` methods of a class, Java 5.0 introduces the following import statements:

```
import static pakageName.ClassName.*; //to use any (public)
                                      //static method of the class

import static packageName.ClassName.methodName; //to use a
                                                //specific method of the class
```

These are called `static import` **statements**. After including such statements in your program, when you use a (`public`) `static` method (or any other `public static` member) of a `class`, you can omit the name of the class and the dot operator.

For example, after including the `import` statement:

```
import static java.lang.Math.*;
```

you can determine $2.5^{3.5}$ by using the expression:

```
pow(2.5, 3.5)
```

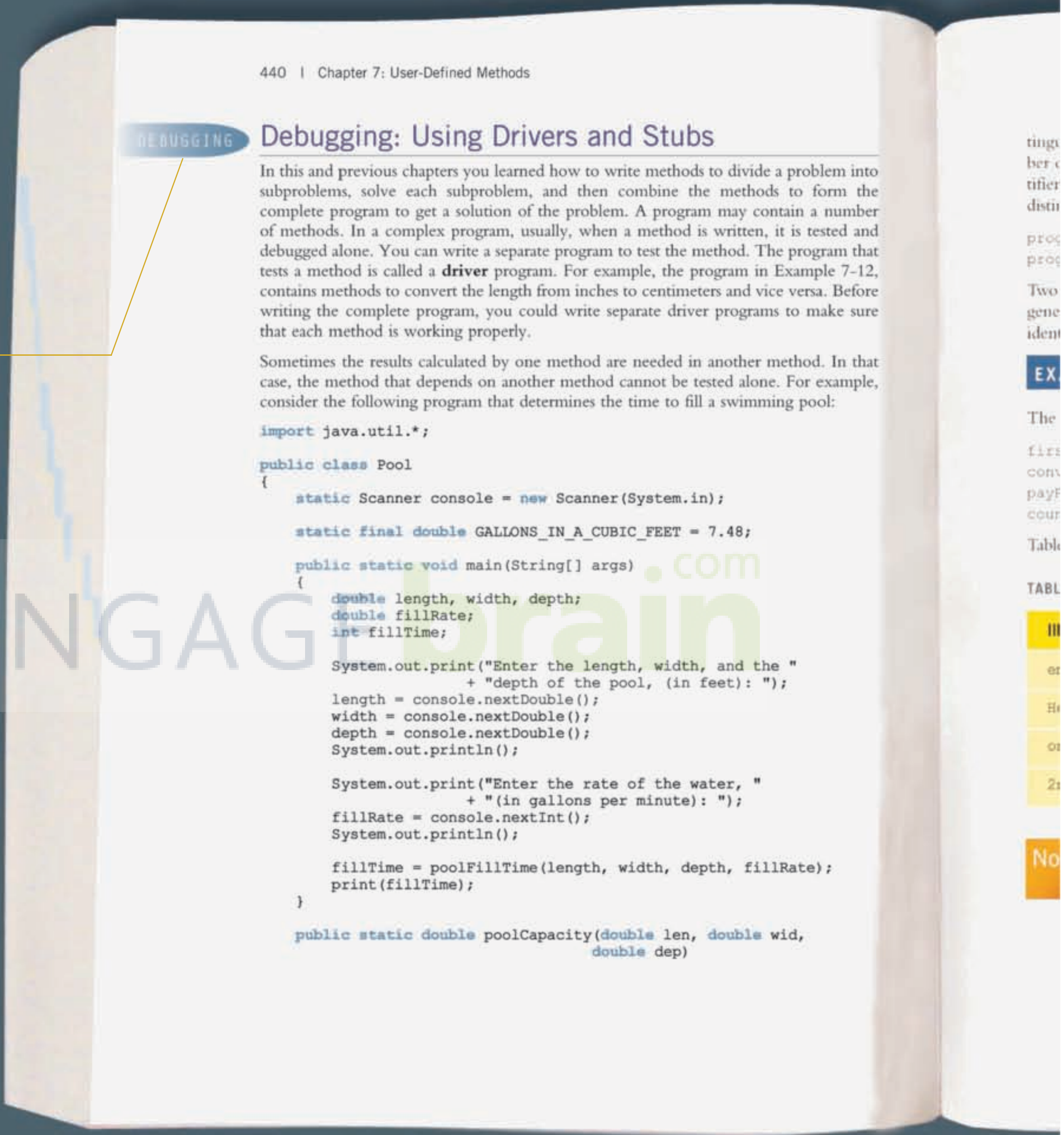
NOTE After including the `static import` statement, in reality, you have a choice. When you use a (`public`) `static` method of a `class`, you can either use the name of the class and the dot operator or omit them. For example, after including the `static import` statement:

```
import static java.lang.Math.*;
```

in a program, you can determine $2.5^{3.5}$ by using either the expression `Math.pow(2.5, 3.5)` or the expression `pow(2.5, 3.5)`.

The `static import` statement is *not* available in versions of Java lower than 5.0. Therefore, if you are using, say, Java 4.0, then you must use a `static` method of the `class Math` using the name of the class and the dot operator.

Four-color interior design shows accurate code and related comments.



DEBUGGING

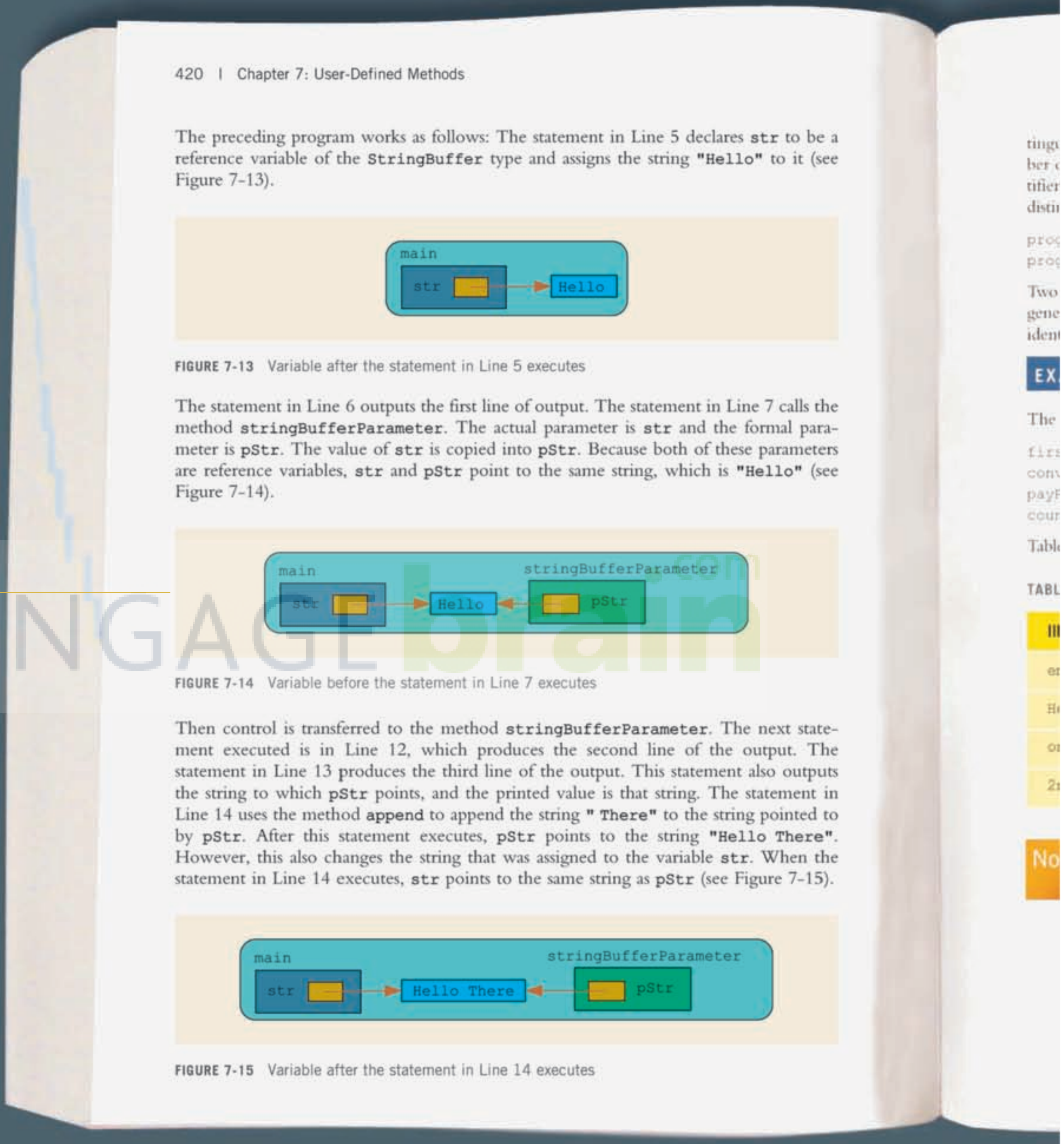
Debugging: Using Drivers and Stubs

In this and previous chapters you learned how to write methods to divide a problem into subproblems, solve each subproblem, and then combine the methods to form the complete program to get a solution of the problem. A program may contain a number of methods. In a complex program, usually, when a method is written, it is tested and debugged alone. You can write a separate program to test the method. The program that tests a method is called a **driver** program. For example, the program in Example 7-12, contains methods to convert the length from inches to centimeters and vice versa. Before writing the complete program, you could write separate driver programs to make sure that each method is working properly.

Sometimes the results calculated by one method are needed in another method. In that case, the method that depends on another method cannot be tested alone. For example, consider the following program that determines the time to fill a swimming pool:

```
import java.util.*;

public class Pool
{
    static Scanner console = new Scanner(System.in);

    static final double GALLONS_IN_A_CUBIC_FEET = 7.48;

    public static void main(String[] args)
    {
        double length, width, depth;
        double fillRate;
        int fillTime;

        System.out.print("Enter the length, width, and the "
                       + "depth of the pool, (in feet): ");
        length = console.nextDouble();
        width = console.nextDouble();
        depth = console.nextDouble();
        System.out.println();

        System.out.print("Enter the rate of the water, "
                       + "(in gallons per minute): ");
        fillRate = console.nextInt();
        System.out.println();

        fillTime = poolFillTime(length, width, depth, fillRate);
        print(fillTime);
    }

    public static double poolCapacity(double len, double wid,
                                      double dep)
```

The debugging sections show how to find and correct syntax and semantic (logical) errors.



420 | Chapter 7: User-Defined Methods

The preceding program works as follows: The statement in Line 5 declares **str** to be a reference variable of the **StringBuffer** type and assigns the string **"Hello"** to it (see Figure 7-13).

FIGURE 7-13 Variable after the statement in Line 5 executes

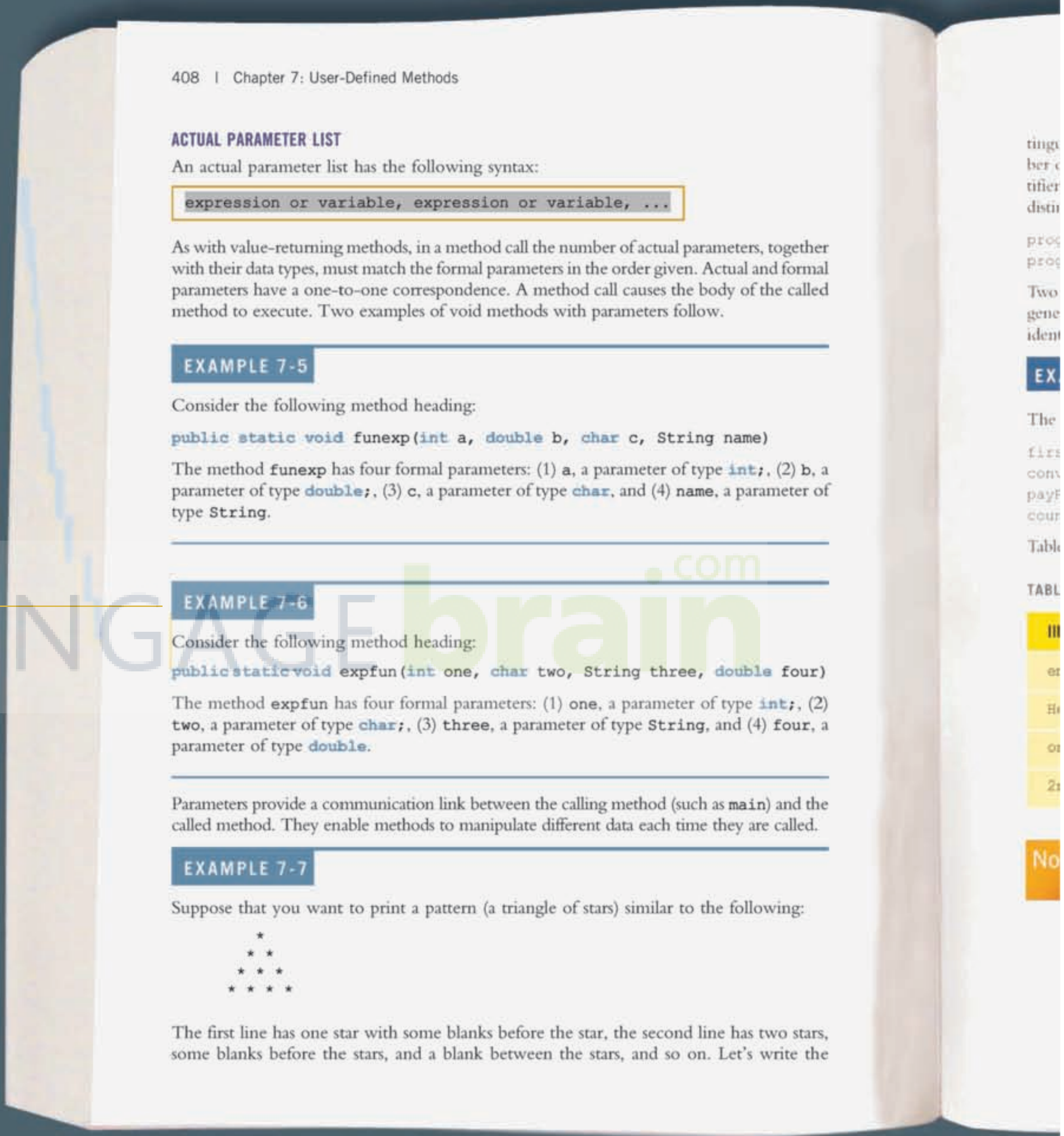
The statement in Line 6 outputs the first line of output. The statement in Line 7 calls the method **stringBufferParameter**. The actual parameter is **str** and the formal parameter is **pStr**. The value of **str** is copied into **pStr**. Because both of these parameters are reference variables, **str** and **pStr** point to the same string, which is **"Hello"** (see Figure 7-14).

FIGURE 7-14 Variable before the statement in Line 7 executes

Then control is transferred to the method **stringBufferParameter**. The next statement executed is in Line 12, which produces the second line of the output. The statement in Line 13 produces the third line of the output. This statement also outputs the string to which **pStr** points, and the printed value is that string. The statement in Line 14 uses the method **append** to append the string **" There"** to the string pointed to by **pStr**. After this statement executes, **pStr** points to the string **"Hello There"**. However, this also changes the string that was assigned to the variable **str**. When the statement in Line 14 executes, **str** points to the same string as **pStr** (see Figure 7-15).

FIGURE 7-15 Variable after the statement in Line 14 executes

More than 250 visual diagrams, both extensive and exhaustive, illustrate difficult concepts.



ACTUAL PARAMETER LIST

An actual parameter list has the following syntax:

```
expression or variable, expression or variable, ...
```

As with value-returning methods, in a method call the number of actual parameters, together with their data types, must match the formal parameters in the order given. Actual and formal parameters have a one-to-one correspondence. A method call causes the body of the called method to execute. Two examples of void methods with parameters follow.

EXAMPLE 7-5

Consider the following method heading:

```
public static void funexp(int a, double b, char c, String name)
```

The method **funexp** has four formal parameters: (1) **a**, a parameter of type **int**;, (2) **b**, a parameter of type **double**;, (3) **c**, a parameter of type **char**, and (4) **name**, a parameter of type **String**.

EXAMPLE 7-6

Consider the following method heading:

```
public static void expfun(int one, char two, String three, double four)
```

The method **expfun** has four formal parameters: (1) **one**, a parameter of type **int**;, (2) **two**, a parameter of type **char**;, (3) **three**, a parameter of type **String**, and (4) **four**, a parameter of type **double**.

Parameters provide a communication link between the calling method (such as **main**) and the called method. They enable methods to manipulate different data each time they are called.

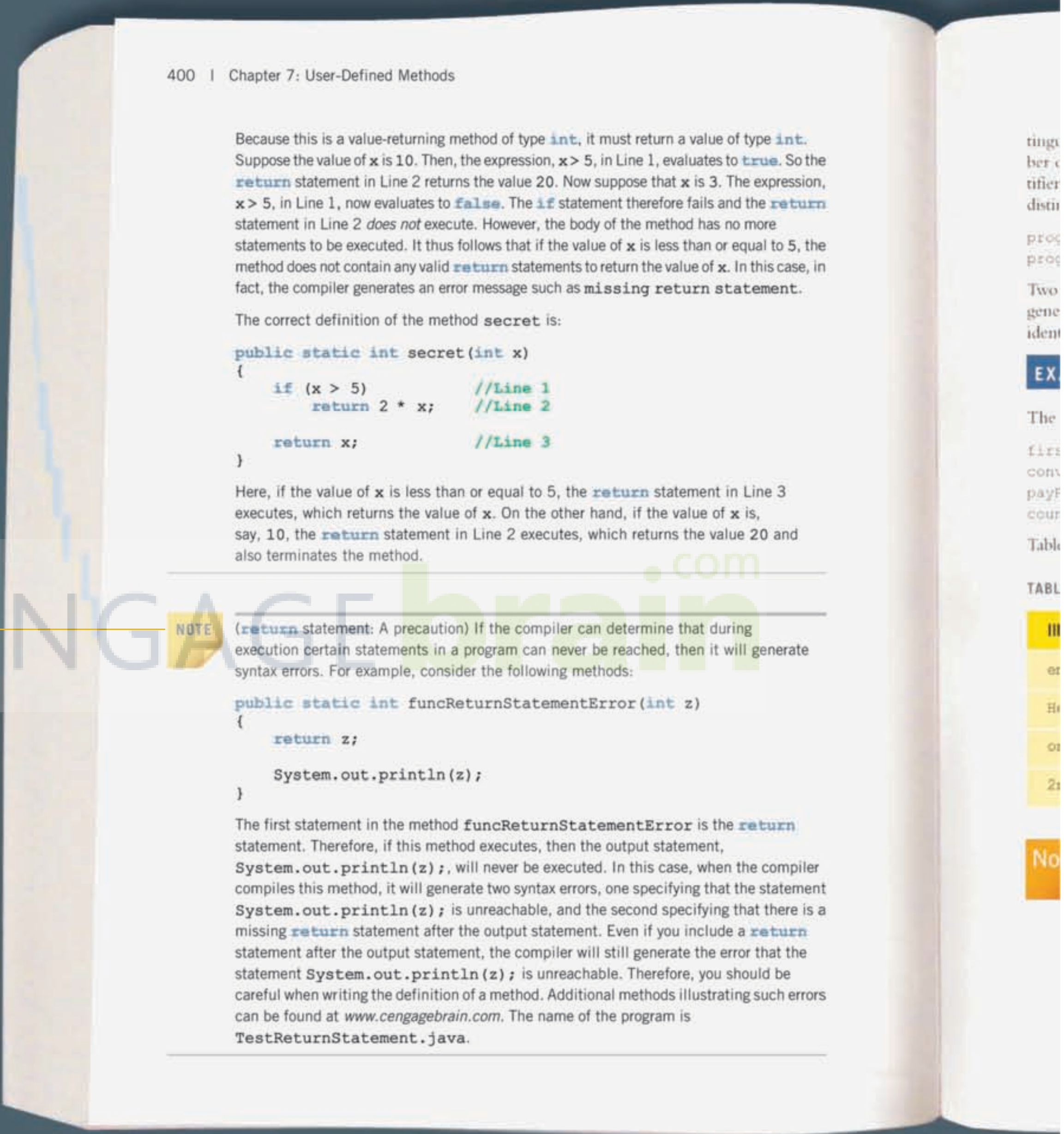
EXAMPLE 7-7

Suppose that you want to print a pattern (a triangle of stars) similar to the following:

```
   *
  * *
 * * *
* * * *
```

The first line has one star with some blanks before the star, the second line has two stars, some blanks before the stars, and a blank between the stars, and so on. Let's write the

Numbered Examples illustrate the key concepts with their relevant code. The programming code in these examples is followed by a Sample Run. An explanation then follows that describes what each line in the code does.



400 | Chapter 7: User-Defined Methods

Because this is a value-returning method of type `int`, it must return a value of type `int`. Suppose the value of **x** is 10. Then, the expression, **x** > 5, in Line 1, evaluates to `true`. So the `return` statement in Line 2 returns the value 20. Now suppose that **x** is 3. The expression, **x** > 5, in Line 1, now evaluates to `false`. The `if` statement therefore fails and the `return` statement in Line 2 *does not* execute. However, the body of the method has no more statements to be executed. It thus follows that if the value of **x** is less than or equal to 5, the method does not contain any valid `return` statements to return the value of **x**. In this case, in fact, the compiler generates an error message such as `missing return statement`.

The correct definition of the method `secret` is:

```
public static int secret(int x)
{
    if (x > 5)              //Line 1
        return 2 * x;       //Line 2

    return x;               //Line 3
}
```

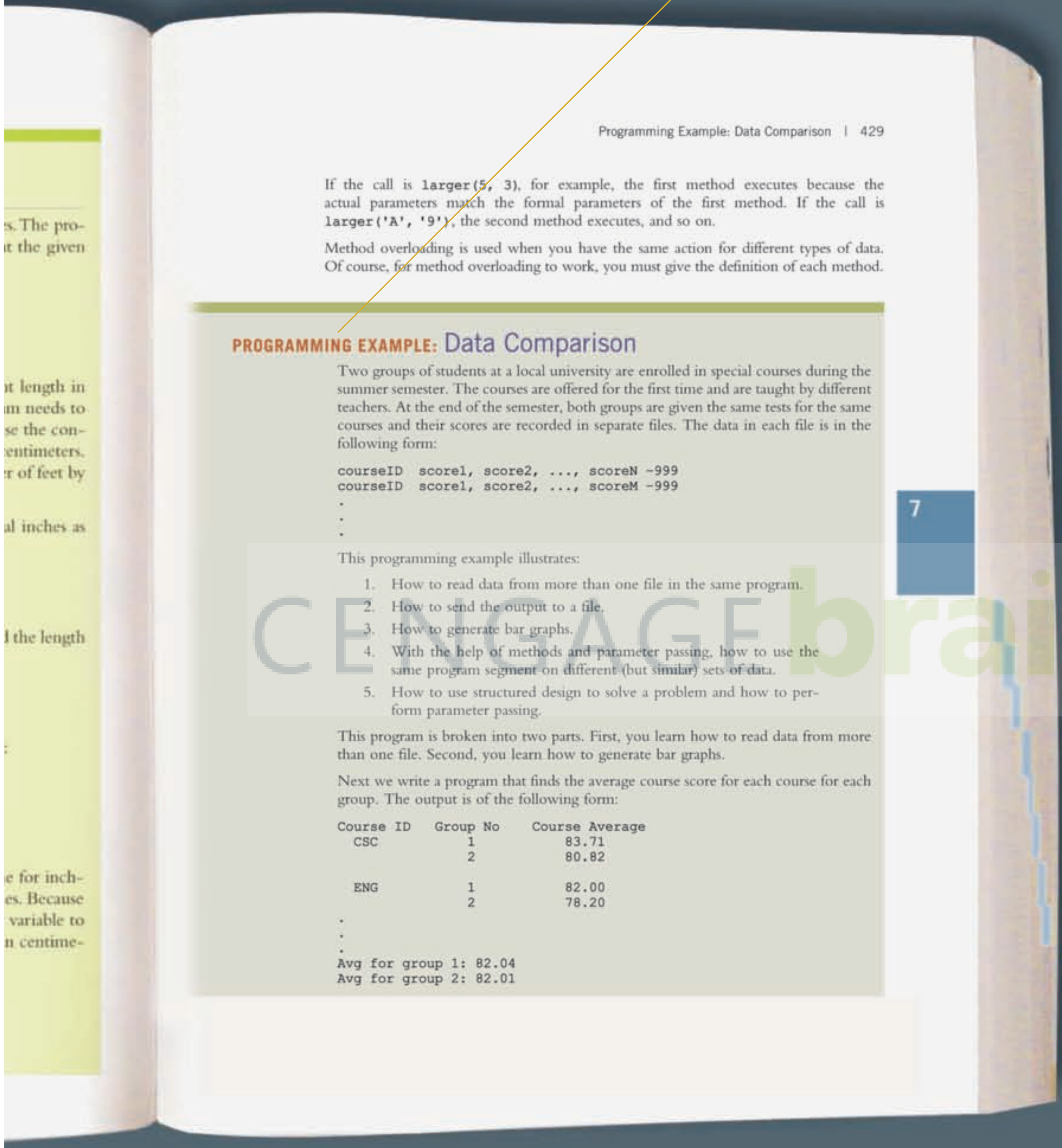
Here, if the value of **x** is less than or equal to 5, the `return` statement in Line 3 executes, which returns the value of **x**. On the other hand, if the value of **x** is, say, 10, the `return` statement in Line 2 executes, which returns the value 20 and also terminates the method.

NOTE (`return` statement: A precaution) If the compiler can determine that during execution certain statements in a program can never be reached, then it will generate syntax errors. For example, consider the following methods:

```
public static int funcReturnStatementError(int z)
{
    return z;

    System.out.println(z);
}
```

The first statement in the method `funcReturnStatementError` is the `return` statement. Therefore, if this method executes, then the output statement, `System.out.println(z);`, will never be executed. In this case, when the compiler compiles this method, it will generate two syntax errors, one specifying that the statement `System.out.println(z);` is unreachable, and the second specifying that there is a missing `return` statement after the output statement. Even if you include a `return` statement after the output statement, the compiler will still generate the error that the statement `System.out.println(z);` is unreachable. Therefore, you should be careful when writing the definition of a method. Additional methods illustrating such errors can be found at *www.cengagebrain.com*. The name of the program is `TestReturnStatement.java`.

Notes highlight important facts about the concepts introduced in the chapter.



If the call is **larger(5, 3)**, for example, the first method executes because the actual parameters match the formal parameters of the first method. If the call is **larger('A', '9')**, the second method executes, and so on.

Method overloading is used when you have the same action for different types of data. Of course, for method overloading to work, you must give the definition of each method.

PROGRAMMING EXAMPLE: Data Comparison

Two groups of students at a local university are enrolled in special courses during the summer semester. The courses are offered for the first time and are taught by different teachers. At the end of the semester, both groups are given the same tests for the same courses and their scores are recorded in separate files. The data in each file is in the following form:

```
courseID  score1, score2, ..., scoreN -999
courseID  score1, score2, ..., scoreM -999
.
.
.
```

This programming example illustrates:

1. How to read data from more than one file in the same program.
2. How to send the output to a file.
3. How to generate bar graphs.
4. With the help of methods and parameter passing, how to use the same program segment on different (but similar) sets of data.
5. How to use structured design to solve a problem and how to perform parameter passing.

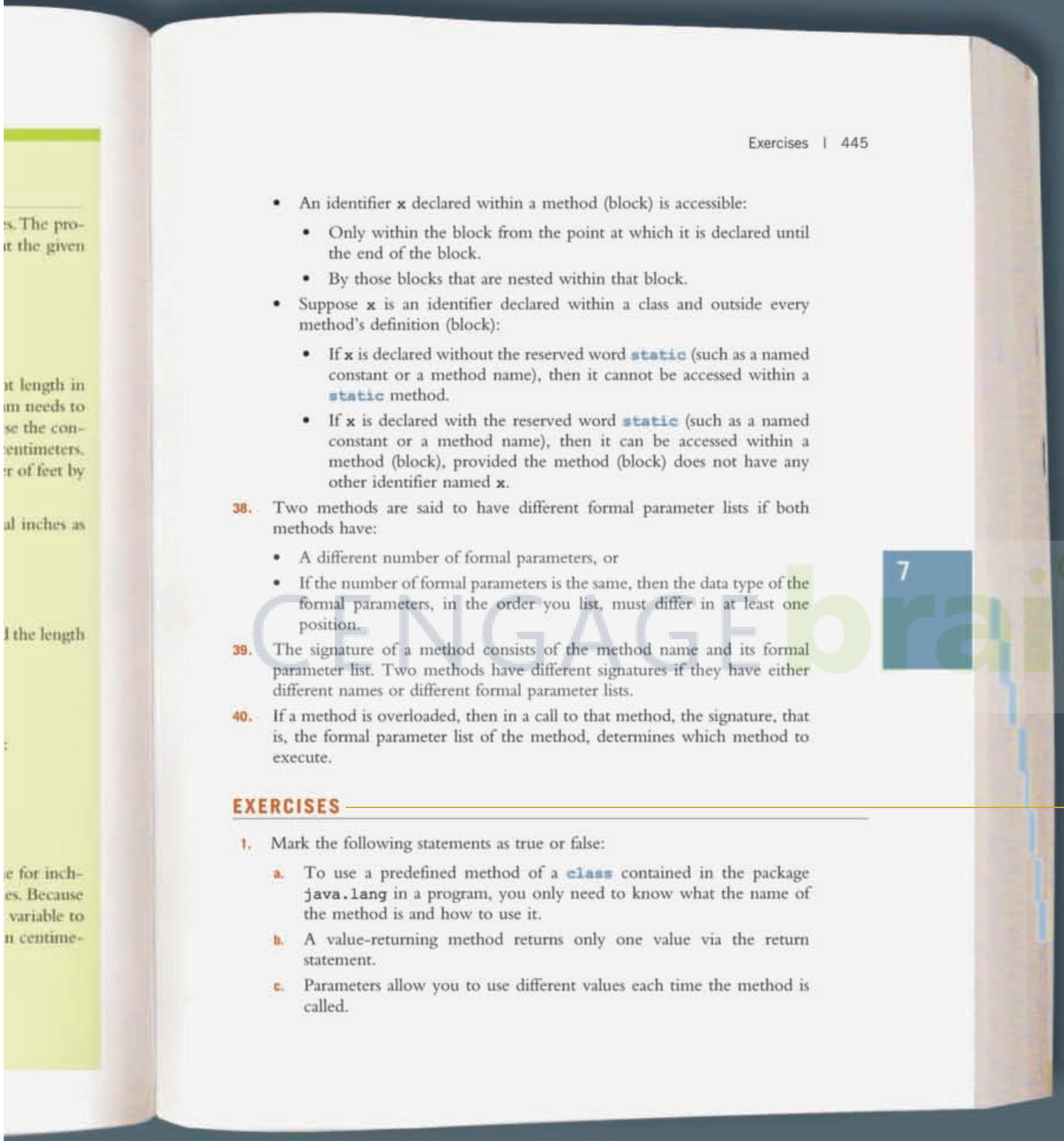
This program is broken into two parts. First, you learn how to read data from more than one file. Second, you learn how to generate bar graphs.

Next we write a program that finds the average course score for each course for each group. The output is of the following form:

```
Course ID   Group No    Course Average
  CSC          1           83.71
               2           80.82

  ENG          1           82.00
               2           78.20
.
.
.
Avg for group 1: 82.04
Avg for group 2: 82.01
```

7

Programming Examples are complete programs featured in each chapter. These examples include the accurate, concrete stages of Input, Output, Problem Analysis and Algorithm Design, and a Complete Program Listing.



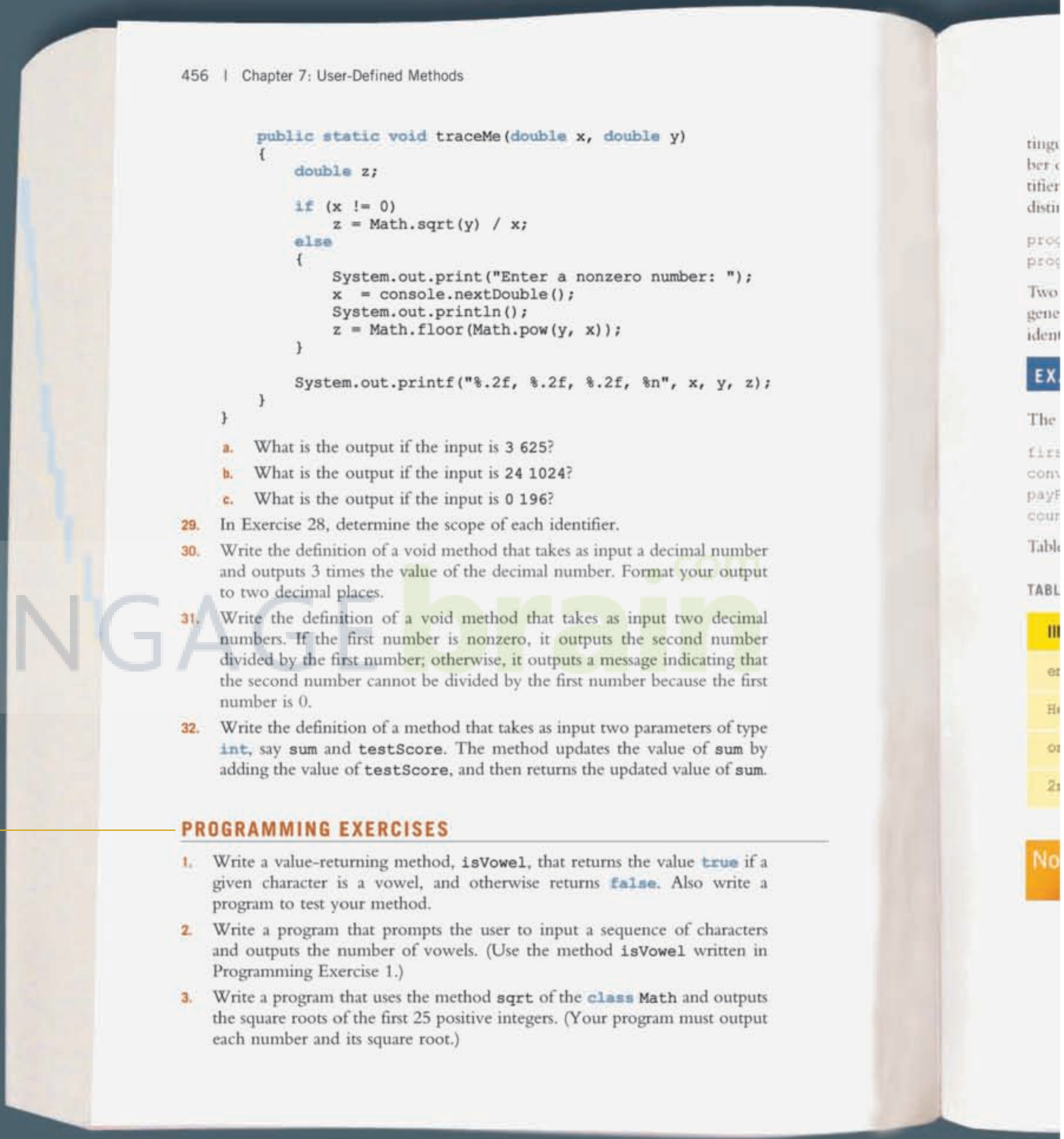
- An identifier **x** declared within a method (block) is accessible:
  - Only within the block from the point at which it is declared until the end of the block.
  - By those blocks that are nested within that block.
- Suppose **x** is an identifier declared within a class and outside every method's definition (block):
  - If **x** is declared without the reserved word **static** (such as a named constant or a method name), then it cannot be accessed within a **static** method.
  - If **x** is declared with the reserved word **static** (such as a named constant or a method name), then it can be accessed within a method (block), provided the method (block) does not have any other identifier named **x**.

38. Two methods are said to have different formal parameter lists if both methods have:
    - A different number of formal parameters, or
    - If the number of formal parameters is the same, then the data type of the formal parameters, in the order you list, must differ in at least one position.
39. The signature of a method consists of the method name and its formal parameter list. Two methods have different signatures if they have either different names or different formal parameter lists.
40. If a method is overloaded, then in a call to that method, the signature, that is, the formal parameter list of the method, determines which method to execute.

EXERCISES

1. Mark the following statements as true or false:
   a. To use a predefined method of a `class` contained in the package `java.lang` in a program, you only need to know what the name of the method is and how to use it.
   b. A value-returning method returns only one value via the return statement.
   c. Parameters allow you to use different values each time the method is called.

Exercises further reinforce learning and ensure that students have, in fact, mastered the material.



```
    public static void traceMe(double x, double y)
    {
        double z;

        if (x != 0)
            z = Math.sqrt(y) / x;
        else
        {
            System.out.print("Enter a nonzero number: ");
            x  = console.nextDouble();
            System.out.println();
            z = Math.floor(Math.pow(y, x));
        }

        System.out.printf("%.2f, %.2f, %.2f, %n", x, y, z);
    }
}
```

a. What is the output if the input is `3 625`?

b. What is the output if the input is `24 1024`?

c. What is the output if the input is `0 196`?

29. In Exercise 28, determine the scope of each identifier.

30. Write the definition of a void method that takes as input a decimal number and outputs 3 times the value of the decimal number. Format your output to two decimal places.

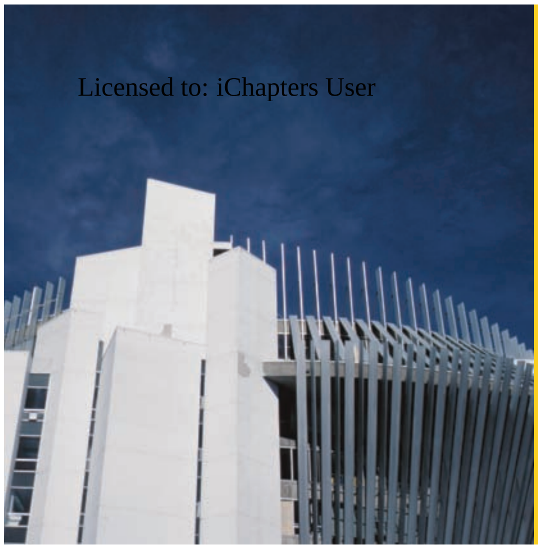
31. Write the definition of a void method that takes as input two decimal numbers. If the first number is nonzero, it outputs the second number divided by the first number; otherwise, it outputs a message indicating that the second number cannot be divided by the first number because the first number is 0.

32. Write the definition of a method that takes as input two parameters of type `int`, say `sum` and `testScore`. The method updates the value of `sum` by adding the value of `testScore`, and then returns the updated value of `sum`.

PROGRAMMING EXERCISES

1. Write a value-returning method, `isVowel`, that returns the value `true` if a given character is a vowel, and otherwise returns `false`. Also write a program to test your method.
2. Write a program that prompts the user to input a sequence of characters and outputs the number of vowels. (Use the method `isVowel` written in Programming Exercise 1.)
3. Write a program that uses the method `sqrt` of the `class Math` and outputs the square roots of the first 25 positive integers. (Your program must output each number and its square root.)

Programming Exercises challenge students to write Java programs with a specified outcome.



Supplemental Resources

The following supplemental materials are available when this book is used in a classroom setting.

Most instructor teaching tools, outlined below, are available with this book on a single CD-ROM, and are also available for instructor access at *login.cengage.com*.

Electronic Instructor's Manual

The Instructor's Manual that accompanies this textbook includes:

- Additional instructional material to assist in class preparation, including suggestions for lecture topics.
- Solutions to all the end-of-chapter materials, including the Programming Exercises.

ExamView®

This textbook is accompanied by ExamView, a powerful testing software package that allows instructors to create and administer printed, computer (LAN-based), and Internet exams. ExamView includes hundreds of questions that correspond to the topics covered in this text, enabling students to generate detailed study guides that include page references for further review. These computer-based and Internet testing components allow students to take exams at their computers, and save the instructor time because each exam is graded automatically.

PowerPoint Presentations

Microsoft PowerPoint slides are available for each chapter. These slides are provided as a teaching aid for classroom presentations, either to make available to students on the network for chapter review, or to be printed for classroom distribution. Instructors can add their own slides for additional topics that they introduce to the class.

Distance Learning

Course Technology is proud to present online courses in WebCT and Blackboard to provide the most complete and dynamic learning experience possible. For more information on how to bring distance learning to your course, contact your local Course Technology sales representative.

Source Code

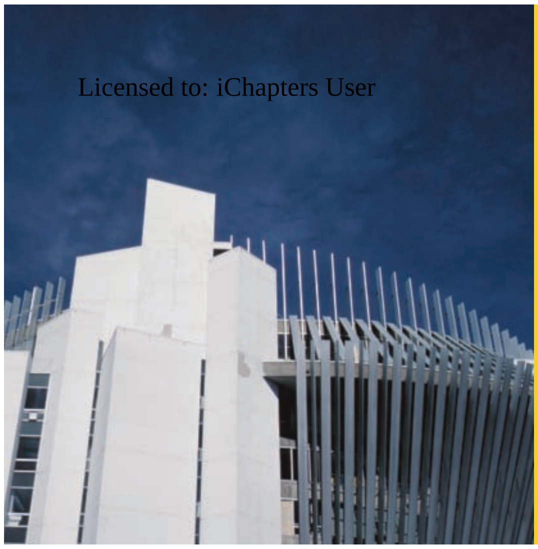
The source code is available for students at *www.cengagebrain.com*. At the *cengagebrain.com* home page, search for the ISBN of your title (from the back cover of your book) using the search box at the top of the page. This will take you to the product page where these resources can be found. The source code is also available on the Instructor Resources CD-ROM. The input files needed to run some of the programs are also included with the source code.

Additional Student Files

The Additional Student Files referenced throughout the text are available on the Instructor Resources CD. Students can download these files directly at *www.cengagebrain.com*. At the *cengagebrain.com* home page, search for the ISBN of your title using the search box at the top of the page. This will take you to the product page where these resources can be found. Click the *Access Now* link below the book cover to find all study tools and additional files available directly to students. Additional Student Files appear on the left navigation and provide access to additional Java programs, selected solutions, and more.

Solution Files

The solution files for all programming exercises are available for instructor download at *http://login.cengage.com* and are also available on the Instructor Resources CD-ROM. The input files needed to run some of the programming exercises are also included with the solution files.



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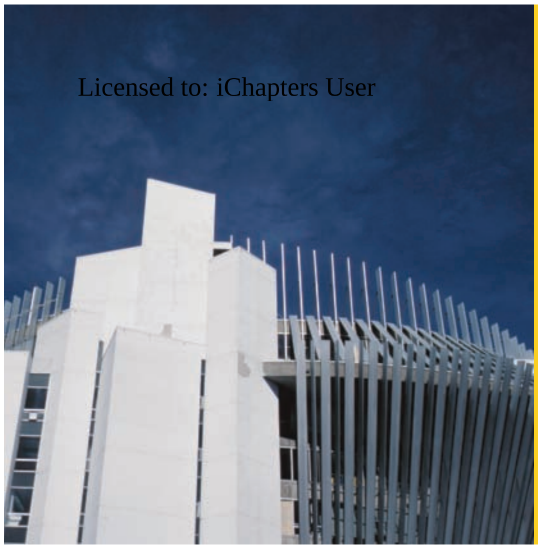
We welcome any comments concerning the text. Comments may be forwarded to the following e-mail address: `malik@creighton.edu`.

D.S. Malik

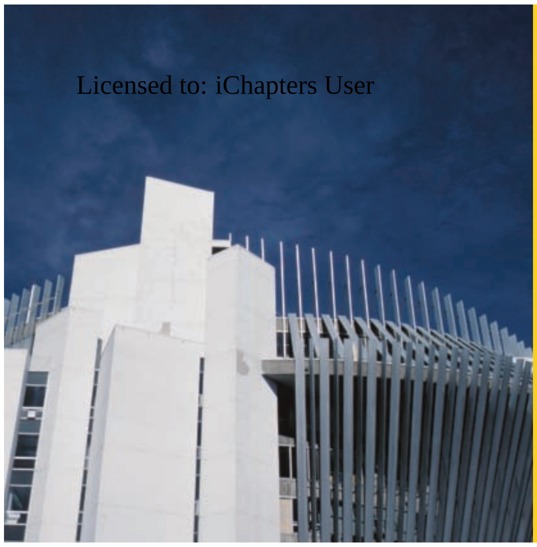


APPENDIX A JAVA RESERVED WORDS

The following table lists Java reserved words in alphabetical order.

`abstract`	`else`	`interface`	`switch`
`assert`	`enum`	`long`	`synchronized`
`boolean`	`extends`	`native`	`this`
`break`	`false`	`new`	`throw`
`byte`	`final`	`null`	`throws`
`case`	`finally`	`package`	`transient`
`catch`	`float`	`private`	`true`
`char`	`for`	`protected`	`try`
`class`	`goto`	`public`	`void`
`const`	`if`	`return`	`volatile`
`continue`	`implements`	`short`	`while`
`default`	`import`	`static`	
`do`	`instanceof`	`strictfp`	
`double`	`int`	`super`	

The reserved words `const` and `goto` are *not* currently in use.



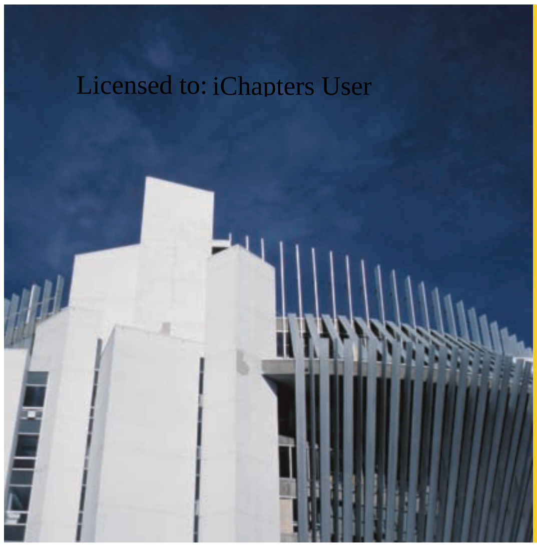
APPENDIX B OPERATOR PRECEDENCE

The following table shows the precedence of operators in Java from highest to lowest, and their associativity.

Operator	Description	Precedence Level	Associativity
.	Object member access	1	Left to right
[ ]	Array subscripting	1	Left to right
(parameters)	Method call	1	Left to right
++	Postincrement	1	Left to right
--	Postdecrement	1	Left to right
++	Preincrement	2	Right to left
--	Predecrement	2	Right to left
+	Unary plus	2	Right to left
-	Unary minus	2	Right to left
!	Logical not	2	Right to left
~	Bitwise not	2	Right to left
new	Object instantiation	3	Right to left
(type)	Type conversion	3	Right to left
*	Multiplication	4	Left to right
/	Division	4	Left to right
%	Remainder (modulus)	4	Left to right

Operator	Description	Precedence Level	Associativity
+	Addition	5	Left to right
–	Subtraction	5	Left to right
+	String concatenation	5	Left to right
<<	Left shift	6	Left to right
>>	Right shift with sign extension	6	Left to right
>>>	Right shift with zero extension	6	Left to right
<	Less than	7	Left to right
<=	Less than or equal to	7	Left to right
>	Greater than	7	Left to right
>=	Greater than or equal to	7	Left to right
`instanceof`	Type comparison	7	Left to right
==	Equal to	8	Left to right
!=	Not equal to	8	Left to right
&	Bitwise AND	9	Left to right
&	Logical AND	9	Left to right
^	Bitwise XOR	10	Left to right
^	Logical XOR	10	Left to right
|	Bitwise OR	11	Left to right
|	Logical OR	11	Left to right
&&	Logical AND	12	Left to right

Operator	Description	Precedence Level	Associativity
`||`	Logical OR	13	Left to right
`?:`	Conditional operator	14	Right to left
`=`	Assignment	15	Right to left
	Compound Operators		
`+=`	Addition, then assignment	15	Right to left
`+=`	String concatenation, then assignment	15	Right to left
`-=`	Subtraction, then assignment	15	Right to left
`*=`	Multiplication, then assignment	15	Right to left
`/=`	Division, then assignment	15	Right to left
`%=`	Remainder, then assignment	15	Right to left
`<<=`	Bitwise left shift, then assignment	15	Right to left
`>>=`	Bitwise right shift, then assignment	15	Right to left
`>>>=`	Bitwise unsigned-right shift, then assignment	15	Right to left
`&=`	Bitwise AND, then assignment	15	Right to left
`&=`	Logical AND, then assignment	15	Right to left
`|=`	Bitwise OR, then assignment	15	Right to left
`|=`	Logical OR, then assignment	15	Right to left
`^=`	Bitwise XOR, then assignment	15	Right to left
`^=`	Logical XOR, then assignment	15	Right to left



APPENDIX C CHARACTER SETS

This appendix lists and describes the character sets for ASCII (American Standard Code for Information Interchange), which also comprises the first 128 characters of the Unicode character set, and EBCDIC (Extended Binary Coded Decimal Interchange Code).

ASCII (American Standard Code for Information Interchange), the First 128 Characters of the Unicode Character Set

The following table shows the first 128 characters of the Unicode (ASCII) character set.

ASCII

	0	1	2	3	4	5	6	7	8	9
0	nul	soh	stx	etx	eot	enq	ack	bel	bs	ht
1	lf	vt	ff	cr	so	si	dle	dc1	dc2	dc3
2	dc4	nak	syn	etb	can	em	sub	esc	fs	gs
3	rs	us	b	!	"	#	$	%	&	'
4	(	)	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[	\	]	^	_	`	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{	|	}	~	del		

NOTE For more information on the Unicode/ASCII character set, visit the Web site at *http://www.unicode.org*.

Note that the character b at position 32 represents the space character. The first 32 characters, that is, the characters at positions 00–31 and at position 127 are nonprintable characters. The following table shows the abbreviations and meanings of these characters.

nul	null character	ff	form feed	can	cancel
soh	start of header	cr	carriage return	em	end of medium
stx	start of text	so	shift out	sub	substitute
etx	end of text	si	shift in	esc	escape
eot	end of transmission	dle	data link escape	fs	file separator
enq	enquiry	dc1	device control 1	gs	group separator
ack	acknowledge	dc2	device control 2	rs	record separator
bel	bell	dc3	device control 3	us	unit separator
bs	backspace	dc4	device control 4	b	space
ht	horizontal tab	nak	negative acknowledge	del	delete
lf	line feed	syn	synchronous idle		
vt	vertical tab	etb	end of transmitted block		

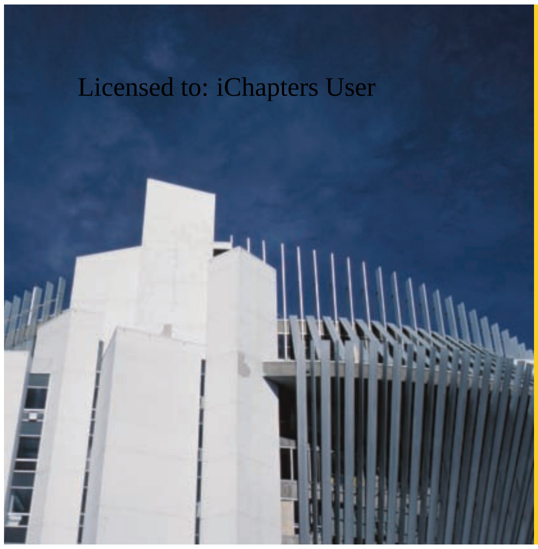
EBCDIC (Extended Binary Coded Decimal Interchange Code)

The following table shows some of the characters in the EBCDIC character set.

EBCDIC										
	0	1	2	3	4	5	6	7	8	9
6					b					
7						.	<	(	+	|
8	&									
9	!	$	*	)	;	¬	-	/		
10								'	%	_

EBCDIC										
11	>	?								
12		`	:	#	@	'	=	"		a
	0	1	2	3	4	5	6	7	8	9
13	b	c	d	e	f	g	h	i		
14						j	k	l	m	n
15	o	p	q	r						
16		~	s	t	u	v	w	x	y	z
17										
18	[	]								
19				A	B	C	D	E	F	G
20	H	I								J
21	K	L	M	N	O	P	Q	R		
22							S	T	U	V
23	W	X	Y	Z						
24	0	1	2	3	4	5	6	7	8	9

The numbers 6–24 in the first column specify the left digit(s) and the numbers 0–9 in the second row specify the right digits of the characters in the EBCDIC data set. For example, the character in the row marked 19 (the number in the first column) and the column marked 3 (the number in the second row) is `A`. Therefore, the character at position 193 (which is the 194th character) is `A`. Moreover, the character b at position 64 represents the space character. This table does not show all the characters in the EBCDIC character set. In fact, the characters at positions 00–63 and 250–255 are nonprintable control characters.



APPENDIX D
ADDITIONAL JAVA TOPICS

Binary (Base 2) Representation of a Nonnegative Integer

Converting a Base 10 Number to a Binary Number (Base 2)

Chapter 1 noted that `A` is the 66th character in the ASCII character set, but its position is 65 because the position of the first character is `0`. Furthermore, the binary number `1000001` is the binary representation of `65`. The number system that we use daily is called the **decimal number system** or **base 10 system**. The number system that the computer uses is called the **binary number system** or **base 2 system**. In this section, we describe how to find the binary representation of a nonnegative integer and vice versa.

Consider 65. Note that:

$$65 = 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0.$$

Similarly:

$$\begin{aligned}711 = {} & 1 \times 2^9 + 0 \times 2^8 + 1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 \\ & + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0.\end{aligned}$$

In general, if m is a nonnegative integer, then m can be written as:

$$m = a_k \times 2^k + a_{k-1} \times 2^{k-1} + a_{k-2} \times 2^{k-2} + \cdots + a_1 \times 2^1 + a_0 \times 2^0,$$

for some nonnegative integer k, and where $a_i = 0$ or 1, for each $i = 0, 1, 2, \ldots, k$. The binary number $a_k a_{k-1} a_{k-2} \ldots a_1 a_0$ is called the **binary** or **base 2 representation** of m. In this case, we usually write:

$$m_{10} = (a_k a_{k-1} a_{k-2} \cdots a_1 a_0)_2$$

and say that m to the base 10 is $a_k a_{k-1} a_{k-2} \ldots a_1 a_0$ to the base 2.

For example, for the integer 65, $k = 6$, $a_6 = 1$, $a_5 = 0$, $a_4 = 0$, $a_3 = 0$, $a_2 = 0$, $a_1 = 0$, and $a_0 = 1$. Thus, $a_6a_5a_4a_3a_2a_1a_0 = 1000001$, so the binary representation of 65 is 1000001, that is:

$$65_{10} = (1000001)_2.$$

If no confusion arises, then we write $(1000001)_2$ as 1000001_2.

Similarly, for the number 711, $k = 9$, $a_9 = 1$, $a_8 = 0$, $a_7 = 1$, $a_6 = 1$, $a_5 = 0$, $a_4 = 0$, $a_3 = 0$, $a_2 = 1$, $a_1 = 1$, and $a_0 = 1$. Thus:

$$711_{10} = 1011000111_2.$$

It follows that to find the binary representation of a nonnegative integer, we need to find the coefficients, which are 0 or 1, of various powers of 2. However, there is an easy algorithm, described next, that can be used to find the binary representation of a nonnegative integer. First, note that:

$$0_{10} = 0_2,\ 1_{10} = 1_2,\ 2_{10} = 10_2,\ 3_{10} = 11_2,\ 4_{10} = 100_2,\ 5_{10} = 101_2,\ 6_{10} = 110_2, \text{ and } 7_{10} = 111_2.$$

Let us consider the integer 65. Note that 65 / 2 = 32 and 65 % 2 = 1, where % is the mod operator. Next, 32 / 2 = 16, and 32 % 2 = 0, and so on. It can be shown that a_0 = 65 % 2 = 1, a_1 = 32 % 2 = 0, and so on. We can show this continuous division and obtain the remainder with the help of Figure D-1.

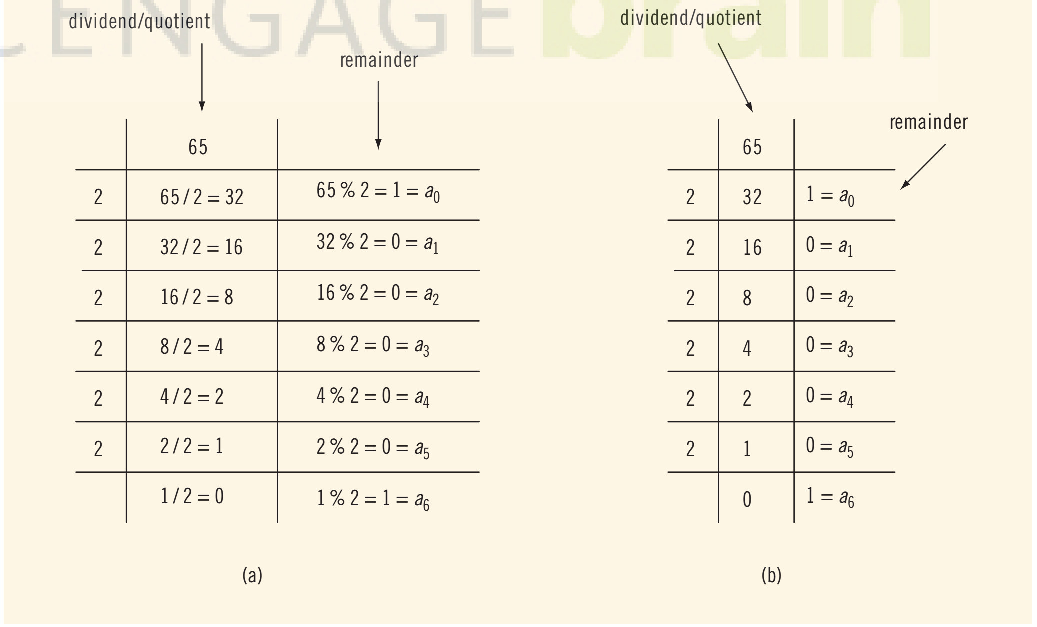
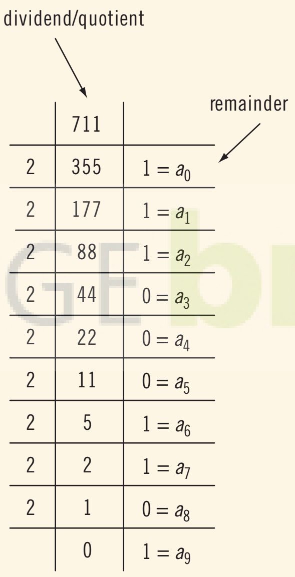

dividend/quotient
remainder
65
2 | 65 / 2 = 32 | 65 % 2 = 1 = a_0
2 | 32 / 2 = 16 | 32 % 2 = 0 = a_1
2 | 16 / 2 = 8 | 16 % 2 = 0 = a_2
2 | 8 / 2 = 4 | 8 % 2 = 0 = a_3
2 | 4 / 2 = 2 | 4 % 2 = 0 = a_4
2 | 2 / 2 = 1 | 2 % 2 = 0 = a_5
1 / 2 = 0 | 1 % 2 = 1 = a_6
(a)
dividend/quotient
remainder
65
2 | 32 | 1 = a_0
2 | 16 | 0 = a_1
2 | 8 | 0 = a_2
2 | 4 | 0 = a_3
2 | 2 | 0 = a_4
2 | 1 | 0 = a_5
0 | 1 = a_6
(b)

FIGURE D-1 Determining the binary representation of 65

Notice that in Figure D-1(a), starting at the second row, the second column contains the quotient when the number in the previous row is divided by 2, and the third column contains the remainder of that division. For example, in the second row, 65 / 2 = 32, and 65 % 2 = 1. In the third row, 32 / 2 = 16 and 32 % 2 = 0, and so on. For each row, the number in the second column is divided by 2, the quotient is written in the row below the current row, and the remainder appears in the third column. When using a figure such as D-1 to find the binary representation of a nonnegative integer, we typically show only the quotients and remainders, as shown in Figure D-1(b). You can write the binary representation of the number, starting with the last remainder in the third column, followed by the second to the last remainder, and so on. Thus:

$65_{10} = 1000001_2$.

Next, consider the number 711. Figure D-2 shows the quotients and the remainders.



	711	
2	355	$1 = a_0$
2	177	$1 = a_1$
2	88	$1 = a_2$
2	44	$0 = a_3$
2	22	$0 = a_4$
2	11	$0 = a_5$
2	5	$1 = a_6$
2	2	$1 = a_7$
2	1	$0 = a_8$
	0	$1 = a_9$

FIGURE D-2 Determining the binary representation of 711

From Figure D-2, it follows that:

$711_{10} = 1011000111_2$.

Converting a Binary Number (Base 2) to Base 10

To convert a number from base 2 to base 10, we first find the weight of each bit in the binary number, which is assigned from right to left. The weight of the rightmost bit is 0.

The weight of the bit immediately to the left of the rightmost bit is 1, the weight of the bit immediately to the left of it is 2, and so on. Consider the binary number 1001101. The weight of each bit is as follows:

Weight	6	5	4	3	2	1	0
	1	0	0	1	1	0	1

We use the weight of each bit to find the equivalent decimal number. For each bit, we multiply the bit by 2 to the power of its weight and then we add all of the numbers. For the above binary number, the equivalent decimal number is:

$$1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

$$= 64 + 0 + 0 + 8 + 4 + 0 + 1$$

$$= 77.$$

Converting a Binary Number (Base 2) to Octal (Base 8) and Hexadecimal (Base 16)

The previous sections described how to convert a binary number to a decimal number (base 2). Even though the language of a computer is binary, if the binary number is too long, then it will be hard to manipulate it manually. To effectively deal with binary numbers, two more number systems, octal (base 8) and hexadecimal (base 16), are of interest to computer scientists.

The digits in the octal number system are 0, 1, 2, 3, 4, 5, 6, and 7. The digits in the hexadecimal number system are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F. So A in hexadecimal is 10 in decimal, B in hexadecimal is 11 in decimal, and so on.

The algorithm to convert a binary number into an equivalent number in octal (or hexadecimal) is quite simple. Before we describe the method to do so, let us review some notations. Suppose a_b represents the number a to the base b. For example, $2A0_{16}$ means 2A0 to the base 16, and 63_8 means 63 to the base 8.

First, we describe how to convert a binary number into an equivalent octal number and vice versa. Table D-1 describes the first 8 octal numbers.

TABLE D-1 Binary Representation of First 8 Octal Numbers

Binary	Octal		Binary	Octal
000	0		100	4
001	1		101	5
010	2		110	6
011	3		111	7

Consider the binary number 1101100010101. To find the equivalent octal number, starting from right to left, we consider three digits at a time and write their octal representation. Note that the binary number 1101100010101 has only 13 digits. So when we consider three digits at a time, at the end, we will be left with only one digit. In this case, we just add two 0s to the left of the binary number; the equivalent binary number is 001101100010101. Thus:

$$\begin{aligned} 1101100010101_2 &= 001101100010101_2 \\ &= 001\ 101\ 100\ 010\ 101 \\ &= 15425_8 \text{ because } 001_2 = 1_8,\ 101_2 = 5_8,\ 100_2 = 4_8,\ 010_2 = 2_8, \text{ and } 101_2 = 5_8. \end{aligned}$$

Thus, $1101100010101_2 = 15425_8$.

To convert an octal number into an equivalent binary number, using Table D-1, write the binary representation of each octal digit in the number. For example:

$$\begin{aligned} 3761_8 &= 011\ 111\ 110\ 001_2 \\ &= 011111110001_2 \\ &= 11111110001_2. \end{aligned}$$

Thus, $3761_8 = 11111110001_2$.

Next, we discuss how to convert a binary number into an equivalent hexadecimal number and vice versa. The method to do so is similar to converting a number from binary to octal and vice versa, except that here we work with four binary digits. Table D-2 gives the binary representation of the first 16 hexadecimal numbers.

TABLE D-2 Binary Representation of First 16 Hexadecimal Numbers

Binary	Hexadecimal		Binary	Hexadecimal
0000	0		1000	8
0001	1		1001	9
0010	2		1010	A
0011	3		1011	B
0100	4		1100	C
0101	5		1101	D
0110	6		1110	E
0111	7		1111	F

Consider the binary number 1111101010001010101_2. Now:

$$\begin{aligned} 1111101010001010101_2 &= 111\ 1101\ 0100\ 0101\ 0101_2 \\ &= 0111\ 1101\ 0100\ 0101\ 0101_2, \text{ add one zero to the left} \\ &= 7D455_{16}. \end{aligned}$$

Hence, $1111101010001010101_2 = 7D455_{16}$.

Next, to convert a hexadecimal number into an equivalent binary number, write the four-digit binary representation of each hexadecimal digit into that number. For example:

$$\begin{aligned} A7F32_{16} &= 1010\ 0111\ 1111\ 0011\ 0010_2 \\ &= 10100111111100110010_2. \end{aligned}$$

Thus, $A7F32_{16} = 10100111111100110010_2$.

Executing Java Programs Using the Command-Line Statements

When you install JDK 7.0 in the Windows 7.0 environment, the system creates two main subdirectories: `Java\jdk1.7.0` and `Java\jre1.7.0`. These two subdirectories are, typically, created within the directory `c:\Program Files\Java`. However, these subdirectories might also be created in the directory c: as `c:\jdk1.7.0` and `c:\jre1.7.0`. (Check your systems documentation.) The files necessary to compile and execute Java programs are placed within these subdirectories, along with other files. For example, the file `javac.exe` to compile a Java program and the file `java.exe` to execute a Java application program are placed within the subdirectory `jdk1.7.0\bin` or `jdk1.7.0\fastdebug\bin`. You can set (or alter) the Windows system environment variable `Path` to add the path where the files `javac.exe` and `java.exe` are located. This will allow you to conveniently compile a Java program from within any subdirectory. In the Windows 7.0 Professional environment, you can also set the environment variable `CLASSPATH` so that when you execute a Java program, the system can find the compiled code of the program. Next, we describe how to set up the `Path`.

Setting the Path in Windows 7.0 (Professional)

To set the `Path` so that you can compile a Java program from within any subdirectory, perform the following steps.

1. Click the `Start` button (lower-left corner of the window.)
2. Select `Control Panel`. A window similar to the window shown in Figure D-3 appears.

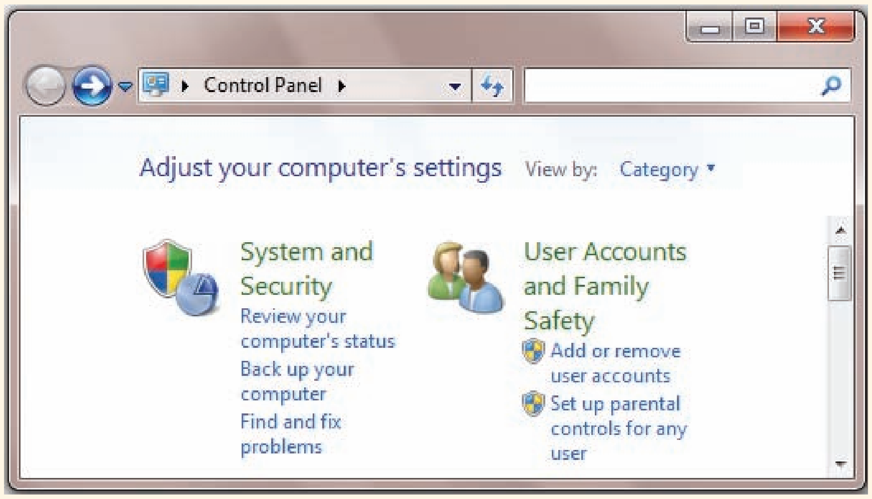

Control Panel
Adjust your computer's settings
View by: Category
System and Security
Review your computer's status
Back up your computer
Find and fix problems
User Accounts and Family Safety
Add or remove user accounts
Set up parental controls for any user

FIGURE D-3 Control Panel

3. Select the `System and Security` option. A window similar to the window shown in Figure D-4 appears.

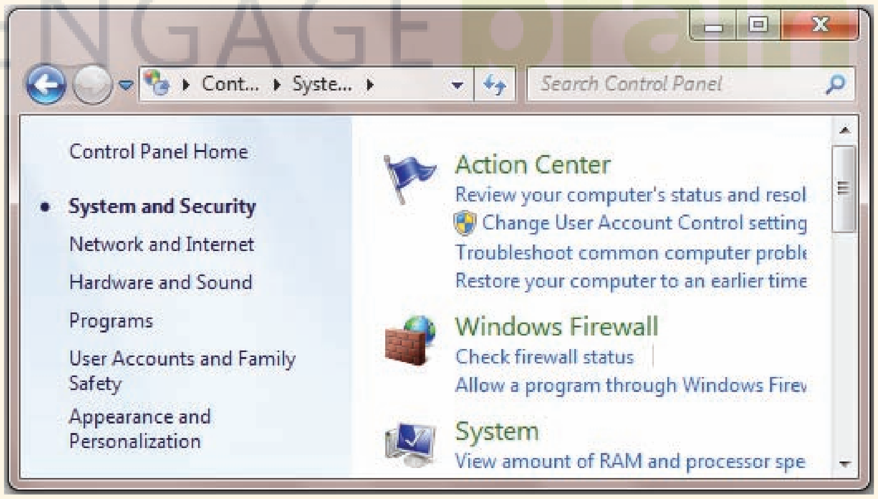
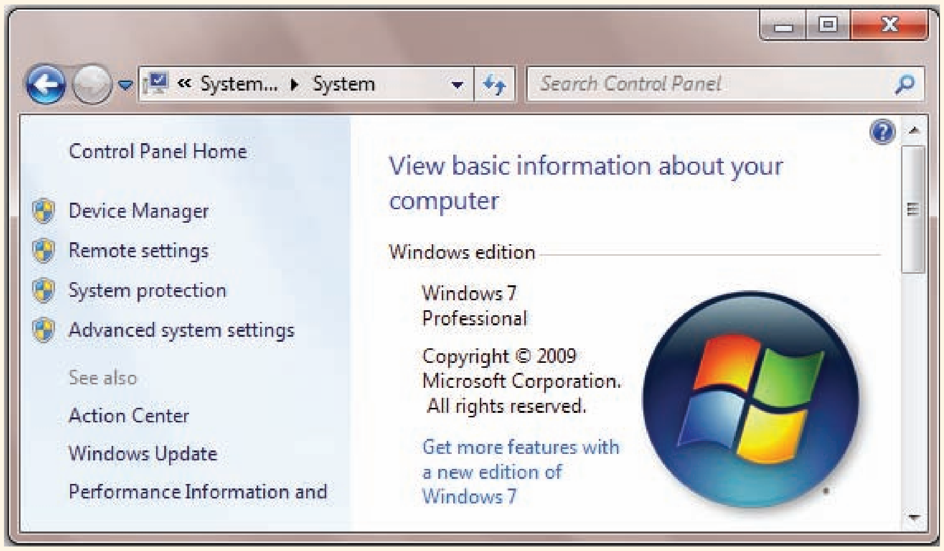

Cont... Syste...
Search Control Panel
Control Panel Home
System and Security
Network and Internet
Hardware and Sound
Programs
User Accounts and Family Safety
Appearance and Personalization
Action Center
Review your computer's status and resol
Change User Account Control setting
Troubleshoot common computer probl
Restore your computer to an earlier time
Windows Firewall
Check firewall status
Allow a program through Windows Firev
System
View amount of RAM and processor spe

FIGURE D-4 System and Security window

4. Select the option `System` shown on the right side. A window similar to the window shown in Figure D-5 appears.



View basic information about your computer

Windows edition

Windows 7 Professional

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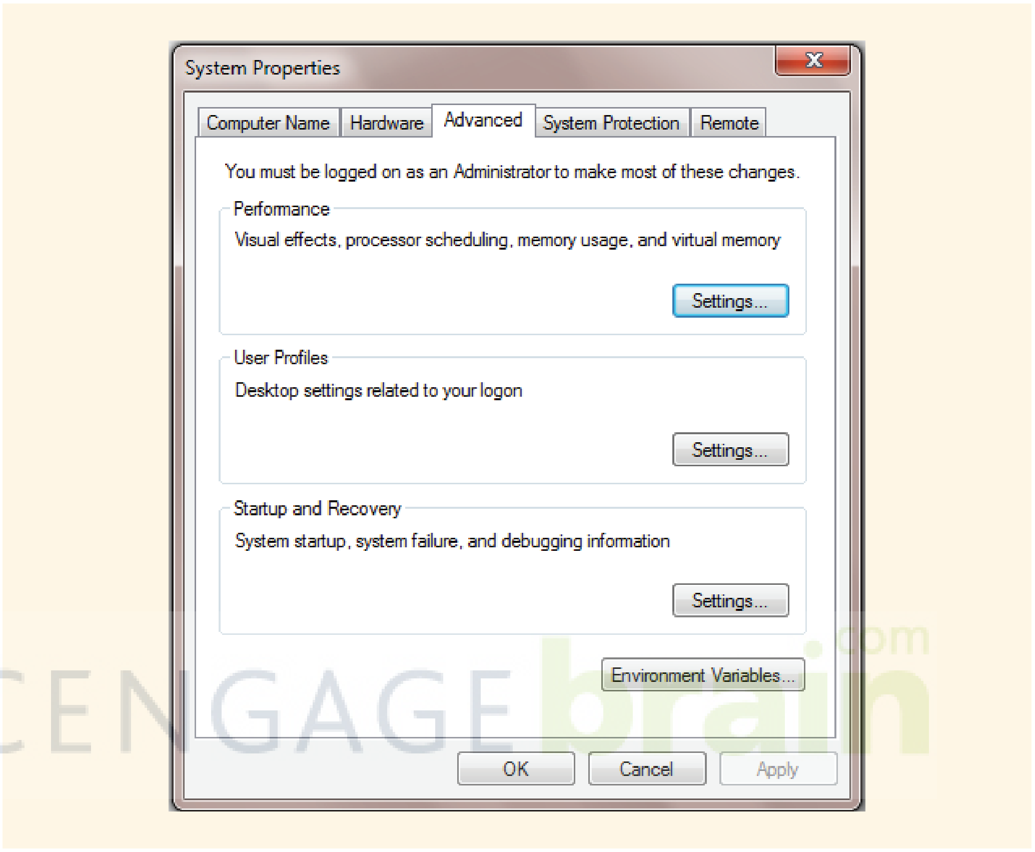
Get more features with a new edition of Windows 7

FIGURE D-5 System window

5. Select the option `Advanced system settings` shown on the left side. A window similar to the window shown in Figure D-6 appears.



You must be logged on as an Administrator to make most of these changes.

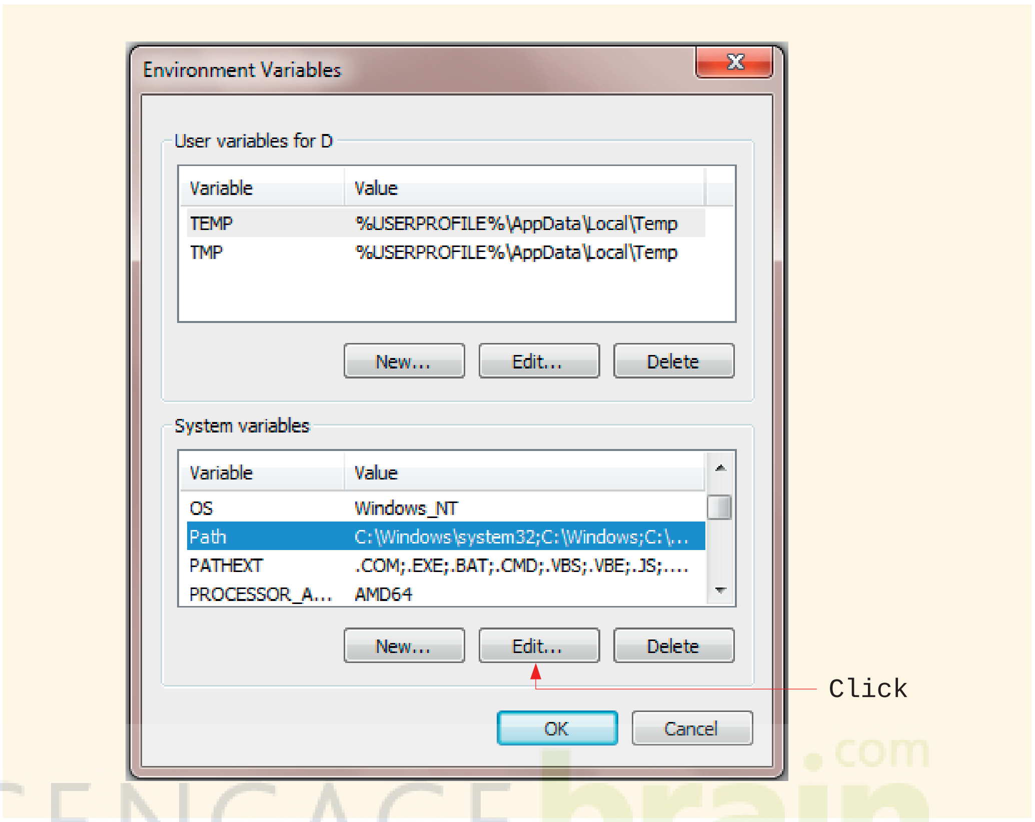
Performance
Visual effects, processor scheduling, memory usage, and virtual memory

User Profiles
Desktop settings related to your logon

Startup and Recovery
System startup, system failure, and debugging information

FIGURE D-6 Selecting the `Advanced` tab

6. In the window in Figure D-6, click `Environment Variables`. A window similar to the one shown in Figure D-7 appears. In this window, in the `System variables` section, scroll down, select `Path`, and then click `Edit`.



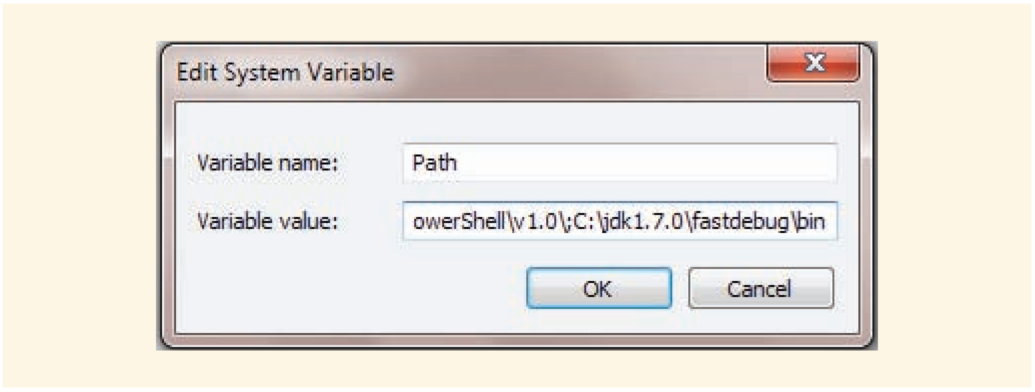
Variable	Value
TEMP	%USERPROFILE%\AppData\Local\Temp
TMP	%USERPROFILE%\AppData\Local\Temp

Variable	Value
OS	Windows_NT
Path	C:\Windows\system32;C:\Windows;C:\...
PATHEXT	.COM;.EXE;.BAT;.CMD;.VBS;.VBE;.JS;....
PROCESSOR_A...	AMD64

FIGURE D-7 Selecting Path in System variables

7. After you select `Edit`, the window in Figure D-8 appears. In the box following `Variable value:`, type the following and then click `OK` three times. (If the path is different on your system, type in the path as it corresponds to your own installation. For example, the path on your system might be `C:\Program Files\Java\jdk1.7.0\bin`)

   `;C:\jdk1.7.0\fastdebug\bin`



Variable name: Path

Variable value: owerShell\v1.0\;C:\jdk1.7.0\fastdebug\bin

FIGURE D-8 Editing Path

The preceding steps should set the `Path`. To be absolutely certain about the `Path` and also to set the `CLASSPATH`, check your operating system's documentation.

Executing Java Programs

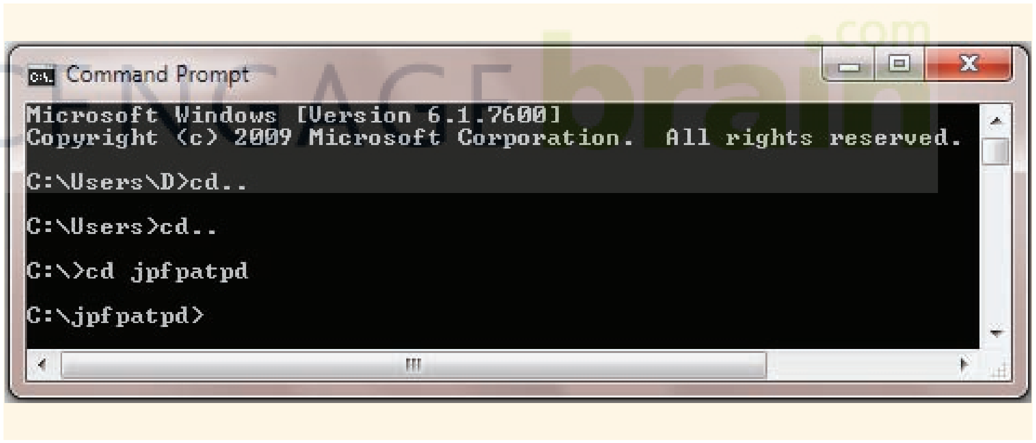
The following discussion assumes that you have set the `Path` so that the files `javac.exe` and `java.exe` can be executed from within any subdirectory.

You can use an editor such as Notepad to create Java programs. The name of the class containing the Java program and the name of the file containing the program must be the same. Moreover, the file containing the Java program must have the extension `.java`.

Suppose that the file `Welcome.java` is in the subdirectory `c:\jpfpatpd` and contains the following Java application program:

```
public class Welcome
{
    public static void main(String[] args)
    {
        System.out.println("Welcome to Java Programming.");
    }
}
```

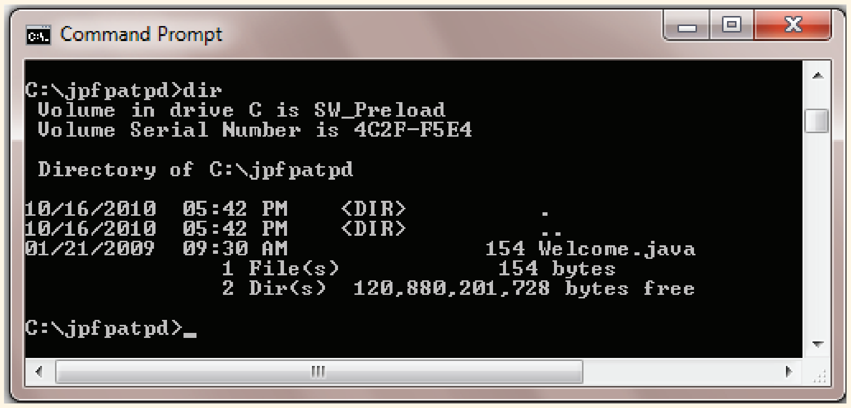
We assume that you have switched to the subdirectory `c:\jpfpatpd` (see Figure D-9).



```
Microsoft Windows [Version 6.1.7600]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\D>cd..

C:\Users>cd..

C:\>cd jpfpatpd

C:\jpfpatpd>
```

FIGURE D-9 Windows console environment

Figure D-10 shows the files in the subdirectory `c:\jpfpatpd`.

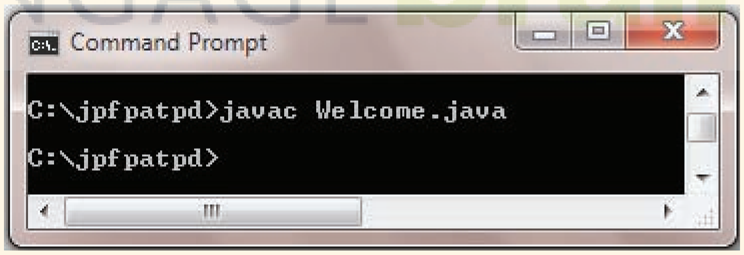


```
C:\jpfpatpd>dir
 Volume in drive C is SW_Preload
 Volume Serial Number is 4C2F-F5E4

 Directory of C:\jpfpatpd

10/16/2010  05:42 PM    <DIR>          .
10/16/2010  05:42 PM    <DIR>          ..
01/21/2009  09:30 AM               154 Welcome.java
               1 File(s)            154 bytes
               2 Dir(s)  120,880,201,728 bytes free

C:\jpfpatpd>_
```

FIGURE D-10 Files in the subdirectory `c:\jpfpatpd`

To place the compiled code of the program `Welcome.java` in the subdirectory `c:\jpfpatpd`, you can execute the following command, as shown in Figure D-11:

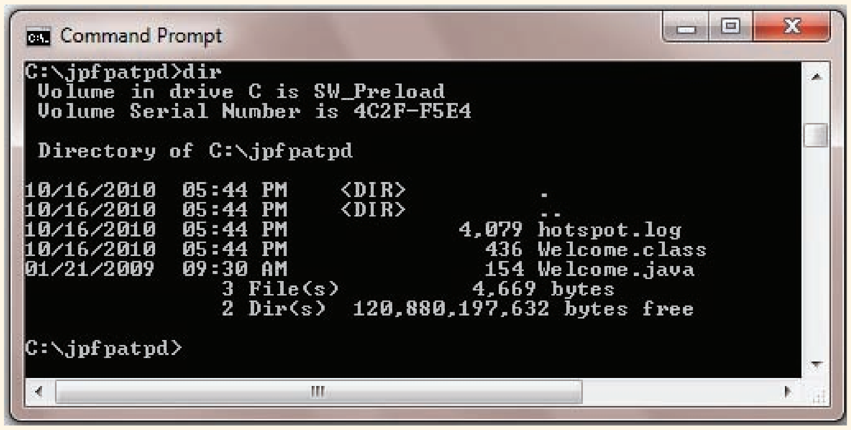
```
javac Welcome.java
```



```
C:\jpfpatpd>javac Welcome.java

C:\jpfpatpd>
```

FIGURE D-11 Compile `Welcome.java` program

The preceding command creates the file `Welcome.class`, which contains the compiled code of the program `Welcome.java` and places it in the subdirectory `c:\jpfpatpd` (see Figure D-12).

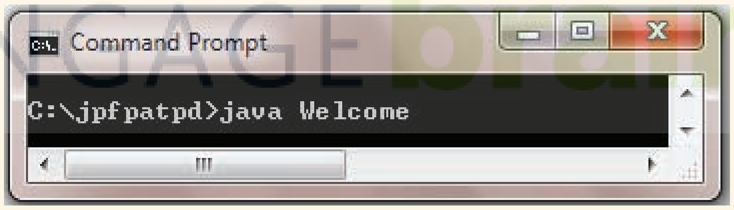


```
C:\jpfpatpd>dir
 Volume in drive C is SW_Preload
 Volume Serial Number is 4C2F-F5E4

 Directory of C:\jpfpatpd

10/16/2010  05:44 PM    <DIR>          .
10/16/2010  05:44 PM    <DIR>          ..
10/16/2010  05:44 PM             4,079 hotspot.log
10/16/2010  05:44 PM               436 Welcome.class
01/21/2009  09:30 AM               154 Welcome.java
               3 File(s)          4,669 bytes
               2 Dir(s)  120,880,197,632 bytes free

C:\jpfpatpd>
```

FIGURE D-12 The file `Welcome.class` program

You can now issue the following command to execute the `Welcome` program (see Figure D-13):

```
java Welcome
```

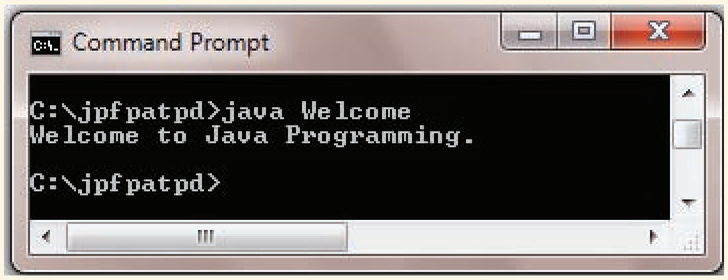


```
C:\jpfpatpd>java Welcome
```

FIGURE D-13 Executing `Welcome` program

After this statement executes, the following line appears on the screen, as shown in Figure D-14:

```
Welcome to Java Programming.
```



```
C:\jpfpatpd>java Welcome
Welcome to Java Programming.

C:\jpfpatpd>
```

FIGURE D-14 Execution of the `Welcome` program

The preceding command, after compiling the program, places the compiled code in the same subdirectory as the program. However, when you compile a Java program using the command-line compiler, you can instruct the system to store the program's compiled code in any subdirectory you want. To place the compiled code in a specific directory, you include the option `–d` and the name of the subdirectory where you want the command code placed when you compile the program. For example, the command:

```
javac -d c:\jdk1.7.0\fastdebug\bin\classes Welcome.java
```

places the compiled code of the program Welcome.java in the subdirectory:

```
c:\jdk1.7.0\fastdebug\bin\classes
```

Note that the subdirectory `c:\jdk1.7.0\fastdebug\bin\classes` must exist before you execute the command to compile the program.

Similarly, the following command places the compiled code of the program `Welcome.java` in the subdirectory `c:\jpfpatpd`:

```
javac -d c:\jpfpatpd Welcome.java
```

To be absolutely certain that the directory path is correct, check your system's documentation.

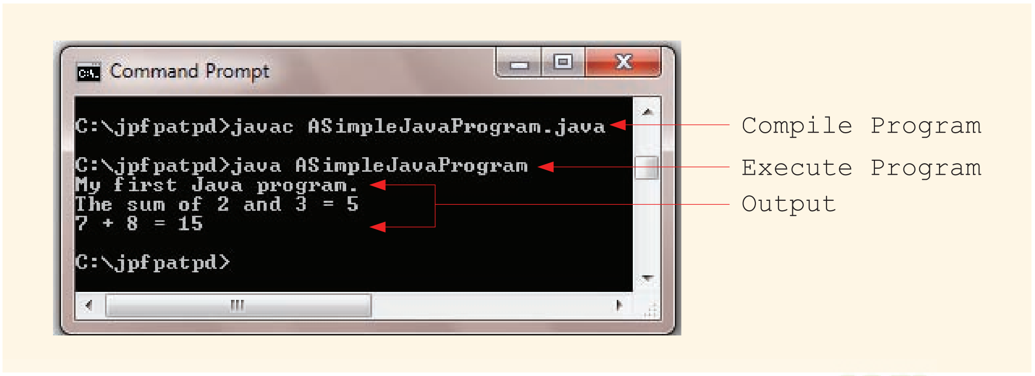
Suppose that you have placed the file `Welcome.class` within the subdirectory `c:\jdk1.7.0\fastdebug\bin\classes`. In addition, suppose that you have not set the `CLASSPATH` to allow the system to look for the compiled code on specific locations on your computer. In this case, you can use the option `-classpath` and the name of the subdirectory that contains the compiled code to execute the program. For example, the following command looks for the compiled code of the `Welcome` program in the subdirectory `c:\jdk1.7.0\fastdebug\bin\classes`:

```
java -classpath c:\jdk1.7.0\fastdebug\bin\classes Welcome
```

NOTE

If the compiled code of the classes is in the subdirectory, say c:\jpfpatpd, you can set the system variable CLASSPATH to c:\jpfpatpd. If the system variable CLASSPATH already exists, you can add the path c:\jpfpatpd to it. To be absolutely certain how to set CLASSPATH in the Windows environment, check your operating system's documentation. Moreover, if you are using other operating systems, such as UNIX, check the documentation to set the variables so that you can conveniently compile and execute a Java program.

The subdirectory c:\jpfpatpd also contains the file ASimpleJavaProgram.java. Figure D-15 shows the compile command, execute command, and the output of the program.

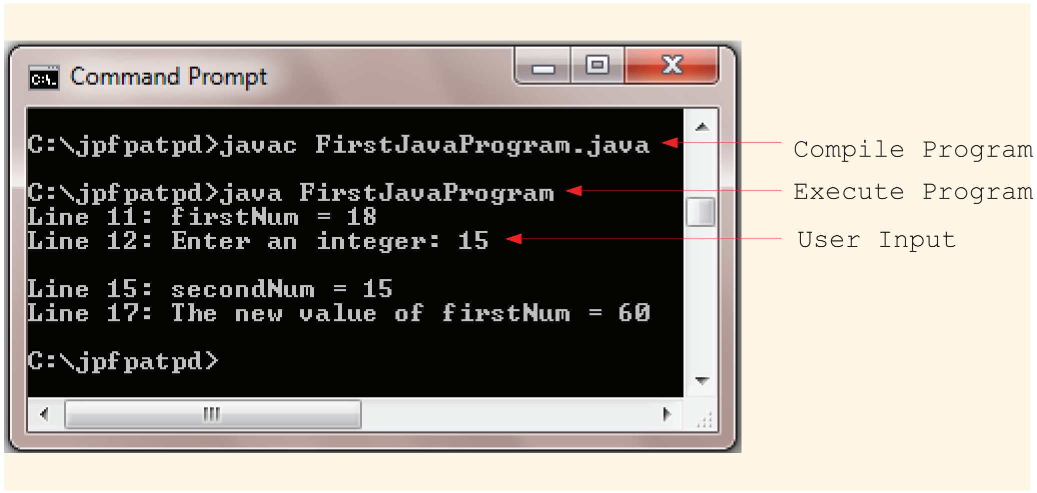


```
C:\jpfpatpd>javac ASimpleJavaProgram.java

C:\jpfpatpd>java ASimpleJavaProgram
My first Java program.
The sum of 2 and 3 = 5
7 + 8 = 15

C:\jpfpatpd>
```

FIGURE D-15 Compiling and executing the program ASimpleJavaProgram.java

Note that the program ASimpleJavaProgram is the same as that discussed in Chapter 2.

The subdirectory c:\jpfpatpd also contains the file FirstJavaProgram.java. Figure D-16 shows the compile command, execute command, and program output.



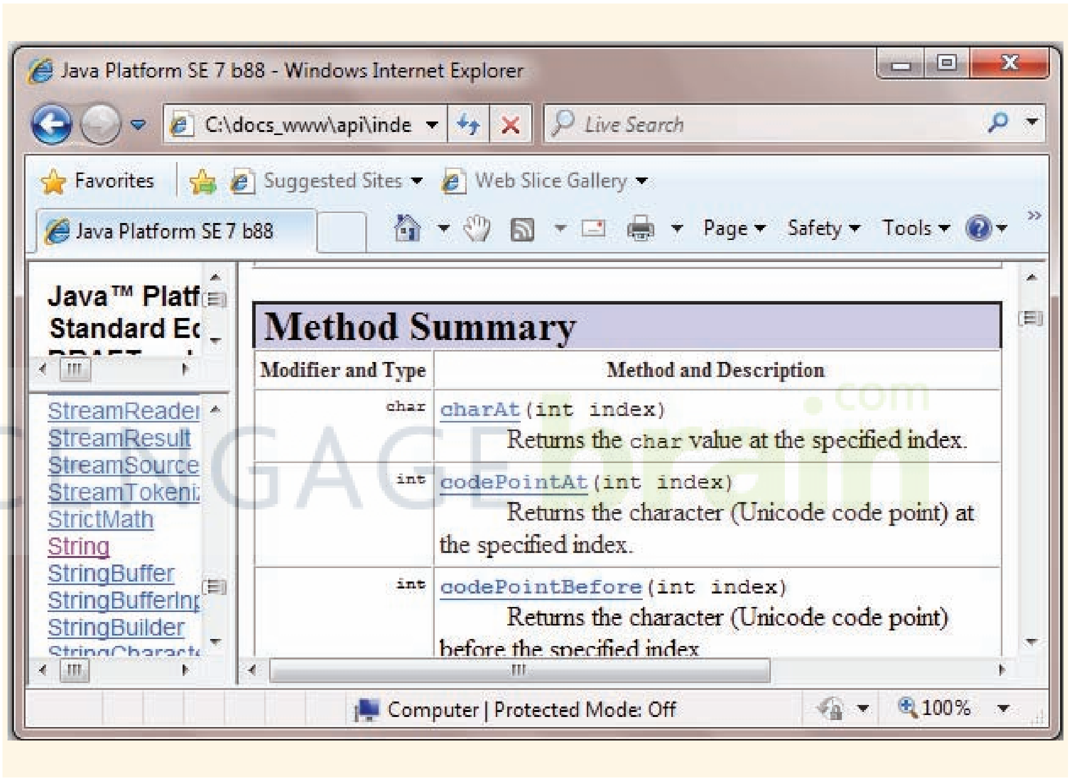
```
C:\jpfpatpd>javac FirstJavaProgram.java

C:\jpfpatpd>java FirstJavaProgram
Line 11: firstNum = 18
Line 12: Enter an integer: 15

Line 15: secondNum = 15
Line 17: The new value of firstNum = 60

C:\jpfpatpd>
```

FIGURE D-16 Compiling and executing the program FirstJavaProgram.java

Note that the program `FirstJavaProgram` is the same as that discussed in Example 2-26 in Chapter 2.

Java Style Documentation

In this book, whenever we designed a class, among others, we provided an explanation of the methods. We also noted that Java provides a wealth of predefined classes. For example, if you visit the Web site *http://java.sun.com/javase/6/docs/api* or *http://java.sun.com/javase/7/docs/api* you can find a description of the **`class`** `String` as shown in Figure D-17. (Note that the URL locations of these api documentations may change without any notice.)



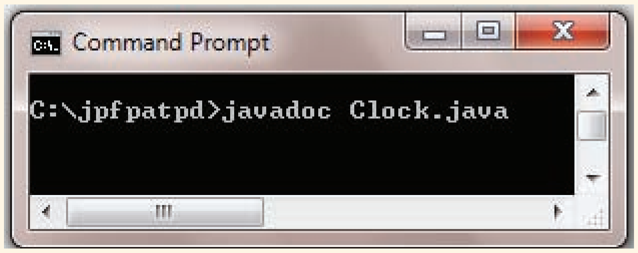
Method Summary

Modifier and Type	Method and Description
char	`charAt(int index)` Returns the char value at the specified index.
int	`codePointAt(int index)` Returns the character (Unicode code point) at the specified index.
int	`codePointBefore(int index)` Returns the character (Unicode code point) before the specified index

FIGURE D-17 The **`class`** `String`

This description of the **`class`** `String` as shown in Figure D-17 is Java style documentation. You can also produce this type of documentation for the classes you design using the command `javadoc`. We illustrate how to produce the Java style documentation of the **`class`** `Clock`, designed in Chapter 8.

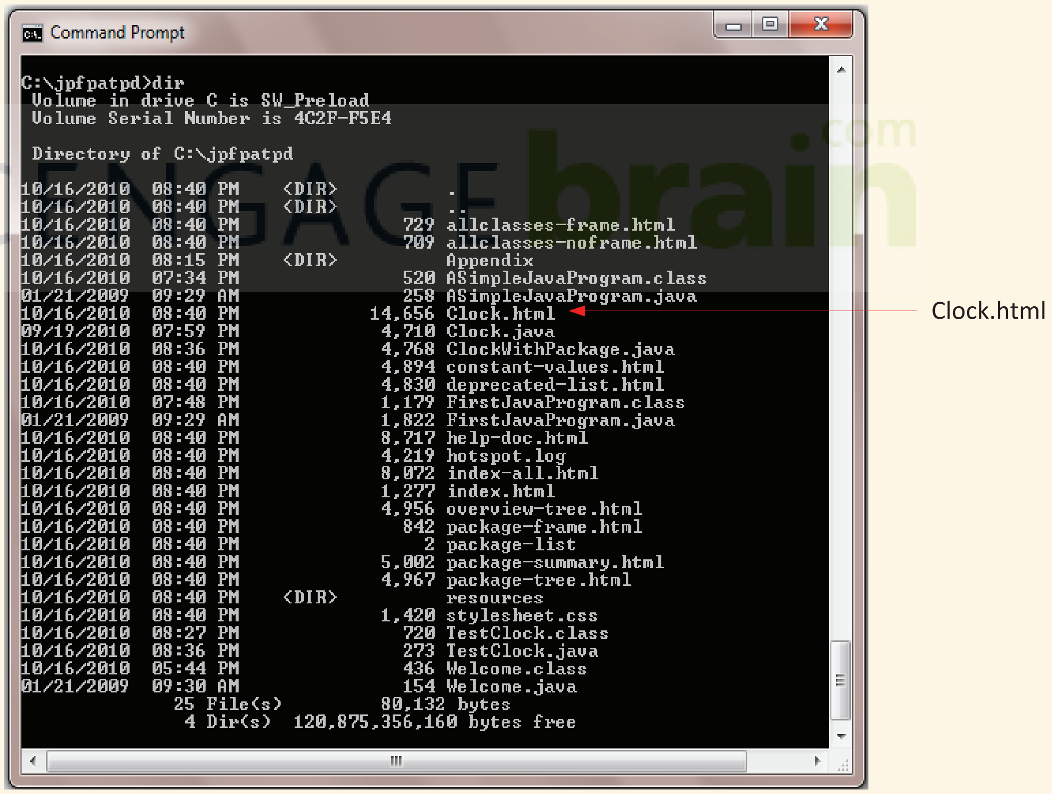
Suppose that the definition of the `class` `Clock` is in the subdirectory `c:\jpfpatpd`. Next execute the command: `javadoc Clock.java`, see Figure D-18.



```
C:\jpfpatpd>javadoc Clock.java
```

FIGURE D-18 Execute the command `javadoc Clock.java`

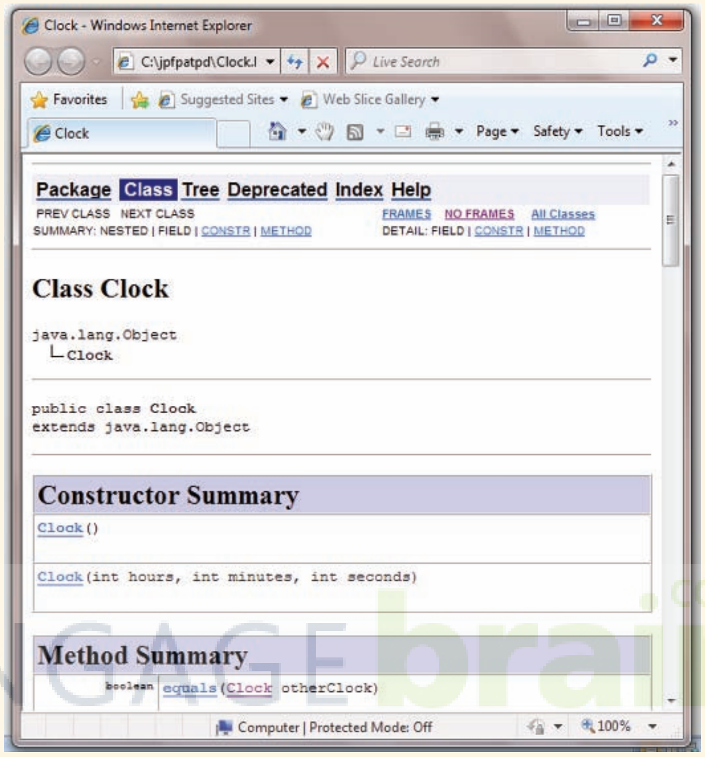
The preceding command creates a number of files as shown in Figure D-19.



```
C:\jpfpatpd>dir
 Volume in drive C is SW_Preload
 Volume Serial Number is 4C2F-F5E4

 Directory of C:\jpfpatpd

10/16/2010  08:40 PM    <DIR>          .
10/16/2010  08:40 PM    <DIR>          ..
10/16/2010  08:40 PM               729 allclasses-frame.html
10/16/2010  08:40 PM               709 allclasses-noframe.html
10/16/2010  08:15 PM    <DIR>          Appendix
10/16/2010  07:34 PM               520 ASimpleJavaProgram.class
01/21/2009  09:29 AM               258 ASimpleJavaProgram.java
10/16/2010  08:40 PM            14,656 Clock.html
09/19/2010  07:59 PM             4,710 Clock.java
10/16/2010  08:36 PM             4,768 ClockWithPackage.java
10/16/2010  08:40 PM             4,894 constant-values.html
10/16/2010  08:40 PM             4,830 deprecated-list.html
10/16/2010  07:48 PM             1,179 FirstJavaProgram.class
01/21/2009  09:29 AM             1,822 FirstJavaProgram.java
10/16/2010  08:40 PM             8,717 help-doc.html
10/16/2010  08:40 PM             4,219 hotspot.log
10/16/2010  08:40 PM             8,072 index-all.html
10/16/2010  08:40 PM             1,277 index.html
10/16/2010  08:40 PM             4,956 overview-tree.html
10/16/2010  08:40 PM               842 package-frame.html
10/16/2010  08:40 PM                 2 package-list
10/16/2010  08:40 PM             5,002 package-summary.html
10/16/2010  08:40 PM             4,967 package-tree.html
10/16/2010  08:40 PM    <DIR>          resources
10/16/2010  08:40 PM             1,420 stylesheet.css
10/16/2010  08:27 PM               720 TestClock.class
10/16/2010  08:36 PM               273 TestClock.java
10/16/2010  05:44 PM               436 Welcome.class
01/21/2009  09:30 AM               154 Welcome.java
              25 File(s)         80,132 bytes
               4 Dir(s)  120,875,356,160 bytes free
```

FIGURE D-19 The files produced by the command `javadoc Clock.java`

Next, if you switch to the Windows environment and double click on the file `Clock.html`, it shows you the Java style documentation of the **`class`** `Clock` shown in Figure D-20.



Package Class Tree Deprecated Index Help
PREV CLASS NEXT CLASS FRAMES NO FRAMES All Classes
SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD

Class Clock

```
java.lang.Object
  └Clock
```

```
public class Clock
extends java.lang.Object
```

Constructor Summary

```
Clock()
Clock(int hours, int minutes, int seconds)
```

Method Summary

```
boolean equals(Clock otherClock)
```

FIGURE D-20 Java style documentation of the **`class`** `Clock`

Creating Your Own Packages

Recall that a package is a collection of related classes. As you develop classes, you can create packages and categorize your classes. You can import your classes in the same way that you import classes from the packages provided by Java.

To create a package and add a class to the package so that the class can be used in a program, you do the following:

1. Define the class to be **`public`**. If the class is not **`public`**, it can be used only within the package.
2. Choose a name for the package. To organize your package, you can create subdirectories within the directory that contains the compiled code of the classes. For

example, you could create a directory for the classes you create in this book. Because the title of this book is *Java Programming: From Problem Analysis to Program Design*, you could create a directory named jpfpatpd. You could then make subdirectories for the classes used in each chapter, such as the subdirectory Appendix within the directory jpfpatpd.

Suppose that you want to create a **package** to group the classes related to time. You could call this **package** clockPackage. To add the **class** Clock to this package and to place the package clockPackage within the subdirectory Appendix of the directory jpfpatpd, you include the following package statement with the file containing the **class** Clock (Note that the **class** Clock is the same as discussed in Chapter 8):

```
package jpfpatpd.Appendix.clockPackage;
```

We put this statement before the definition of the **class**, like this:

```
package jpfpatpd.Appendix.clockPackage;

public class Clock
{
    //put instance variables and methods here
}
```

The next step is to compile the file Clock.java using the compile command in the IDE (integrated development environment) you are using.

The following discussion assumes that you have set the Path so that the files javac.exe and java.exe can be executed from within any subdirectory. Suppose that the file Clock.java is in the subdirectory c:\jpfpatpd. We assume that you have switched to the subdirectory c:\jpfpatpd.

If you are using Java 7.0, which contains a command-line compiler, you include the option -d to place the compiled code of the program Clock.java in a specific directory. For example, the command:

```
javac -d c:\jre1.7.0\lib\classes Clock.java
```

places the compiled code of the program Clock.java in the subdirectory:

```
c:\jre1.7.0\lib\classes\jpfpatpd\Appendix\clockPackage
```

Similarly, the following command places the compiled code of the program Clock.java in the subdirectory c:\jpfpatpd\Appendix\clockPackage:

```
javac -d c:\ Clock.java
```

If the directories jpfpatpd, Appendix, and clockPackage do not exist, then the compiler automatically creates these directories. Note that for the earlier command to execute successfully, the subdirectory c:\jre1.7.0\lib\classes must exist. If this subdirectory does not exist, you must first create it. Also, to be absolutely sure about the correct directory path, check your system's documentation. Moreover, if you do not use the -d option with the path of the subdirectory to specify the subdirectory in which to store the compiled code, then the compiled code is, typically, stored in the current subdirectory.

Once the package is created, you can use the appropriate import command in your program to make use of the class. For example, to use the class Clock, as created in the preceding code, you use the following import statement in your program:

```
import jpfpatpd.Appendix.clockPackage.Clock;
```

In Java, package is a reserved word.

Example D-1 further explains how to use a package in a program. We assume that the class Clock has been compiled and placed in the subdirectory c:\jpfpatpd\Appendix\clockPackage.

EXAMPLE D-1

The following program uses the class Clock.

```
import jpfpatpd.Appendix.clockPackage.Clock;

public class TestClock
{
    public static void main(String[] args)
    {
        Clock myClock = new Clock(12,30,45);

        System.out.println("myClock: " + myClock);
    }
}
```

Because this program uses the class Clock, when you compile the program using the compiler command, you use the option -classpath to specify where to find the compiled code of the class Clock. Suppose that the file TestClock.java is in the subdirectory c:\jpfpatpd. Consider the following command:

```
javac -classpath c:\ TestClock.java
```

This command finds Clock.class in the subdirectory c:\jpfpatpd\Appendix\clockPackage. The compiled code TestClock.class of the program TestClock.java is placed in the current subdirectory. On the other hand, the following command places the compiled code, TestClock.class, in the subdirectory c:\jpfpatpd:

```
javac -d c:\jpfpatpd -classpath c:\ TestClock.java
```

Suppose the file TestClock.class is in the subdirectory c:\jpfpatpd. The following command executes the program TestClock.class:

```
java -classpath .;c:\ TestClock
```

If you are using an IDE to create Java programs, you need to be familiar with the commands to compile and execute them. Typically, an IDE automatically stores the compiled code of the classes in an appropriate subdirectory.

Multiple-File Programs

In the preceding section, you learned how to create a `package`. Creating a `package` to group related `class`(es) is very useful if the classes are to be used again and again. On the other hand, if a `class` is to be used in only one program, or if you have divided your program so that it uses more than one `class`, rather than create a `package`, you can directly add the file(s) containing the `class`(es) to the program.

The Java IDEs—J++ Builder and JGrasp—put the editor, compiler, and loader all into one program. With one command, a program is compiled. These IDEs also manage multiple-file programs in the form of a project. A **project** consists of several files, called the project files. These IDEs include a command that allows you to add several files to a project. Also, these IDEs usually have commands such as **build**, **rebuild**, or **make** (check your software's documentation) to automatically compile all the files required. When one or more files in the project change, you can use these commands to recompile the files.

Formatting the Output of Decimal Numbers Using the **class DecimalFormat**

Chapter 3 explained how to format the output of floating-point numbers, using the method format of the `class String`, to a specific number of decimal places. Chapter 3 also noted that another way to format the output of floating-point numbers is to use the `class DecimalFormat`.

Recall that the default output of decimal numbers of the type `float` is up to six decimal places. Similarly, the default output of decimal numbers of the type `double` is up to 15 decimal places. For example, consider the statements in Table D-3; the output is shown to the right.

TABLE D-3 Default Output of Floating-Point Numbers

Statement	Output
`System.out.println(22.0 / 7.0);`	`3.142857142857143`
`System.out.println(75.0 / 7.0);`	`10.714285714285714`
`System.out.println((float)(33.0 / 16.0));`	`2.0625`
`System.out.println((float)(22.0 / 7.0));`	`3.142857`

As discussed in Chapter 3, sometimes floating-point numbers must be output in a specific way. For example, a paycheck must be printed to two decimal places, whereas the results of a scientific experiment might require the output of floating-point numbers to six, seven, or perhaps even 10 decimal places.

You can use the Java `class DecimalFormat` to format decimal numbers in a specific manner. The method `format` of the `class DecimalFormat` is applied to the decimal value being formatted. The following steps explain how to use these features to format decimal numbers:

1. Create a `DecimalFormat` object and initialize it to the specific format. Consider the following statement:

   ```
   DecimalFormat twoDecimal = new DecimalFormat("0.00");
   ```

   This statement creates the `DecimalFormat` object `twoDecimal` and initializes it to the string `"0.00"`. Each `0` in the string is a **format flag**. The string `"0.00"` specifies the formatting of the decimal number. This string indicates that the decimal number being formatted with the object `twoDecimal` will have at least one digit to the left of the decimal point and exactly two digits to the right of the decimal point. If the number being formatted does not meet the formatting requirement, that is, it does not have digits at the specified places, those places are automatically filled with 0. Moreover, suppose that you have the following statement:

   ```
   DecimalFormat twoDigits = new DecimalFormat("0.##");
   ```

   The object `twoDigits` can be used to format the number with two decimal places, but the `##` symbols indicate that trailing zeros will appear as spaces.
2. Next, use the method `format` of the `class DecimalFormat`. (Assume the first declaration of Step 1.) For example, the statement:

   ```
   twoDecimal.format(56.379);
   ```

   formats the decimal number `56.379` as `56.38` (the decimal number is rounded). The method format returns the string containing the digits of the formatted number.
3. The `class DecimalFormat` is included in the `package java.text`. You must import this `class` into your program.

Example D-2 illustrates how to format the output of decimal numbers.

EXAMPLE D-2

```
//Program: Formatting output of decimal numbers using
//the class DecimalFormat

import java.text.DecimalFormat;

public class FormattingDecimalNum
{
    public static void main(String[] args)
    {
        double x = 15.674;                              //Line 1
        double y = 235.73;                              //Line 2
        double z = 9525.9864;                           //Line 3
```

```
        DecimalFormat twoDecimal =
                       new DecimalFormat("0.00");     //Line 4
        DecimalFormat threeDecimal =
                         new DecimalFormat("0.000");  //Line 5

        System.out.println("Line 6: Outputting the "
                         + "values of x, y, and z \n"
                         + "        with two decimal "
                         + "places.");                //Line 6
        System.out.println("Line 7: x = "
                         + twoDecimal.format(x));     //Line 7
        System.out.println("Line 8: y = "
                         + twoDecimal.format(y));     //Line 8
        System.out.println("Line 9: z = "
                         + twoDecimal.format(z));     //Line 9

        System.out.println("Line 10: Outputting the "
                         + "values of x, y, and z \n"
                         + "         with three "
                         + "decimal places.");        //Line 10
        System.out.println("Line 11: x = "
                         + threeDecimal.format(x));   //Line 11
        System.out.println("Line 12: y = "
                         + threeDecimal.format(y));   //Line 12
        System.out.println("Line 13: z = "
                         + threeDecimal.format(z));   //Line 13
    }
}
```

Sample Run:

```
Line 6: Outputting the values of x, y, and z
        with two decimal places.
Line 7: x = 15.67
Line 8: y = 235.73
Line 9: z = 9525.99
Line 10: Outputting the values of x, y, and z
         with three decimal places.
Line 11: x = 15.674
Line 12: y = 235.730
Line 13: z = 9525.986
```

The statements in Lines 1, 2, and 3 declare and initialize `x`, `y`, and `z` to `15.674`, `235.73`, and `9525.9864`, respectively. The statement in Line 4 creates and initializes the `DecimalFormat` object `twoDecimal` to output decimal numbers to two decimal places. Similarly, the statement in Line 5 creates and initializes the `DecimalFormat` object `threeDecimal` to output decimal numbers with three decimal places.

The statements in Lines 7, 8, and 9 output the values of `x`, `y`, and `z` to two decimal places, respectively. Note that the printed values of `x` in Line 7 and `z` in Line 9 are rounded.

The statements in Lines 11, 12, and 13 output the values of `x`, `y`, and `z`, respectively, to three decimal places. Note that the value of `y` in Line 12 is output to three decimal places. Because the number stored in `y` has only two decimal places, a `0` is printed as the third decimal place.

Packages and User-Defined Classes

Chapter 7 discusses user-defined methods, in particular methods with parameters. As explained in Chapter 3, there are two types of variables in Java—primitive and reference. The program in Example 7-8 illustrates that if a formal parameter is of the primitive type and the corresponding actual parameter is a variable, then the formal parameter cannot change the value of the actual parameter. Changing the value of a formal parameter of a primitive data type has no effect on the actual parameter. However, if a formal parameter is a reference variable, then both the actual and the formal parameter refer to the same object. That is, only formal parameters that are reference variables are capable of passing values outside the function.

Java provides classes corresponding to each primitive data type, so that values of primitive data types can be considered objects. For example, you can use the `class Integer` to treat `int` values as objects, `class Double` to treat `double` values as objects, and so on. These classes, called wrapper classes, were described in Chapter 6.

As noted in Chapter 7, Java does not provide any class that wraps primitive type values in objects and, when passed as parameters, change their values. If a method returns only one value of a primitive type, then you can write a value-returning method. However, if you encounter a situation that requires you to write a method that needs to pass more than one value of a primitive type, then you should design your own classes. In the next section, we introduce various classes to accomplish this. For example, we design the `class IntClass` so that values of the `int` type can be wrapped in an object. The `class IntClass` also provides methods to change the value of an `IntClass` object. We use reference variables of the `IntClass` type to pass `int` values outside a method.

Primitive Type Classes

This section presents the definitions of the `class`es `IntClass`, `LongClass`, `CharClass`, `FloatClass`, `DoubleClass`, and `BooleanClass`.

Class: IntClass

```
public class IntClass
{
    private int x;    //variable to store the number

        //default constructor
        //Postcondition: x = 0
    public IntClass()
    {
        x = 0;
    }
```

```
        //constructor with parameter
        //Postcondition: x = num
    public IntClass(int num)
    {
        x = num;
    }

       //Method to set the data member x
       //Postcondition: x = num
    public void setNum(int num)
    {
        x = num;
    }

       //Method to return the value of x
       //Postcondition: The value of x is returned
    public int getNum()
    {
        return x;
    }

        //Method to update the value of x by adding
        //the value of num
        //Postcondition: x = x + num;
    public void addToNum(int num)
    {
        x = x + num;
    }
        //Method to update the value of x by multiplying
        //the value of x by num
        //Postcondition: x = x * num;
    public void multiplyToNum(int num)
    {
        x = x * num;
    }

        //Method to compare the value of x with the value of num
        //Postcondition: Returns a value < 0 if x < num
        //               Returns 0 if x == num
        //               Returns a value > 0 if x > num
    public int compareTo(int num)
    {
        return (x - num);
    }

        //Method to compare x with num for equality
        //Postcondition: Returns true if x == num;
        //               otherwise it returns false
    public boolean equals(int num)
    {
        if (x == num)
            return true;
        else
            return false;
    }
```

```
        //Method to return the value of x as a string
    public String toString()
    {
        return (String.valueOf(x));
    }
}
```

Consider the following statements:

```
IntClass firstNum = new IntClass();       //Line 1
IntClass secondNum = new IntClass(5);     //Line 2
int num;                                  //Line 3
```

The statement in Line 1 creates the object `firstNum` and initializes it to `0`. The statement in Line 2 creates the object `secondNum` and initializes it to `5`. The statement in Line 3 declares `num` to be an `int` variable. Now consider the following statements:

```
firstNum.setNum(24);                      //Line 4
secondNum.addToNum(6);                    //Line 5
num = firstNum.getNum();                  //Line 6
```

The statement in Line 4 sets the value of `firstNum` (in fact, the value of the data member `x` of `firstNum`) to `24`. The statement in Line 5 updates the value of `secondNum` to `11` (the previous value `5` is updated by adding `6` to it.) The statement in Line 6 retrieves the value of the object `firstNum` (the value of the data member `x`) and assigns it to `num`. After this statement executes, the value of `num` is `24`.

The following statements output the values of `firstNum` and `secondNum` (in fact, the values of their data members):

```
System.out.println("firstNum = " + firstNum);
System.out.println("secondNum = " + secondNum);
```

Table D-4 shows how variables of `int` type and the corresponding reference variables of `IntClass` type work.

TABLE D-4 Variables of `int` Type and the Corresponding Reference Variables of `IntClass`

	`int`	`IntClass`

Declaration without or with initialization	`int x, y = 5;`	`IntClass x, y;`
		`x = new IntClass();`
		`y = new IntClass(5);`

Assignment	`x = 24;`	`x.setNum(24);`
	`y = x;`	`y.setNum(x.getNum());`
Addition	`x = x + 10;`	`x.addToNum(10);`
	`x = x + y;`	`x.addToNum(y.getNum());`

TABLE D-4 Variables of `int` Type and the Corresponding Reference Variables of `IntClass` (continued)

	`int`	`IntClass`
Multiplication	`x = x * 10;`	`x.multiplyToNum(10);`
	`x = x * y;`	`x.multiplyToNum(y.getNum());`
Comparison	`if (x < 10)`	`if (x.compareTo(10) < 0)`
	`if (x < y)`	`if (x.compareTo(y.getNum()) < 0)`
	`if (x <= 10)`	`if (x.compareTo(10) <= 0)`
	`if (x <= y)`	`if (x.compareTo(y.getNum()) <= 0)`
	`if (x == 10)`	`if (x.compareTo(10) == 0)` or `if (x.equals(10))`
	`if (x == y)`	`if (x.compareTo(y.getNum()) == 0)` or `if (x.equals(y.getNum()))`
	`if (x > 10)`	`if (x.compareTo(10) > 0)`
	`if (x > y)`	`if (x.compareTo(y.getNum()) > 0)`
	`if (x >= 10)`	`if (x.compareTo(10) >= 0)`
	`if (x >= y)`	`if (x.compareTo(y.getNum()) >= 0)`
	`if (x != 10)`	`if (x.compareTo(10) != 0)` or `if (!x.equals(10))`
	`if (x != y)`	`if (x.compareTo(y.getNum()) != 0)` or `if (!x.equals(y.getNum()))`
Output		`System.out.println(x);`
		`System.out.println(x);`

Class: LongClass

```
public class LongClass
{
    private long x;

    public LongClass()
    {
        x = 0;
    }

    public LongClass(long num)
    {
        x = num;
    }

    public void setNum(long num)
    {
        x = num;
    }

    public long getNum()
    {
        return x;
    }

    public void addToNum(long num)
    {
        x = x + num;
    }

    public void multiplyToNum(long num)
    {
        x = x * num;
    }

    public long compareTo(long num)
    {
        return (x - num);
    }

    public boolean equals(long num)
    {
        if (x == num)
            return true;
        else
            return false;
    }

    public String toString()
    {
        return (String.valueOf(x));
    }
}
```

Class: CharClass

```
public class CharClass
{
    private char ch;

    public CharClass()
    {
        ch = ' ';
    }

    public CharClass(char c)
    {
        ch = c;
    }

    public void setChar(char c)
    {
        ch = c;
    }

    public int getChar()
    {
        return ch;
    }

    public char nextChar()
    {
        return (char)((int)ch + 1);
    }

    public char prevChar()
    {
        return (char)((int)ch - 1);
    }

    public String toString()
    {
        return (String.valueOf(ch));
    }
}
```

Class: FloatClass

```
public class FloatClass
{
    private float x;

    public FloatClass()
    {
        x = 0;
    }

    public FloatClass(float num)
    {
        x = num;
    }
    public void setNum(float num)
    {
        x = num;
    }

    public float getNum()
    {
        return x;
    }

    public void addToNum(float num)
    {
        x = x + num;
    }

    public void multiplyToNum(float num)
    {
        x = x * num;
    }

    public float compareTo(float num)
    {
        return (x - num);
    }

    public boolean equals(float num)
    {
        if (x == num)
            return true;
        else
            return false;
    }

    public String toString()
    {
        return (String.valueOf(x));
    }
}
```

Class: DoubleClass

```
public class DoubleClass
{
    private double x;

    public DoubleClass()
    {
        x = 0;
    }

    public DoubleClass(double num)
    {
        x = num;
    }
    public void setNum(double num)
    {
        x = num;
    }

    public double getNum()
    {
        return x;
    }

    public void addToNum(double num)
    {
        x = x + num;
    }

    public void multiplyToNum(double num)
    {
        x = x * num;
    }

    public double compareTo(double num)
    {
        return (x - num);
    }

    public boolean equals(double num)
    {
        if (x == num)
            return true;
        else
            return false;
    }
    public String toString()
    {
        return (String.valueOf(x));
    }
}
```

Class: BooleanClass

```
public class BooleanClass
{
    private boolean flag;

    public BooleanClass()
    {
        flag = false;
    }

    public BooleanClass(boolean f)
    {
        flag = f;
    }
    public boolean get()
    {
        return flag;
    }

    public void set(boolean f)
    {
        flag = f;
    }

    public String toString()
    {
        return (String.valueOf(flag));
    }

}
```

Using Primitive Type Classes in a Program

This section describes how to use the classes introduced in the previous section.

The class IntClass can be used in two ways. One way is to keep the file IntClass.java and the program in the same directory. First, compile the file IntClass.java, then compile the program.

The second way is to first create a package, and then put this class in that package. For example, you can create the package:

```
jpfpatpd.ch07.primitiveTypeClasses
```

and put the class in this package.

In this case, you place the statement:

```
package jpfpatpd.ch07.primitiveTypeClasses;
```

before the definition of the class IntClass.

The class IntClass definition is in the file IntClass.java. We need to compile this file and place the compiled code in the directory: jpfpatpd.ch07. primitiveTypeClasses. To do so, we execute the following command at the command line:

```
javac -d c:\jre1.7.0\lib\classes IntClass.java
```

The file IntClass.class is now placed in the subdirectory jpfpatpd\ch07 \primitiveTypeClasses of the directory c:\jre1.7.0 \lib\classes.

On the other hand, the command:

```
javac IntClass.java
```

places the file IntClass.class in the subdirectory jpfpatpd\ch07\primitive TypeClasses of the same directory. Note that the system automatically creates the subdirectory jpfpatpd\ch07\primitiveTypeClasses if it does not exist.

You can now import this class in a program using the import statement. For example, you can use either of the following statements to use the `class IntClass` in your program:

```
import jpfpatpd.ch07.primitiveTypeClasses.*;
```

or

```
import jpfpatpd.ch07.primitiveTypeClasses.IntClass;
```

USING A SOFTWARE DEVELOPMENT KIT (SDK)

If you are using an SDK, such as CodeWarrior or J++ Builder, you can place the file containing the definition of the class in the same directory that contains your program. You do not need to create a package. However, you can also create a package using the SDK. In this case, place the appropriate `package` statement before the definition of the class, and use the compile command provided by the SDK. (In most cases, you do not need to specify a subdirectory.) The compiled file will be placed in the appropriate directory. You can now import the class without adding it to the project.

NOTE If you have created a package for your classes, to avoid compilation errors, do not add the file containing the definition of the class to the project.

Enumeration Types

Chapter 2 defined a data type as a set of values, combined with a set of operations on those values. It then introduced the primitive data types: `int`, `char`, `double`, and `float`. Using primitive data types, Chapter 8 discussed how to design classes to create your own data types. In other words, primitive data types are the building blocks of classes.

The values belonging to primitive data types are predefined. Java allows programmers to create their own data types by specifying the values of that data type. These are called **enumeration** or **enum** types and are defined using the keyword `enum`. *The values that you specify for the data types are identifiers*. For example, consider the following statement:

```
enum Grades {A, B, C, D, F};
```

This statement defines `Grades` to be an `enum` type; the values belonging to this type are `A`, `B`, `C`, `D`, and `F`. The values of an `enum` type are called **enumeration** or **enum** constants. Note that the values are enclosed in braces and separated by commas. Also, the `enum` constants within an `enum` type must be unique.

Similarly, the statement:

```
enum Sports {BASEBALL, BASKETBALL, FOOTBALL, GOLF,
             HOCKEY, SOCCER, TENNIS};
```

defines `Sports` to be an `enum` type and the values belonging to this type, that is, the `enum` constants, are `BASEBALL`, `BASKETBALL`, `FOOTBALL`, `GOLF`, `HOCKEY`, `SOCCER`, and `TENNIS`.

Each `enum` type is a *special type of class*, and the values belonging to the `enum` type are (special types of) objects of that class. For example, `Grades` is, in fact, a class and `A`, `B`, `C`, `D`, and `F` are `public static` reference variables to objects of the type `Grades`.

After an `enum` type is defined, you can declare reference variables of that type. For example, the following statement declares `myGrade` to be a reference variable of the `Grades` type:

```
Grades myGrade;
```

Because each of the variables `A`, `B`, `C`, `D`, and `F` is `public` and `static`, they can be accessed using the name of the class and the dot operator. Therefore, the following statement assigns the object `B` to `myGrade`:

```
myGrade = Grades.B;
```

The output of the statement:

```
System.out.println("myGrade: " + myGrade);
```

is:

```
myGrade: B
```

Similarly, the output of the statement:

```
System.out.println("Grades.B: " + Grades.B);
```

is:

```
Grades.B: B
```

Each `enum` constant in an `enum` type has a specific value, called the **ordinal value**. The ordinal value of the first `enum` constant is `0`, the ordinal value of the second `enum` constant is 1, and so on. Therefore, in the `enum` type `Grades`, the ordinal value of `A` is `0` and the ordinal value of `C` is `2`.

Associated with `enum` type is a set of methods that can be used to work with `enum` types. Table D-5 describes some of those methods.

TABLE D-5 Methods Associated with `enum` Types

Method	Description
`ordinal()`	Returns the ordinal value of an `enum` constant
`name()`	Returns the name of the `enum` value
`values()`	Returns the values of an `enum` type as a list

Example D-3 illustrates how these methods work.

EXAMPLE D-3

```
public class EnumExample1
{
    enum Grades {A, B, C, D, F};                         //Line 1

    enum Sports {BASEBALL, BASKETBALL, FOOTBALL,
                 GOLF, HOCKEY, SOCCER, TENNIS};          //Line 2

    public static void main(String[] args)               //Line 3
    {
        Grades myGrade;                                  //Line 4
        Sports mySport;                                  //Line 5

        myGrade = Grades.A;                              //Line 6

        mySport = Sports.BASKETBALL;                     //Line 7

        System.out.println("Line 8: My grade: "
                         + myGrade);                     //Line 8
        System.out.println("Line 9: The ordinal "
                         + "value of myGrade is "
                         + myGrade.ordinal());           //Line 9
        System.out.println("Line 10: myGrade name: "
                         + myGrade.name());              //Line 10

        System.out.println("Line 11: My sport: "
                         + mySport);                     //Line 11
        System.out.println("Line 12: The ordinal "
                         + "value of mySport is "
                         + mySport.ordinal());           //Line 12
        System.out.println("Line 13: mySport name: "
                          + mySport.name());             //Line 13

        System.out.println("Line 14: Sports: ");         //Line 14

        for (Sports sp : Sports.values())                //Line 15
            System.out.println(sp + "'s ordinal "
                             + "value is "
                             + sp.ordinal());            //Line 16

        System.out.println();                            //Line 17
    }
}
```

Sample Run:

```
Line 8: My grade: A
Line 9: The ordinal value of myGrade is 0
Line 10: myGrade name: A
Line 11: My sport: BASKETBALL
Line 12: The ordinal value of mySport is 1
Line 13: mySport name: BASKETBALL
Line 14: Sports:
BASEBALL's ordinal value is 0
BASKETBALL's ordinal value is 1
FOOTBALL's ordinal value is 2
GOLF's ordinal value is 3
HOCKEY's ordinal value is 4
SOCCER's ordinal value is 5
TENNIS's ordinal value is 6
```

The preceding program works as follows. The statements in Lines 1 and 2 define the **enum** type Grades and Sports, respectively. The statement in Line 4 declares myGrade to be a reference variable of the type Grades, and the statement in Line 5 declares mySport to be a reference variable of the type Sports. The statement in Line 6 assigns the object A to myGrade, and the statement in Line 7 assigns the object BASKETBALL to mySport.

The statement in Line 8 outputs myGrade, the statement in Line 9 uses the method ordinal to output the ordinal value of myGrade, and the statement in Line 10 uses the method name to output the name of myGrade.

The statement in Line 11 outputs mySport, the statement in Line 12 uses the method ordinal to output the ordinal value of mySport, and the statement in Line 13 uses the method name to output the name of mySport.

The foreach loop in Line 15 outputs the value of Sports and their ordinal values. Note that the method values, in the expression Sports.values(), returns the value of the **enum** type Sport as a list. The loop control variable sp ranges over those values one-by-one, starting at the first value.

The beginning of this section noted that an **enum** type is a special type of class, and the **enum** constants are reference variables to the objects of that **enum** type. Because each **enum** type is a class, in addition to the **enum** constants, it can also contain constructors, (**private**) data members, and methods. Before describing enumeration type or **enum** in more detail, let us note the following:

1. Enumeration types are defined using the keyword **enum** rather than **class**.
2. **enum** types are implicitly **final** because **enum** constants should not be modified.
3. **enum** constants are implicitly **static**.

4. Once an **enum** type is created, you can declare reference variables of that type, but you cannot instantiate objects using the operator **new**. In fact, an attempt to instantiate an object using the operator **new** will result in a compilation error.

(Because **enum** objects cannot be instantiated using the operator **new**, the constructor, if any, of an enumeration *cannot* be **public**. In fact, the constructors of an **enum** type are implicitly **private**.)

The **enum** type `Grades` was defined earlier in this section. Let us redefine this **enum** type by adding constructors, data members, and methods. Consider the following definition:

```java
public enum Grades
{
    A ("Range 90% to 100%"),
    B ("Range 80% to 89.99%"),
    C ("Range 70% to 79.99%"),
    D ("Range 60% to 69.99%"),
    F ("Range 0% to 59.99%");

    private final String range;

    private Grades()
    {
        range = "";
    }

    private Grades(String str)
    {
        range = str;
    }

    public String getRange()
    {
        return range;
    }
}
```

This **enum** type `Grades` contains the **enum** constants `A`, `B`, `C`, `D`, and `F`. It has a **private** named constant `range` of the type `String`, two constructors, and the method `getRange`. Note that each `Grades` object has the data member `range`. Let us consider the statement:

```java
A ("Range 90% to 100%")
```

This statement creates the `Grades` object, using the constructor with parameters, with the string `"Range 90% to 100%"`, and assigns that object to the reference variable `A`. The method `getRange` is used to return the string contained in the object.

It is not necessary to specify the modifier **private** in the heading of the constructor. Each constructor is implicitly **private**. Therefore, the two constructors of the **enum** type `Grades` can be written as:

```
Grades()
{
    range = "";
}

Grades(String str)
{
    range = str;
}
```

Example D-4 illustrates how the **enum** type `Grades` works.

EXAMPLE D-4

```
public class EnumExample2
{
    public static void main(String[] args)
    {
        System.out.println("Grade Ranges");     //Line 1

        for (Grades gr : Grades.values())       //Line 2
            System.out.println(gr + " "
                             + gr.getRange()); //Line 3

        System.out.println();                   //Line 4
    }
}
```

Sample Run:

```
Grade Ranges
A Range 90% to 100%
B Range 80% to 89.99%
C Range 70% to 79.99%
D Range 60% to 69.99%
F Range 0% to 59.99%
```

The foreach loop in Line 2 uses the method `values` to retrieve the **enum** constants as a list. The method `getRange` in Line 3 is used to retrieve the string contained in the `Grades` object.

The following programming example uses an **enum** type to create a program to play the game of rock, paper, and scissors.

PROGRAMMING EXAMPLE: The Rock, Paper, and Scissors Game

Everyone is familiar with the rock, paper, and scissors game. The game has two players, each of whom chooses one of the three objects: rock, paper, or scissors. If player 1 chooses rock and player 2 chooses paper, player 2 wins the game because paper covers the rock. The game is played according to the following rules:

- If both players choose the same object, this play is a tie.
- If one player chooses rock and the other chooses scissors, the player choosing the rock wins this play because the rock crushes the scissors.
- If one player chooses rock and the other chooses paper, the player choosing the paper wins this play because the paper covers the rock.
- If one player chooses scissors and the other chooses paper, the player choosing the scissors wins this play because the scissors cut the paper.

We write an interactive program that allows two players to play this game.

Input: This program has two types of input:

- The players' responses to play the game
- The players' choices

Output: The players' choices and the winner of each play. After the game is over, the total number of plays and the number of times that each player won should be output as well.

PROBLEM ANALYSIS AND ALGORITHM DESIGN

Two players play this game. Players enter their choices via the keyboard. Each player enters `R` or `r` for Rock, `P` or `p` for Paper, or `S` or `s` for Scissors. While the first player enters a choice, the second player looks away. Once both entries are in, if the entries are valid, the program outputs the players' choices and declares the winner of the play. The game continues until one of the players decides to quit. After the game ends, the program outputs the total number of plays and the number of times that each player won. This discussion translates into the following algorithm:

1. Provide a brief explanation of the game and how it is played.
2. Ask the users if they want to play the game.
3. Get plays for both players.
4. If the plays are valid, output the plays and the winner.
5. Update the total game count and winner count.
6. Repeat Steps 2–5 while the users continue to play the game.
7. Output the number of plays and times that each player won.

To describe the objects ROCK, PAPER, and SCISSORS, we define the following enum type:

```
public enum RockPaperScissors
{
    ROCK ("Rock crushes scissors."),
    PAPER ("Paper covers rock."),
    SCISSORS ("Scissors cuts paper.");

    private String mgs;

    private RockPaperScissors()
    {
        mgs = "";
    }

    private RockPaperScissors(String str)
    {
        mgs = str;
    }

    public String getMessage()
    {
        return mgs;
    }
}
```

Variables (Method main)

It is clear that you need the following variables in the method main:

```
int gameCount;      //to count the number of
                    //games played
int winCount1;      //to count the number of
                    //games won by player 1
int winCount2;      //to count the number of
                    //games won by player 2
int gameWinner;
char response;      //to get the user's response
                    //to play the game
char selection1;
char selection2;

RockPaperScissors play1;  //player1's selection
RockPaperScissors play2;  //player2's selection
```

This program is divided into six methods, which the following sections describe in detail.

- `displayRules`: This method displays some brief information about the game and its rules.
- `validSelection`: This method checks whether a player's selection is valid. The only valid selections are `R`, `r`, `P`, `p`, `S`, and `s`.
- `retrievePlay`: This method uses the entered choice (`R`, `r`, `P`, `p`, `S`, or `s`) and returns the appropriate object.
- `gameResult`: This method outputs the players' choices and the winner of the game.
- `winningObject`: This method determines and returns the winning object.
- `displayResults`: After the game is over, this method displays the final results.

Method `displayRules`

This method has no parameters. It consists only of output statements to explain the game and rules of play. Essentially, this method's definition is:

```
public static void displayRules()
{
    System.out.println("Welcome to the game of Rock, "
                     + "Paper, and Scissors.");
    System.out.println("This is a game for two players. "
                     + "For each game, each player \n"
                     + "selects one of the "
                     + "objects: Rock, Paper or "
                     + "Scissors.");
    System.out.println("The rules for winning the "
                     + "game are: ");
    System.out.println("1. If both players select the "
                     + "same object, it is a tie.");
    System.out.println("2. Rock crushes Scissors: The "
                     + "player who selects Rock wins.");
    System.out.println("3. Paper covers Rock: The "
                     + "player who selects Paper wins.");
    System.out.println("4. Scissors cuts Paper: The "
                     + "player who selects Scissors "
                     + "wins.");
    System.out.println("Enter R or r to select Rock, "
                     + "P or p to select Paper, \n"
                     + "and S or s to select Scissors.");
}
```

Method `validSelection`

This method checks whether a player's selection is valid. Let's use a **`switch`** statement to check for the valid selection. The definition of this method is:

```
public static boolean validSelection(char selection)
{
    switch (selection)
    {
    case 'R':
    case 'r':
    case 'P':
    case 'p':
    case 'S':
    case 's':
        return true;

    default:
        return false;
    }
}
```

Method retrievePlay This method uses the entered choice (`R`, `r`, `P`, `p`, `S`, or `s`) and returns the appropriate object. The method has one parameter of the type `char`. It is a value-returning method and returns a reference to a `RockPaperScissors` object.

The definition of the method `retrievePlay` is:

```
public static RockPaperScissors retrievePlay
                                (char selection)
{
    RockPaperScissors obj = RockPaperScissors.ROCK;

    switch (selection)
    {
    case 'R':
    case 'r':
        obj = RockPaperScissors.ROCK;
        break;

    case 'P':
    case 'p':
        obj = RockPaperScissors.PAPER;
        break;

    case 'S':
    case 's':
        obj = RockPaperScissors.SCISSORS;
    }

    return obj;
}
```

Method `gameResult`

This method decides whether a game is a tie or which player is the winner. It outputs the players' selections and the winner of the game. This method has two parameters: player 1's choice and player 2's choice. It returns the number (1 or 2) of the winning player.

The definition of this method is:

```
public static int gameResult(RockPaperScissors play1,
                             RockPaperScissors play2)
{
    int winner = 0;

    RockPaperScissors winnerObject;

    if (play1 == play2)
    {
        winner = 0;
        System.out.println("Both players selected "
                         + play1
                         + ". This game is a tie.");
    }
    else
    {
        winnerObject = winningObject(play1, play2);

            //Output each player's choice
        System.out.println("Player 1 selected " + play1
                         + " and player 2 selected "
                         + play2 + ".");

            //Decide the winner
        if (play1 == winnerObject)
            winner = 1;
        else if (play2 == winnerObject)
            winner = 2;

            //Output winning object's message
        System.out.println(winnerObject.getMessage());

            //Output the winner
        System.out.println("Player " + winner
                         + " wins this play.");
    }

    return winner;
}
```

Method winningObject

To decide the winner of the game, you look at the players' selections and then at the rules of the game. For example, if one player chooses ROCK and another chooses PAPER, the player who chose PAPER wins. In other words, the winning object is PAPER. The method winningObject, given two objects, decides and returns the winning object. Clearly, this method has two parameters of the type RockPaperScissors, and the value returned by this method is also of the type RockPaperScissors. The definition of this method is:

```
public static RockPaperScissors winningObject
                      (RockPaperScissors play1,
                       RockPaperScissors play2)
{
    if ((play1 == RockPaperScissors.ROCK &&
         play2 == RockPaperScissors.SCISSORS)
       || (play2 == RockPaperScissors.ROCK &&
           play1 == RockPaperScissors.SCISSORS))
        return RockPaperScissors.ROCK;
    else if ((play1 == RockPaperScissors.ROCK &&
              play2 == RockPaperScissors.PAPER)
             || (play2 == RockPaperScissors.ROCK &&
                 play1 == RockPaperScissors.PAPER))
        return RockPaperScissors.PAPER;
    else
        return RockPaperScissors.SCISSORS;
}
```

Method displayResults

After the game is over, this method outputs the final results—that is, the total number of plays and the number of plays won by each player. The total number of plays is stored in the variable gameCount, the number of plays by player 1 is stored in the variable winCount1, and the number of plays won by player 2 is stored in the variable winCount2. This method has three parameters corresponding to these three variables. Essentially, the definition of this method is as follows:

```
public static void displayResults(int gCount, int wCount1,
                                  int wCount2)
{
    System.out.println("The total number of plays: "
                     + gCount);
    System.out.println("The number of plays won by "
                     + "player 1: " + wCount1);
    System.out.println("The number of plays won by "
                     + "player 2: " + wCount2);
}
```

We are now ready to write the algorithm for the method main.

Main Algorithm

```
1. Declare the variables.
2. Initialize the variables.
3. Display the rules.
4. Prompt the users to play the game.
5. Get the users' responses to play the game.
6. while (response is yes)
   {
   a. Prompt player 1 to make a selection.
   b. Get the play for player 1.
   c. Prompt player 2 to make a selection.
   d. Get the play for player 2.
   e. If both the plays are legal
      {
        i. Retrieve both plays.
       ii. Increment the total game count.
      iii. Declare the winner of the game.
       iv. Increment the winner's game win count by 1.
      }
   f. Prompt the users to determine whether they want to play again.
   g. Get the players' responses.
   }
7. Output the game results.
```

PROGRAM LISTING

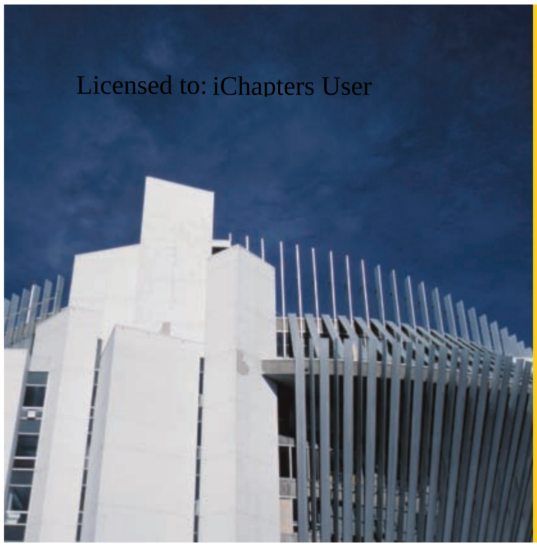
```
import java.util.*;

public class GameRockPaperScissors
{
    static Scanner console = new Scanner(System.in);

    public static void main(String[] args)
    {
              //Step 1
        int gameCount; //to count the number of
                       //games played
        int winCount1; //to count the number of
                       //games won by player 1
        int winCount2; //to count the number of
                       //games won by player 2
```

```
int gameWinner;
char response;  //to get the user's response
                //to play the game
char selection1;
char selection2;

RockPaperScissors play1;  //player1's selection
RockPaperScissors play2;  //player2's selection

    //Initialize the variables; Step 2
gameCount = 0;
winCount1 = 0;
winCount2 = 0;

displayRules();                              //Step 3

System.out.print("Enter Y/y to play "
               + "the game: ");              //Step 4
response = console.nextLine().charAt(0);     //Step 5
System.out.println();

while (response == 'Y' || response == 'y')   //Step 6
{
    System.out.print("Player 1 enter "
                   + "your choice: ");       //Step 6a
    selection1 =
           console.nextLine().charAt(0);     //Step 6b
    System.out.println();

    System.out.print("Player 2 enter "
                   + "your choice: ");       //Step 6c
    selection2 =
            console.nextLine().charAt(0);    //Step 6d
    System.out.println();

        //Step 6e
    if (validSelection(selection1) &&
        validSelection(selection2))
    {
        play1 = retrievePlay(selection1);
        play2 = retrievePlay(selection2);
        gameCount++;
        gameWinner = gameResult(play1, play2);

        if (gameWinner == 1)
            winCount1++;
        else if (gameWinner == 2)
            winCount2++;
    }//end if
```

```
                System.out.print("Enter Y/y to play "
                               + "the game: ");          //Step 6f
                response = console.nextLine().charAt(0); //Step 6g
                System.out.println();
            }//end while

            displayResults(gameCount, winCount1,
                           winCount2);                   //Step 7

        }//end main

        //Place the definitions of the methods displayRules,
        //validSelection, retrievePlay, winningObject,
        //gameResult, and displayResults here.
}
```

Sample Run: (In this sample run, the user input is shaded.)

```
Welcome to the game of Rock, Paper, and Scissors.
This is a game for two players. For each game, each player
selects one of the objects: Rock, Paper or Scissors.
The rules for winning the game are:
1. If both players select the same object, it is a tie.
2. Rock crushes Scissors: The player who selects Rock wins.
3. Paper covers Rock: The player who selects Paper wins.
4. Scissors cuts Paper: The player who selects Scissors wins.
Enter R or r to select Rock, P or p to select Paper,
and S or s to select Scissors.
Enter Y/y to play the game: y

Player 1 enter your choice: R

Player 2 enter your choice: S
Player 1 selected ROCK and player 2 selected SCISSORS.
Rock crushes scissors.
Player 1 wins this play.
Enter Y/y to play the game: Y

Player 1 enter your choice: S

Player 2 enter your choice: P
Player 1 selected SCISSORS and player 2 selected PAPER.
Scissors cuts paper.
Player 1 wins this play.
Enter Y/y to play the game: Y

Player 1 enter your choice: R
Player 2 enter your choice: P
Player 1 selected ROCK and player 2 selected PAPER.
Paper covers rock.
Player 2 wins this play.
Enter Y/y to play the game: n
The total number of plays: 3
The number of plays won by player 1: 2
The number of plays won by player 2: 1
```



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