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C++ PROGRAMMING

Program Design Including Data Structures

D.S. MALIK

Fourth Edition

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C++ Programming:

Program Design Including Data Structures

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PREFACE

WELCOME TO THE FOURTH EDITION OF *C++ Programming: Program Design Including Data Structures*. Designed for a two semester (CS1 and CS2) C++ course, this text will provide a breath of fresh air to you and your students. The CS1 and CS2 courses serve as the cornerstone of the Computer Science curriculum. My primary goal is to motivate and excite all introductory 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 a culmination and development of my classroom notes throughout more than fifty semesters of teaching successful programming to Computer Science students.

C++ Programming: Program Design Including Data Structures started as a collection of brief examples, exercises, and lengthy programming examples to supplement the books that were in use at our university. It soon turned into a collection large enough to develop into a text. *The approach taken in this book is, in fact, driven by the students' demand for clarity and readability.* The material was written and rewritten until the students felt comfortable with it. Most of the examples in this book resulted from student interaction in the classroom.

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As with any profession, practice is essential. Cooking students practice their recipes. Budding violinists practice their scales. New programmers must practice solving problems and writing code. This is not a C++ cookbook. We do not simply list the C++ syntax followed by an example; we dissect the "why" behind all the concepts. The crucial question of "why?" is answered for every topic when first introduced. This technique offers a bridge to learning C++. Students must understand the "why?" in order to be motivated to learn.

Traditionally, a C++ programming neophyte needed a working knowledge of another programming language. This book assumes no prior programming experience. However, some adequate mathematics background such as college algebra is required.

Changes in the Fourth Edition

The fourth edition contains more than 20 new programming exercises in Chapters 2 to 12, and 14. Certain programming examples and programming exercises require input from a file. In the earlier editions the input file was assumed to be stored on the floppy disk in drive A. However, newer computers label drives differently. So in this edition, we assume that the input file is in the same directory (subdirectory) as the project containing the source code file. Furthermore, some parts of Chapters 1, 2, 4, and 5 are rewritten and updated. When a programming assignment is given, typically, students are required to include the author of the program and a brief explanation describing the purpose of the program. To emphasize this requirement, Programming Examples in each chapter are modified by including comments showing the author(s) of the programs and a brief explanation describing the purpose of the program.

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Approach

The programming language C++, which evolved from C, is no longer considered an industry-only language. Numerous colleges and universities use C++ for their first programming language course. C++ is a combination of structured programming and object-oriented programming, and this book addresses both types.

This book is intended for a two-semester course, CS1 and CS2, in Computer Science. The first 11 or 12 chapters can be covered in the first course and the remaining in the second course.

In July 1998, ANSI/ISO Standard C++ was officially approved. This book focuses on ANSI/ISO Standard C++. Even though the syntax of Standard C++ and ANSI/ISO Standard C++ is very similar, Chapter 8 discusses some of the features of ANSI/ISO Standard C++ that are not available in Standard C++.

Chapter 1 briefly reviews the history of computers and programming languages. The reader can quickly skim through this chapter and become familiar with some of the hardware components and the software parts of the computer. This chapter contains a section on processing a C++ program. This chapter also describes structured and object-oriented programming.

Chapter 2 discusses the basic elements of C++. After completing this chapter, students become familiar with the basics of C++ and are ready to write programs that are complicated enough to do some computations. Input/output is fundamental to any programming language. It is introduced early, in Chapter 3, and is covered in detail.

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Chapters 4 and 5 introduce control structures to alter the sequential flow of execution. Chapters 6 and 7 study user-defined functions. It is recommended that readers with no prior programming background spend extra time on Chapters 6 and 7. Several examples are provided to help readers understand the concepts of parameter passing and the scope of an identifier.

Chapter 8 discusses the user-defined simple data type (enumeration type), the **`namespace`** mechanism of ANSI/ISO Standard C++, and the `string` type. The earlier versions of C did not include the enumeration type. Enumeration types have very limited use; their main purpose is to make the program readable. This book is organized such that readers can skip the section on enumeration types during the first reading without experiencing any discontinuity, and then later go through this section.

Chapter 9 discusses arrays in detail. Chapter 10 introduces records (**`struct`**s). The introduction of **`struct`**s in this book is similar to C **`struct`**s. This chapter is optional; it is not a prerequisite for any of the remaining chapters.

Chapter 11 begins the study of object-oriented programming (OOP) and introduces classes. The first half of this chapter shows how classes are defined and used in a program. The second half of the chapter introduces abstract data types (ADTs). This chapter shows how classes in C++ are a natural way to implement ADTs. Chapter 12 continues with the fundamentals of object-oriented design (OOD) and OOP, and discusses inheritance and composition. It

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explains how classes in C++ provide a natural mechanism for OOD and how C++ supports OOP. Chapter 12 also discusses how to find the objects in a given problem.

Chapter 13 studies pointers in detail. After introducing pointers and how to use them in a program, this chapter highlights the peculiarities of classes with pointer data members and how to avoid them. Moreover, this chapter also discusses how to create and work with dynamic two-dimensional arrays. Chapter 13 also discusses abstract classes and a type of polymorphism accomplished via virtual functions.

Chapter 14 continues the study of OOD and OOP. In particular, it studies polymorphism in C++. Chapter 14 specifically discusses two types of polymorphism—overloading and templates.

Chapter 15 discusses exception handling in detail. Chapter 16 introduces and discusses recursion. This is a stand-alone chapter, so it can be studied anytime after Chapter 10.

Chapters 17 and 18 are devoted to the study of data structures. Discussed in detail are linked lists in Chapter 17 and stacks and queues in Chapter 18. The programming code developed in these chapters is generic. These chapters effectively use the fundamentals of OOD.

Chapter 19 discusses various searching and sorting algorithms. In addition to showing how these algorithms work, it also provides relevant analysis and results concerning the performance of the algorithms. The algorithm analysis allows the user to decide which algorithm to use in a particular application. This chapter also includes several sorting algorithms. The instructor can decide which algorithms to cover.

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Chapter 20 provides an introduction to binary trees. Various traversal algorithms, as well as the basic properties of binary trees, are discussed and illustrated. Special binary trees, called binary search trees, are introduced. Searching, as well as item insertion and deletion from a binary search tree, are described and illustrated. Chapter 20 also discusses nonrecursive binary tree traversal algorithms. Furthermore, to enhance the flexibility of traversal algorithms, it shows how to construct and pass functions as parameters to other functions. This chapter also discusses AVL (height balanced) trees in detail. Due to text length considerations, discussion on AVL trees is provided as a separate section and is available on the Web site accompanying this book.

Graph algorithms are discussed in Chapter 21. After introducing the basic graph theory terminology, the representation of graphs in computer memory is discussed. This chapter also discusses graph traversal algorithms, the shortest path algorithm, and the minimal spanning tree algorithm. Topological sort is also discussed in this chapter and is available on the Web site accompanying this book.

C++ is equipped with a powerful library—the Standard Template Library (STL)—of data structures and algorithms that can be used effectively in a wide variety of applications. Chapter 22 describes the STL in detail. After introducing the three basic components of the STL, it shows how sequence containers are used in a program. Special containers, such as stack and queue, are also discussed. The latter half of this chapter shows how various STL algorithms can be used in a program. This chapter is fairly long; depending on the availability of time, the

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instructor can at least cover the sequence containers, iterators, the classes `stack` and `queue`, and certain algorithms.

Appendix A lists the reserved words in C++. Appendix B shows the precedence and associativity of the C++ operators. Appendix C lists the ASCII (American Standard Code for Information Interchange) and EBCDIC (Extended Binary Coded Decimal Interchange Code) character sets. Appendix D lists the C++ operators that can be overloaded.

Appendix E has three objectives. First, we discuss how to convert a number from decimal to binary and binary to decimal. We then discuss binary and random access files in detail. Finally, we describe the naming conventions of the header files in both ANSI/ISO Standard C++ and Standard C++. Appendix F discusses some of the most widely used library routines, and includes the names of the standard C++ header files. The programs in Appendix G show how to print the memory size for the built-in data types on your system as well as how to use a random number generator. Appendix H gives selected references for further study. Appendix I provides the answers to odd-numbered exercises in the book.

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How to Use the Book

This book can be used in various ways. Figure 1 shows the dependency of the chapters.

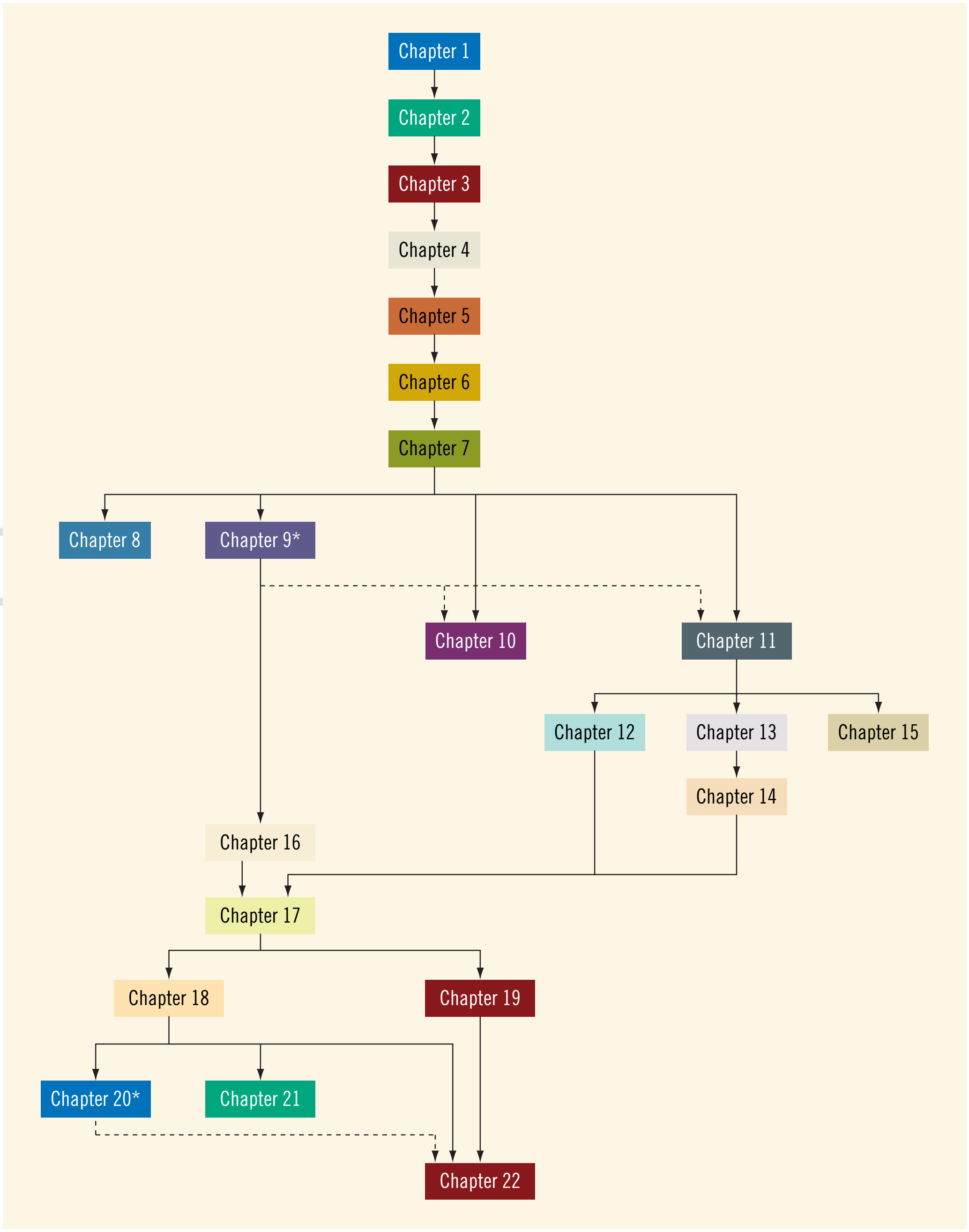

FIGURE 1 Chapter dependency diagram

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In Figure 1, dotted lines mean that the preceding chapter is used in one of the sections of the chapter and is not necessarily a prerequisite for the next chapter. For example, Chapter 9 covers arrays in detail. In Chapters 10 and 11, we show the relationship between arrays and `struct`s and arrays and classes, respectively. However, if Chapter 11 is studied before Chapter 9, then the section dealing with arrays in Chapter 11 can be skipped without any discontinuation. This particular section can be studied after studying Chapter 9.

It is recommended that the first seven chapters be covered sequentially. After covering the first seven chapters, if the reader is interested in learning OOD and OOP early, then Chapter 11 can be studied right after Chapter 7. Chapter 8 can be studied anytime after Chapter 7. After studying the first seven chapters in sequence, some of the approaches are:

1. Study chapters in the sequence: 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22.
2. Study chapters in the sequence: 9, 11, 13, 14, 12, 16, 17, 18, 15, 19, 20, 21, 22.
3. Study chapters in the sequence: 11, 9, 13, 14, 12, 16, 17, 18, 15, 19, 20, 21, 22.

As the chapter dependency diagram shows, Chapters 18 and 19 can be covered in any sequence. However, typically, Chapters 18 and 19 are studied in sequence. Ideally, one should study Chapters 17, 18, 19, and 20 in sequence. Chapters 21 and 22 can be studied in any sequence.

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Features of the Book

From beginning to end, the concepts are introduced at a pace that is conducive to learning. *The writing style of this book is simple and straightforward, and it parallels the teaching style of a classroom*. Before introducing a key concept, we explain why certain elements are necessary. The concepts introduced are then described using examples and small programs.

Each chapter has two types of programs. The first type are small programs that are part of the numbered Examples (*e.g.*, Example 4-1), and are used to explain key concepts. In these examples, each line of the programming code is numbered. The program, illustrated through a Sample Run, is then explained line-by-line. The rationale behind each line is discussed in detail.

The Programming Examples form the backbone of the book and are designed to be methodical and user-friendly. Each Programming Example starts with a Problem Analysis and is followed by the Algorithm Design. Every step of the algorithm is then coded in C++. In addition to teaching problem-solving techniques, these detailed programs show the user how to implement concepts in an actual C++ program. I strongly recommend that students study the Programming Examples very carefully in order to effectively learn C++.

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Quick Review sections at the end of each chapter reinforce learning. After reading the chapter, students can quickly walk through the highlights of the chapter and test themselves using the ensuing Exercises. Many readers refer to the Quick Review as an easy way to review the chapter before an exam.

The features of the text are clearly illustrated on the following pages.

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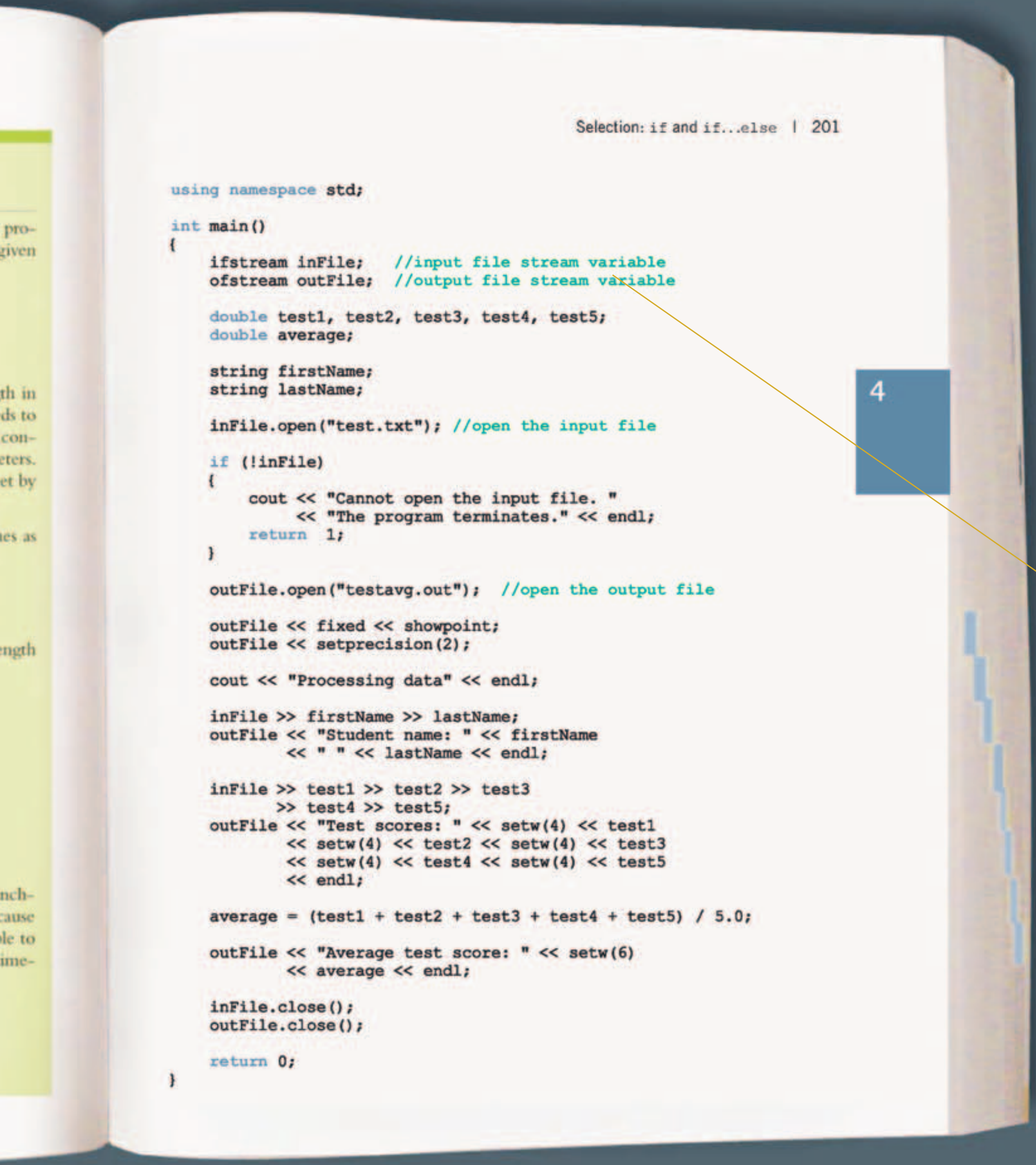
Features of the Book


Selection: if and if...else | 201

```
using namespace std;

int main()
{
    ifstream inFile;   //input file stream variable
    ofstream outFile;  //output file stream variable

    double test1, test2, test3, test4, test5;
    double average;

    string firstName;
    string lastName;

    inFile.open("test.txt"); //open the input file

    if (!inFile)
    {
        cout << "Cannot open the input file. "
             << "The program terminates." << endl;
        return  1;
    }

    outFile.open("testavg.out");  //open the output file

    outFile << fixed << showpoint;
    outFile << setprecision(2);

    cout << "Processing data" << endl;

    inFile >> firstName >> lastName;
    outFile << "Student name: " << firstName
            << " " << lastName << endl;

    inFile >> test1 >> test2 >> test3
           >> test4 >> test5;
    outFile << "Test scores: " << setw(4) << test1
            << setw(4) << test2 << setw(4) << test3
            << setw(4) << test4 << setw(4) << test5
            << endl;

    average = (test1 + test2 + test3 + test4 + test5) / 5.0;

    outFile << "Average test score: " << setw(6)
            << average << endl;

    inFile.close();
    outFile.close();

    return 0;
}
```

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

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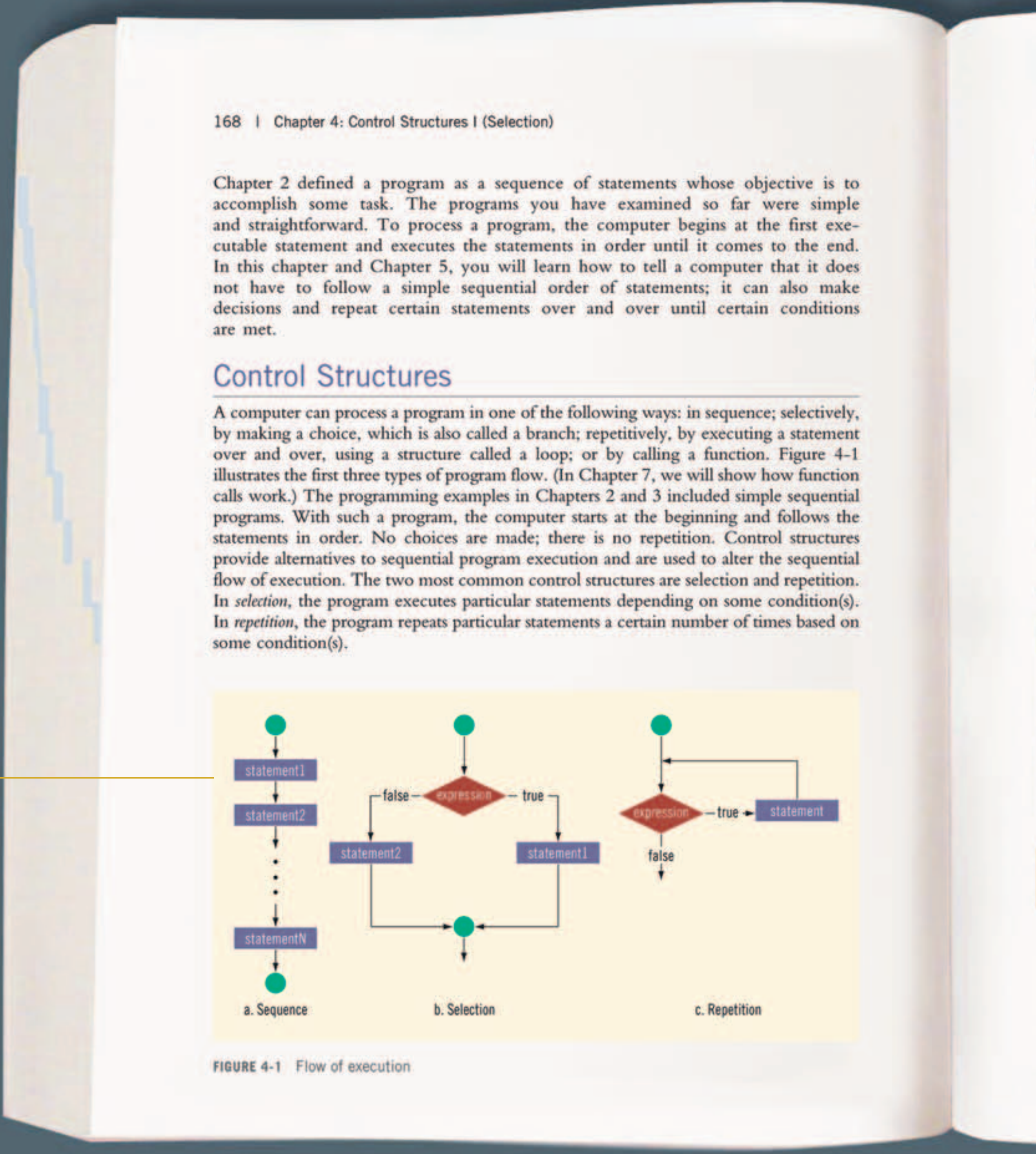

Chapter 2 defined a program as a sequence of statements whose objective is to accomplish some task. The programs you have examined so far were simple and straightforward. To process a program, the computer begins at the first executable statement and executes the statements in order until it comes to the end. In this chapter and Chapter 5, you will learn how to tell a computer that it does not have to follow a simple sequential order of statements; it can also make decisions and repeat certain statements over and over until certain conditions are met.

Control Structures

A computer can process a program in one of the following ways: in sequence; selectively, by making a choice, which is also called a branch; repetitively, by executing a statement over and over, using a structure called a loop; or by calling a function. Figure 4-1 illustrates the first three types of program flow. (In Chapter 7, we will show how function calls work.) The programming examples in Chapters 2 and 3 included simple sequential programs. With such a program, the computer starts at the beginning and follows the statements in order. No choices are made; there is no repetition. Control structures provide alternatives to sequential program execution and are used to alter the sequential flow of execution. The two most common control structures are selection and repetition. In *selection*, the program executes particular statements depending on some condition(s). In *repetition*, the program repeats particular statements a certain number of times based on some condition(s).

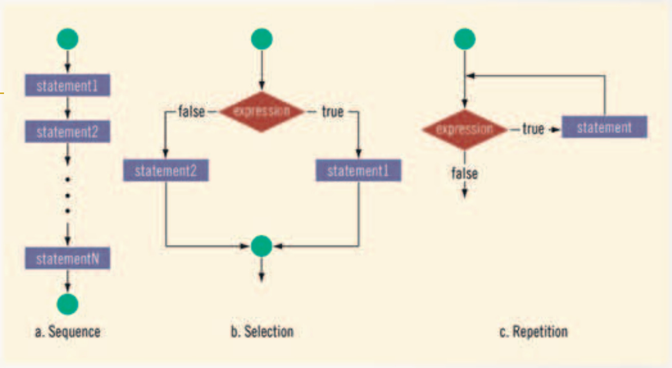

FIGURE 4-1 Flow of execution

More than 420 visual diagrams, both extensive and exhaustive, illustrate difficult concepts.

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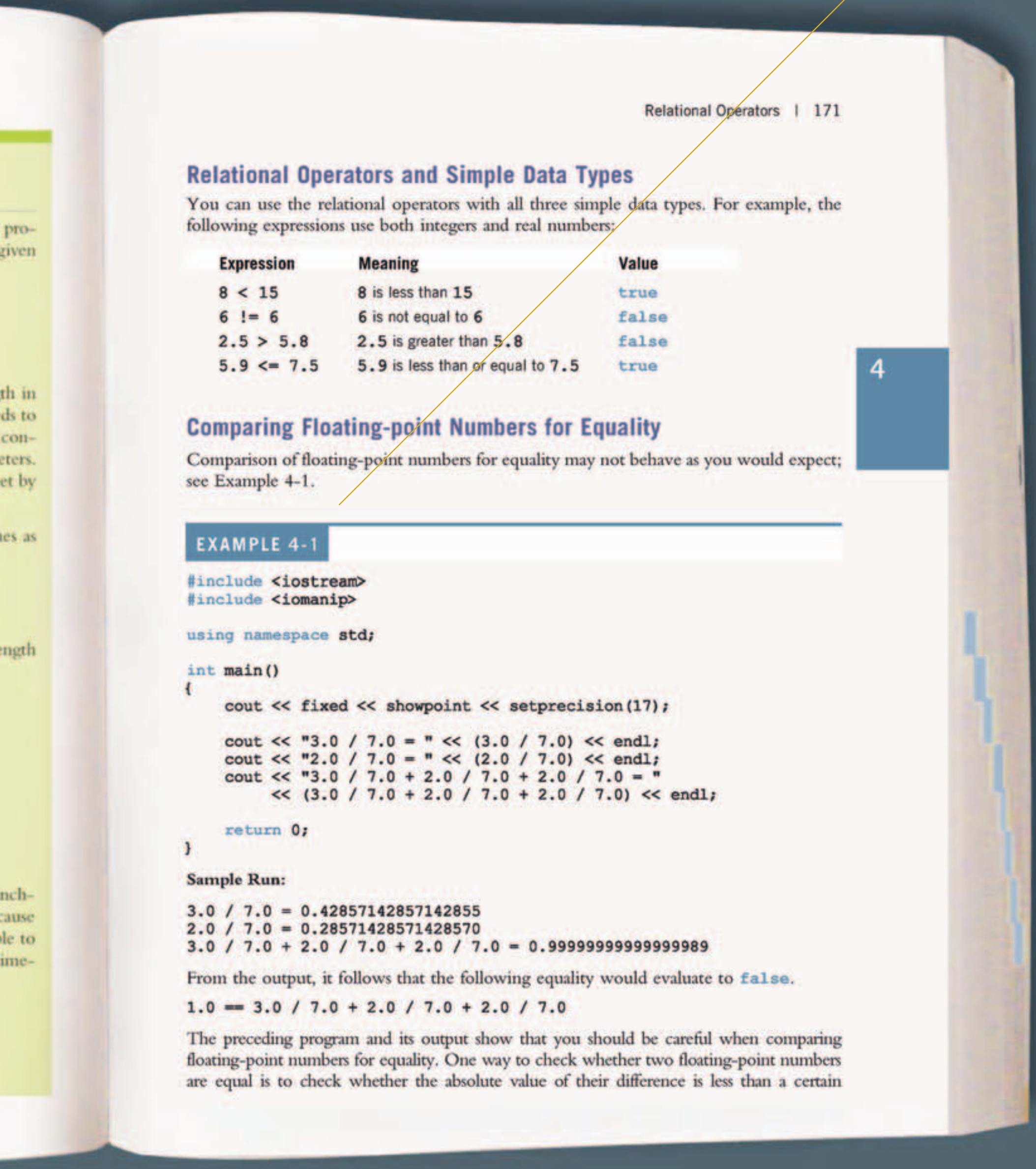
Numbered *Examples* illustrate the key concepts with their relevant code. The programming code in these examples is followed by a Sample Run. An explanation then follows that describes what each line in the code does.



Relational Operators and Simple Data Types

You can use the relational operators with all three simple data types. For example, the following expressions use both integers and real numbers:

Expression	Meaning	Value
`8 < 15`	8 is less than 15	`true`
`6 != 6`	6 is not equal to 6	`false`
`2.5 > 5.8`	2.5 is greater than 5.8	`false`
`5.9 <= 7.5`	5.9 is less than or equal to 7.5	`true`

4

Comparing Floating-point Numbers for Equality

Comparison of floating-point numbers for equality may not behave as you would expect; see Example 4-1.

EXAMPLE 4-1

```
#include <iostream>
#include <iomanip>

using namespace std;

int main()
{
    cout << fixed << showpoint << setprecision(17);

    cout << "3.0 / 7.0 = " << (3.0 / 7.0) << endl;
    cout << "2.0 / 7.0 = " << (2.0 / 7.0) << endl;
    cout << "3.0 / 7.0 + 2.0 / 7.0 + 2.0 / 7.0 = "
         << (3.0 / 7.0 + 2.0 / 7.0 + 2.0 / 7.0) << endl;

    return 0;
}
```

Sample Run:

```
3.0 / 7.0 = 0.42857142857142855
2.0 / 7.0 = 0.28571428571428570
3.0 / 7.0 + 2.0 / 7.0 + 2.0 / 7.0 = 0.99999999999999989
```

From the output, it follows that the following equality would evaluate to `false`.

```
1.0 == 3.0 / 7.0 + 2.0 / 7.0 + 2.0 / 7.0
```

The preceding program and its output show that you should be careful when comparing floating-point numbers for equality. One way to check whether two floating-point numbers are equal is to check whether the absolute value of their difference is less than a certain

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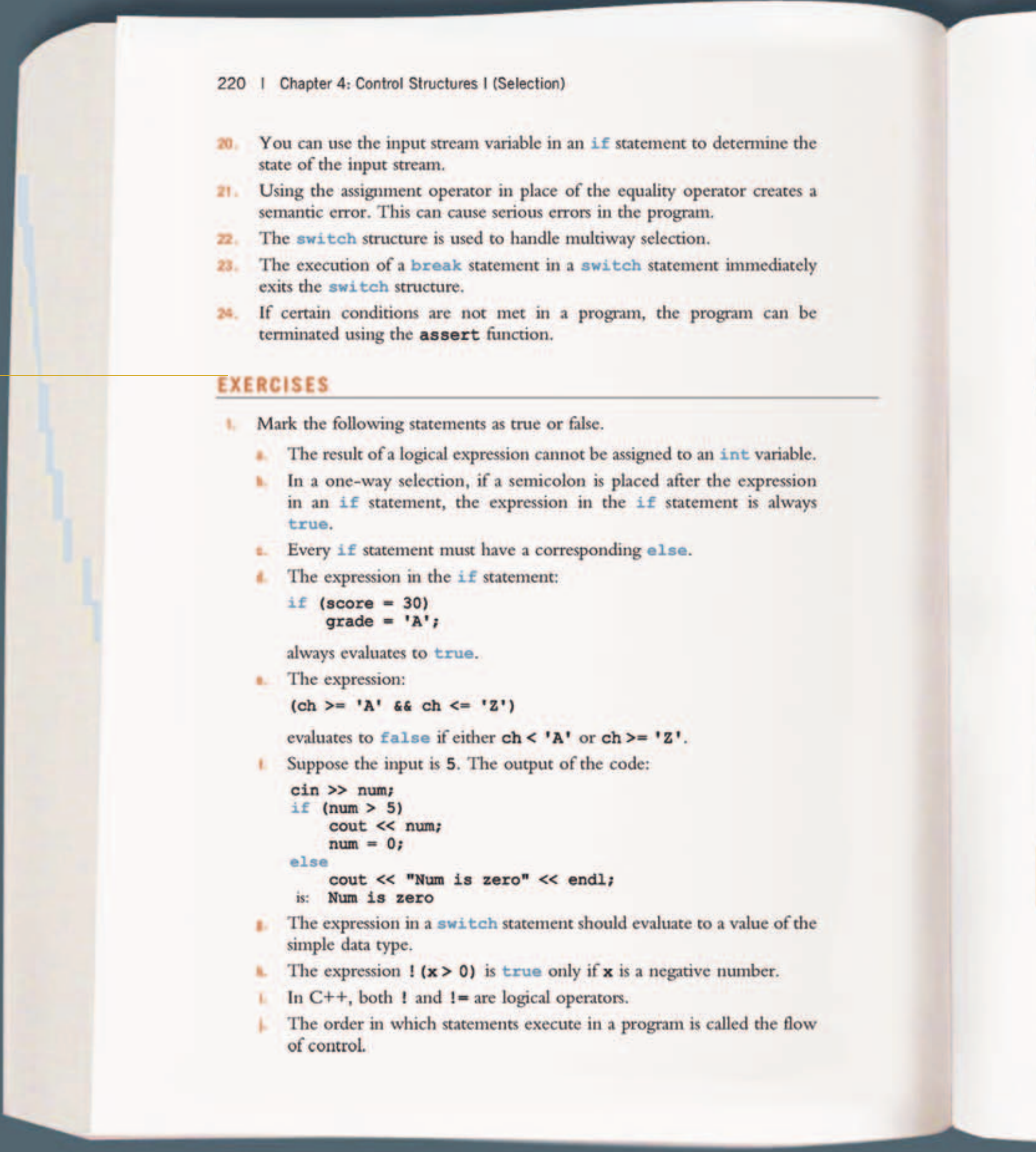
Exercises further reinforce learning and ensure that students have, in fact, mastered the material.



20. You can use the input stream variable in an `if` statement to determine the state of the input stream.
21. Using the assignment operator in place of the equality operator creates a semantic error. This can cause serious errors in the program.
22. The `switch` structure is used to handle multiway selection.
23. The execution of a `break` statement in a `switch` statement immediately exits the `switch` structure.
24. If certain conditions are not met in a program, the program can be terminated using the **`assert`** function.

EXERCISES

1. Mark the following statements as true or false.
   a. The result of a logical expression cannot be assigned to an `int` variable.
   b. In a one-way selection, if a semicolon is placed after the expression in an `if` statement, the expression in the `if` statement is always `true`.
   c. Every `if` statement must have a corresponding `else`.
   d. The expression in the `if` statement:

```
if (score = 30)
    grade = 'A';
```

   always evaluates to `true`.
   e. The expression:

```
(ch >= 'A' && ch <= 'Z')
```

   evaluates to `false` if either `ch < 'A'` or `ch >= 'Z'`.
   f. Suppose the input is `5`. The output of the code:

```
cin >> num;
if (num > 5)
    cout << num;
    num = 0;
else
    cout << "Num is zero" << endl;
```

   is: `Num is zero`
   g. The expression in a `switch` statement should evaluate to a value of the simple data type.
   h. The expression `!(x > 0)` is `true` only if `x` is a negative number.
   i. In C++, both `!` and `!=` are logical operators.
   j. The order in which statements execute in a program is called the flow of control.

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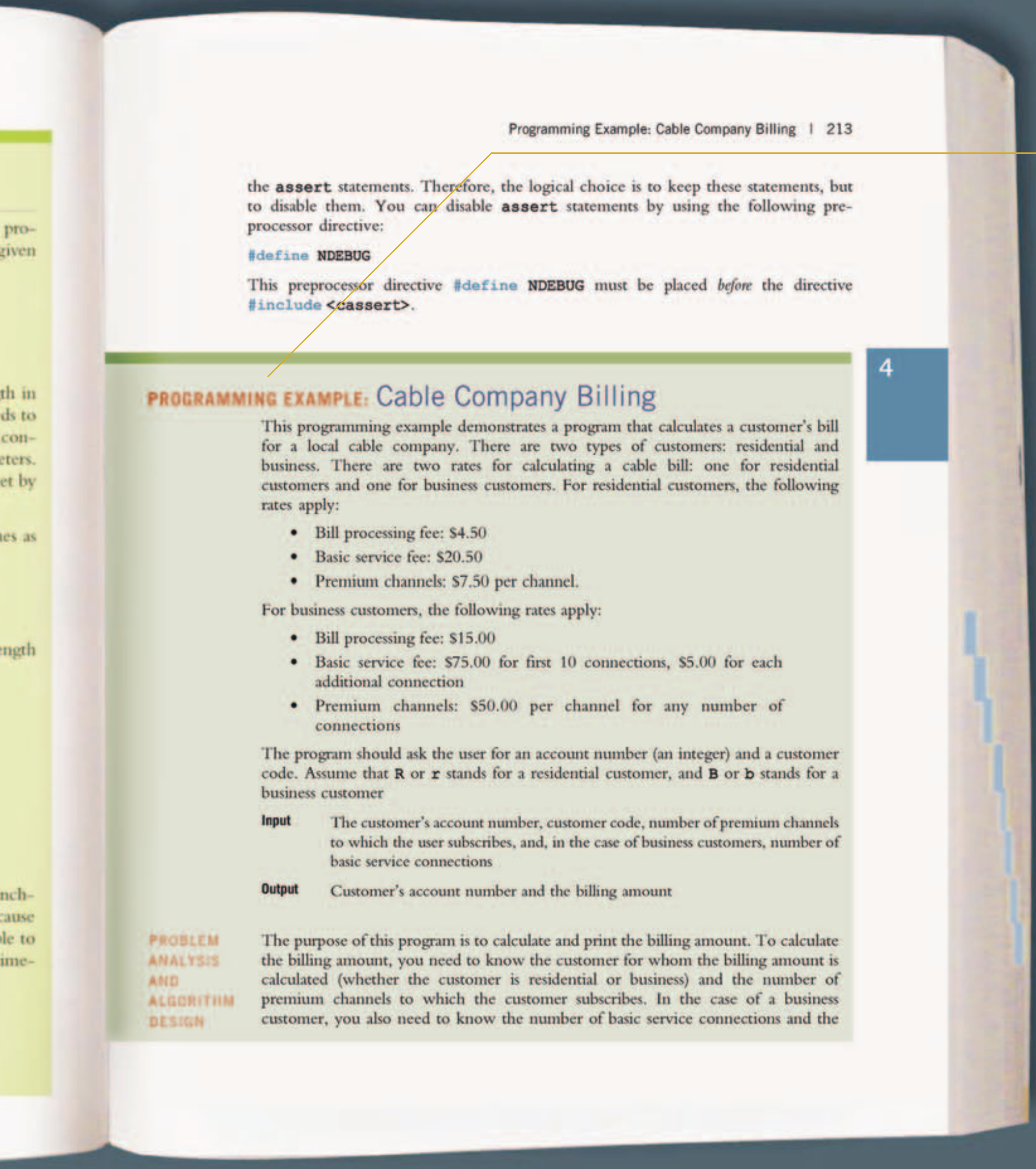

the **`assert`** statements. Therefore, the logical choice is to keep these statements, but to disable them. You can disable **`assert`** statements by using the following preprocessor directive:

```
#define NDEBUG
```

This preprocessor directive `#define` **`NDEBUG`** must be placed *before* the directive `#include` **`<cassert>`**.

4

PROGRAMMING EXAMPLE: Cable Company Billing

This programming example demonstrates a program that calculates a customer's bill for a local cable company. There are two types of customers: residential and business. There are two rates for calculating a cable bill: one for residential customers and one for business customers. For residential customers, the following rates apply:

- Bill processing fee: $4.50
- Basic service fee: $20.50
- Premium channels: $7.50 per channel.

For business customers, the following rates apply:

- Bill processing fee: $15.00
- Basic service fee: $75.00 for first 10 connections, $5.00 for each additional connection
- Premium channels: $50.00 per channel for any number of connections

The program should ask the user for an account number (an integer) and a customer code. Assume that **`R`** or **`r`** stands for a residential customer, and **`B`** or **`b`** stands for a business customer

Input The customer's account number, customer code, number of premium channels to which the user subscribes, and, in the case of business customers, number of basic service connections

Output Customer's account number and the billing amount

PROBLEM ANALYSIS AND ALGORITHM DESIGN

The purpose of this program is to calculate and print the billing amount. To calculate the billing amount, you need to know the customer for whom the billing amount is calculated (whether the customer is residential or business) and the number of premium channels to which the customer subscribes. In the case of a business customer, you also need to know the number of basic service connections and the

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.

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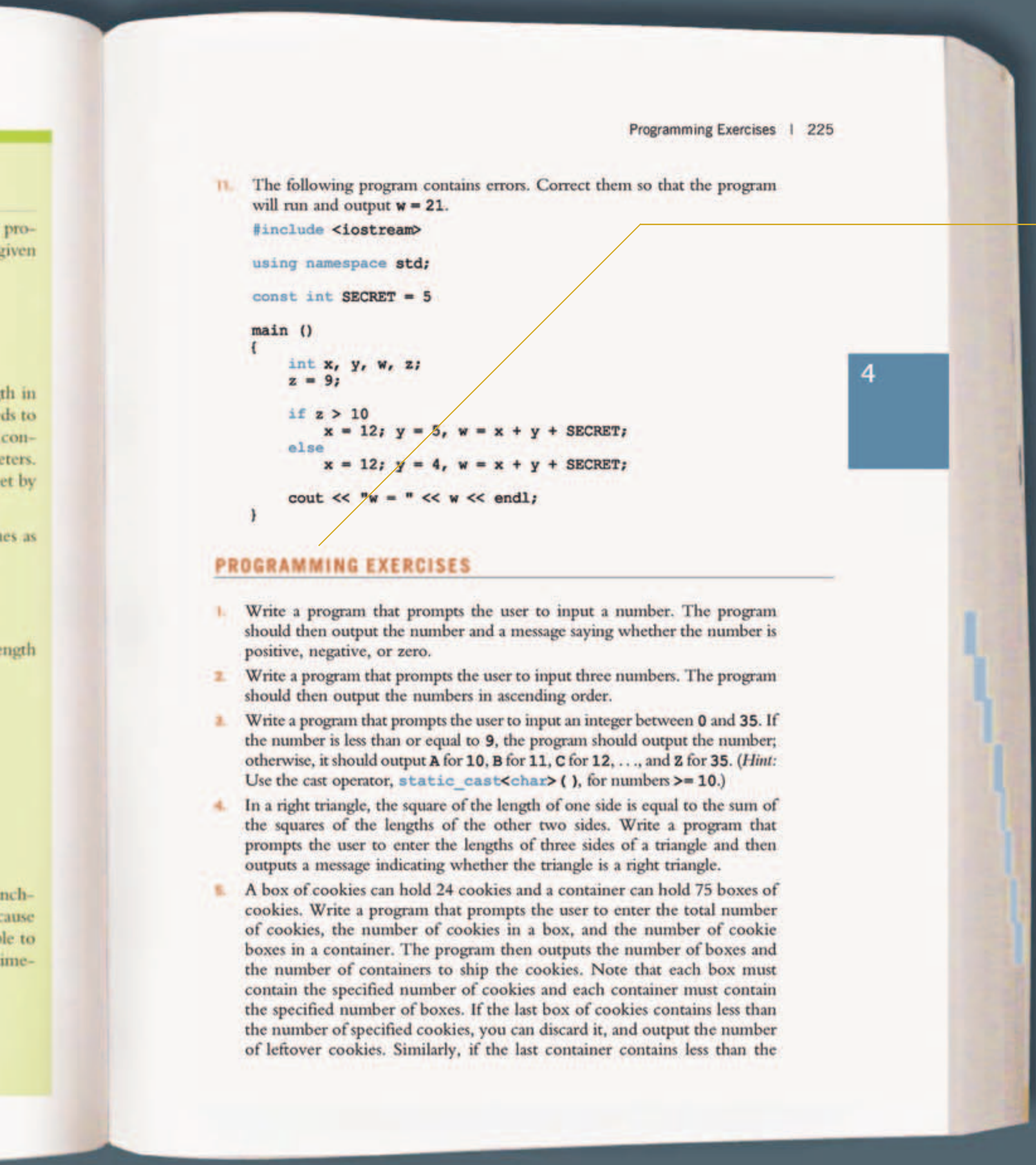

11. The following program contains errors. Correct them so that the program will run and output w = 21.

```
#include <iostream>

using namespace std;

const int SECRET = 5

main ()
{
    int x, y, w, z;
    z = 9;

    if z > 10
        x = 12; y = 5, w = x + y + SECRET;
    else
        x = 12; y = 4, w = x + y + SECRET;

    cout << "w = " << w << endl;
}
```

PROGRAMMING EXERCISES

1. Write a program that prompts the user to input a number. The program should then output the number and a message saying whether the number is positive, negative, or zero.
2. Write a program that prompts the user to input three numbers. The program should then output the numbers in ascending order.
3. Write a program that prompts the user to input an integer between 0 and 35. If the number is less than or equal to 9, the program should output the number; otherwise, it should output A for 10, B for 11, C for 12, . . ., and Z for 35. (*Hint:* Use the cast operator, static_cast<char>( ), for numbers >= 10.)
4. In a right triangle, the square of the length of one side is equal to the sum of the squares of the lengths of the other two sides. Write a program that prompts the user to enter the lengths of three sides of a triangle and then outputs a message indicating whether the triangle is a right triangle.
5. A box of cookies can hold 24 cookies and a container can hold 75 boxes of cookies. Write a program that prompts the user to enter the total number of cookies, the number of cookies in a box, and the number of cookie boxes in a container. The program then outputs the number of boxes and the number of containers to ship the cookies. Note that each box must contain the specified number of cookies and each container must contain the specified number of boxes. If the last box of cookies contains less than the number of specified cookies, you can discard it, and output the number of leftover cookies. Similarly, if the last container contains less than the

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

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Supplemental Resources

The following supplemental materials are available when this book is used in a classroom setting. All instructor materials as outlined below are available on a single CD-ROM.

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®

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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

This book comes with Microsoft PowerPoint slides for each chapter. These are included 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 Cengage Learning 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 Cengage Learning sales representative.

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Source Code

The source code, in ANSI/ISO Standard C++, is available at www.course.com, and is also available on the Teaching Tools CD-ROM. The input files needed to run some of the programs are also included with the source code.

Solution Files

The solution files for all programming exercises, in ANSI/ISO C++, are available at www.course.com, and are also available on the Teaching Tools CD-ROM. The input files needed to run some of the programming exercises are also included with the solution files.

Student Online Companion

This robust Web site, accessible at www.course.com/malik/cpp, offers students a plethora of review and self-assessment options. Each chapter includes a Concepts Review, Chapter Summary, Key Terms, Self-Tests, and Assignments. In addition, the Online Companion features related Web links, source code for all chapters, and compiler tutorials.

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D. S. Malik

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Appendix A
Reserved Words

`and`	`and_eq`	`asm`	`auto`
`bitand`	`bitor`	`bool`	`break`
`case`	`catch`	`char`	`class`
`compl`	`const`	`const_cast`	`continue`
`default`	`delete`	`do`	`double`
`dynamic_cast`	`else`	`enum`	`explicit`
`export`	`extern`	`false`	`float`
`for`	`friend`	`goto`	`if`
`include`	`inline`	`int`	`long`
`mutable`	`namespace`	`new`	`not`
`not_eq`	`operator`	`or`	`or_eq`
`private`	`protected`	`public`	`register`
`reinterpret_cast`	`return`	`short`	`signed`
`sizeof`	`static`	`static_cast`	`struct`
`switch`	`template`	`this`	`throw`
`true`	`try`	`typedef`	`typeid`
`typename`	`union`	`unsigned`	`using`
`virtual`	`void`	`volatile`	`wchar_t`
`while`	`xor`	`xor_eq`	

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Appendix B
Operator Precedence

The following table shows the precedence (highest to lowest) and associativity of the operators in C++.

Operator	Associativity
:: (binary scope resolution)	Left to right
:: (unary scope resolution)	Right to left
()	Left to right
[] -> .	Left to right
++ -- (as postfix operators)	Right to left
typeid dynamic_cast	Right to left
static_cast const_cast	Right to left
reinterpret_cast	Right to left
++ -- (as prefix operators) ! + (unary) - (unary)	Right to left
~ & (address of) * (dereference)	Right to left
new delete sizeof	Right to left
->* -- .*	Left to right
* / %	Left to right
+ -	Left to right
<< >>	Left to right
< <= > >=	Left to right
== !=	Left to right
&	Left to right
^	Left to right
|	Left to right
&&	Left to right

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Operator	Associativity
`||`	Left to right
`?:`	Right to left
`=` `+=` `-=` `*=` `/=` `%=`	Right to left
`<<=` `>>=` `&=` `|=` `^=`	Right to left
`throw`	Right to left
`,` (the sequencing operator)	Left to right

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Appendix C
Character Sets

ASCII (American Standard Code for Information Interchange)

The following table shows the 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	<u>b</u>	!	"	#	$	%	&	'
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		

The numbers 0–12 in the first column specify the left digit(s), and the numbers 0–9 in the second row specify the right digit of each character in the ASCII data set. For example, the character in the row marked 6 (the number in the first column) and the column marked 5 (the number in the second row) is `A`. Therefore, the character at position 65 (which is the 66th character) is `A`. Moreover, the character <u>b</u> at position 32 represents the space character.

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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	back space	dc4	device control 4	$\underline{b}$	space
ht	horizontal tab	nak	negative acknowledge	del	delete
lf	line feed	syn	synchronous idle		
vt	vertical tab	etb	end of transmitted block		

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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					$\underline{b}$					
7						.	<	(	+	|
8	&									
9	!	$	*	)	;	¬	-	/		
10								,	%	_
11	>	?								
12		`	:	#	@	'	=	"		a
13	b	c	d	e	f	g	h	i		

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EBCDIC										
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

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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 b̲ at position 64 represents the space character. The preceding 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.

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Appendix D Operator Overloading

The following table lists the operators that can be overloaded.

Operators that can be overloaded							
+	-	*	/	%	^	&	|
!	&&	||	=	==	<	<=	>
>=	!=	+=	-=	*=	/=	%=	^=
|=	&=	<<	>>	>>=	<<=	++	--
->*	,	->	[]	()	~	**new**	**delete**

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The following table lists the operators that cannot be overloaded.

Operators that cannot be overloaded				
.	.*	::	?:	**sizeof**

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Appendix E
Additional C++ Topics

Binary (Base 2) Representation of a Nonnegative Integer

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

Chapter 1 remarked 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:

$$711 = 1 \times 2^9 + 0 \times 2^8 + 1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

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, $k = 6$, $a_6 = 1$, $a_5 = 0$, $a_4 = 0$, $a_3 = 0$, $a_2 = 0$, $a_1 = 0$, $a_0 = 1$. Thus, $a_6 a_5 a_4 a_3 a_2 a_1 a_0 = 1000001$, 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.

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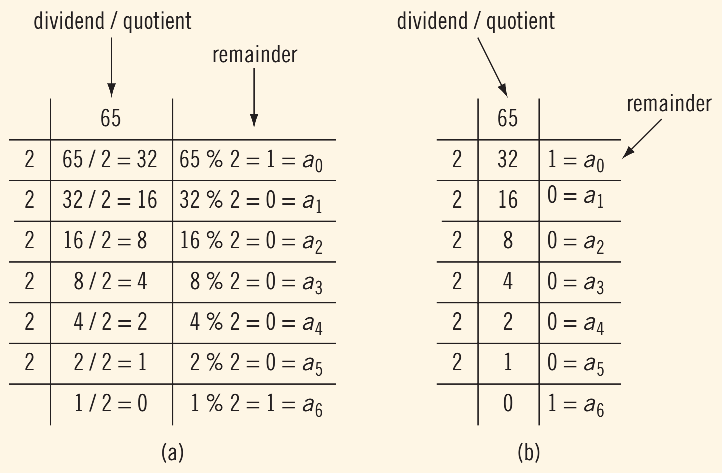
Similarly, for the number 711, $k = 9$, $a_9 = 1$, $a_8 = 0$, $a_7 = 1$, $a_6 = 1$, $a_5 = 0$, $a_4 = 0$, $a_3 = 0$, $a_2 = 1$, $a_1 = 1$, $a_0 = 1$. Thus:

$711_{10} = 1011000111_2$.

It follows that to find the binary representation of a nonnegative, 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 obtaining the remainder with the help of Figure E-1.



	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

	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

FIGURE E-1 Determining the binary representation of 65

Notice that in Figure E-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 next row, below the current row, and the remainder is written in the third column. When using a

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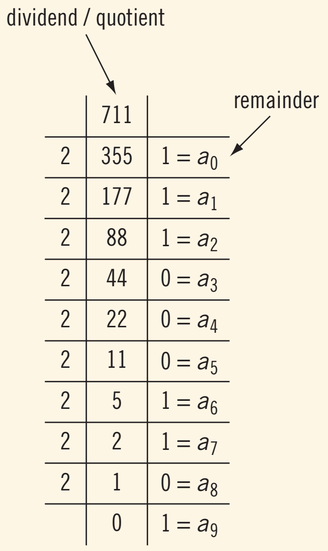
figure, such as E-1, to find the binary representation of a nonnegative integer, typically, we show only the quotients and remainders as in Figure E-1(b). You can write the binary representation of the number starting with the last remainder in the third column, followed by the second last remainder, and so on. Thus:

$65_{10} = 1000001_2$.

Next, consider the number 711. Figure E-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 E-2 Determining the binary representation of 711

From Figure E-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. The weight of each bit in the binary number 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

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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.

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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 E-1 describes the first eight octal numbers.

TABLE E-1 Binary representation of first eight 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

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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,

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

Thus, $1101100010101_2 = 15425_8$.

To convert an octal number into an equivalent binary number, using Table E-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, $3761_8 = 11111110001_2$.

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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 E-2 gives the binary representation of the first 16 hexadecimal numbers.

TABLE E-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

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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, $A7F32_{16} = 10100111111100110010_2$.

More on File Input/Output

In Chapter 3, you learned how to read data from and write data to a file. This section expands on the concepts introduced in that chapter.

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Binary Files

In Chapter 3, you learned how to make a program read data from and write data to a file. However, the files that the programs have used until now are called text files. Data in a text file is stored in the character format. For example, consider the number 45. If 45 is stored in a file, then it is stored as a sequence of two characters—the character '4' followed by the character '5'. The eight-bit machine representation of '4' is 00000100 and the eight-bit machine representation of '5' is 00000101. Therefore, in a text file, 45 is stored as 0000010000000101. When this number is read by a C++ program, it must first be converted to its binary format. Suppose that the integers are represented as 16-bit binary numbers. The 16-bit binary representation of 45 is then 0000000000101101. Similarly, when a program stores the number 45 in a text file, it first must be converted to its text format. It thus follows that reading data from and writing data to a text file is not efficient, because the data must be converted from the text to the binary format and vice versa.

On the other hand, when data is stored in a file in the binary format, reading and writing data is faster because no time is lost in converting the data from one format to another format. Such files are called binary files. More formally, **binary files** are files in which data is stored in the binary format. Data in a text file is also called **formatted data**, and in a binary file it is called **raw data**.

C++ allows a programmer to create binary files. This section explains how to create binary files and also how to read data from binary files.

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To create a binary file, the file must be opened in the binary mode. Suppose outFile is an ofstream variable (object). Consider the following statement:

```
outFile.open("employee.dat", ios::binary);
```

This statement opens the file employee.dat. Data in this file will be written in its binary format. Therefore, the file opening mode ios::binary specifies that the file is opened in the binary mode.

Next, you use the stream function write to write data to the file employee.dat. The syntax to use the function write is:

```
fileVariableName.write(reinterpret_cast<const char *> (buffer),
                       sizeof(buffer));
```

where fileVariableName is the object used to open the output file, and the first argument buffer specifies the starting address of the location in memory where the data is stored. The expression **sizeof**(buffer) specifies the size of the data, in bytes, to be written.

For example, suppose num is an **int** variable. The following statement writes the value of num in the binary format to the file associated with outFile:

```
outFile.write(reinterpret_cast<const char *> (&num),
              sizeof(num));
```

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Similarly, suppose empSalary is an array of, say, 100 components and the component type is **double**. The following statement writes the entire array to the file associated with outFile:

```
outFile.write(reinterpret_cast<const char *> (empSalary),
              sizeof(empSalary));
```

Next, let us discuss how to read data from a binary file. The operation of reading data from a binary file is similar to writing data to a binary file. First, the binary file must be opened. For example, suppose inFile is an ifstream variable, and a program has already created the binary file employee.dat. The following statement opens this file:

```
inFile.open("employee.dat");
```

or:

```
inFile.open("employee.dat", ios::binary);
```

To read data in the binary format, the stream function read is used. The syntax to use the function read is:

```
fileVariableName.read(reinterpret_cast<char *> (buffer),
                      sizeof(buffer));
```

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The first argument buffer specifies the starting address of the location in memory where the data is to be stored. The expression sizeof(buffer) specifies the size of the data, in bytes, to be read.

The program in the following example further explains how to create binary files and read data from a binary file.

EXAMPLE E-1

```
//Creating and reading binary files

#include <iostream>
#include <fstream>

using namespace std;

struct studentType
{
    char firstName[15];
    char lastName[15];
    int ID;
};

int main()
{
        //create and initialize an array of students' IDs
    int studentIDs[5] = {111111, 222222, 333333,
                         444444, 555555};              //Line 1

         //declare and initialize the struct newStudent
    studentType newStudent = {"John", "Wilson",
                              777777};                 //Line 2

    ofstream outFile;                                  //Line 3

        //open the output file as a binary file
    outFile.open("ids.dat", ios::binary);              //Line 4

         //write the array in the binary format
    outFile.write(reinterpret_cast<const char *> (studentIDs),
                  sizeof(studentIDs));                 //Line 5
        //write the newStudent data in the binary format
    outFile.write(reinterpret_cast<const char *> (&newStudent),
                  sizeof(newStudent));                 //Line 6

    outFile.close();  //close the file                 //Line 7

    ifstream inFile;                                   //Line 8
    int arrayID[5];                                    //Line 9
    studentType student;                               //Line 10
```

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```
         //open the input file
    inFile.open("ids.dat");                           //Line 11

    if (!inFile)                                      //Line 12
    {
        cout << "The input file does not exist. "
             << "The program terminates!!!!" << endl; //Line 13
        return 1;                                     //Line 14
    }

       //input the data into the array arrayID
    inFile.read(reinterpret_cast<char *> (arrayID),
                sizeof(arrayID));                     //Line 15
       //output the data of the array arrayID
    for (int i = 0; i < 5; i++)                       //Line 16
        cout << arrayID[i] << " ";                    //Line 17
    cout << endl;                                     //Line 18

         //read the student's data
    inFile.read(reinterpret_cast<char *> (&student),
                sizeof(student));                     //Line 19

         //output studentData
    cout << student.ID << " " << student.firstName
         << " " << student.lastName << endl;          //Line 20

    inFile.close();     //close the file              //Line 21

    return 0;                                         //Line 22
}
```

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Sample Run:

```
111111 222222 333333 444444 555555
777777 John Wilson
```

The output of the preceding program is self-explanatory. The details are left as an exercise for you.

NOTE

In the program in Example E-1, the statement in Line 2 declares the `struct` variable `newStudent` and also initializes it. Because `newStudent` has three components and we want to initialize all the components, three values are specified in braces separated by commas. In other words, `struct` variables can also be initialized when they are declared.

The program in the following example further explains how to create binary files and then read the data from the binary files.

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EXAMPLE E-2

```
//Creating and reading a binary file consisting of
//bank customers' data

#include <iostream>
#include <fstream>
#include <iomanip>

using namespace std;

struct customerType
{
    char firstName[15];
    char lastName[15];
    int ID;
    double balance;
};

int main()
{
    customerType cust;                                    //Line 1
    ifstream inFile;                                      //Line 2
    ofstream outFile;                                     //Line 3

    inFile.open("customerData.txt");                      //Line 4

    if (!inFile)                                          //Line 5
    {
        cout << "The input file does not exist. "
             << "The program terminates!!!!" << endl;     //Line 6
        return 1;                                         //Line 7
    }

   outFile.open("customer.dat", ios::binary);             //Line 8

   inFile >> cust.ID >> cust.firstName >> cust.lastName
          >> cust.balance;                                //Line 9

    while (inFile)                                        //Line 10
    {
         outFile.write(reinterpret_cast<const char *> (&cust),
                       sizeof(cust));                     //Line 11
         inFile >> cust.ID >> cust.firstName >> cust.lastName
                >> cust.balance;                          //Line 12
    }

    inFile.close();                                       //Line 13
    inFile.clear();                                       //Line 14
    outFile.close();                                      //Line 15
```

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```
    inFile.open("customer.dat", ios::binary);          //Line 16

    if (!inFile)                                       //Line 17
    {
        cout << "The input file does not exist. "
             << "The program terminates!!!!" << endl;  //Line 18
        return 1;                                      //Line 19
    }

    cout << left << setw(8) << "ID"
         << setw(16) << "First Name"
         << setw(16) << "Last Name"
         << setw(10) << " Balance" << endl;            //Line 20
    cout << fixed << showpoint << setprecision(2);     //Line 21

        //read and output the data from the binary
        //file customer.dat
    inFile.read(reinterpret_cast<char *> (&cust),
                sizeof(cust));                         //Line 22
    while (inFile)                                     //Line 23
    {
         cout << left << setw(8) << cust.ID
              << setw(16) << cust.firstName
              << setw(16) << cust.lastName
              << right << setw(10) << cust.balance
              << endl;                                 //Line 24
        inFile.read(reinterpret_cast<char *> (&cust),
                    sizeof(cust));                     //Line 25
    }

    inFile.close();     //close the file               //Line 26

    return 0;                                          //Line 27
}
```

Sample Run:

```
ID      First Name      Last Name        Balance
77234   Ashley          White            4563.50
12345   Brad            Smith          128923.45
87123   Lisa            Johnson          2345.93
81234   Sheila          Robinson          674.00
11111   Rita            Gupta           14863.50
23422   Ajay            Kumar           72682.90
22222   Jose            Ramey           25345.35
54234   Sheila          Duffy           65222.00
55555   Tommy           Pitts             892.85
23452   Salma           Quade            2812.90
32657   Jennifer        Ackerman         9823.89
82722   Steve           Sharma          78932.00
```

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Random File Access

In Chapter 3 and the preceding section, you learned how to read data from and write data to a file. More specifically, you used `ifstream` objects to read data from a file and `ofstream` objects to write data to a file. However, the files were read and/or written sequentially. Reading data from a file sequentially does not work very well for a variety of applications. For example, consider a program that processes customers' data in a bank. Typically, there are thousands or even millions of customers in a bank. Suppose we want to access a customer's data from the file that contains such data, say, for an account update. If the data is accessed sequentially, starting from the first position and read until the desired customer's data is found, this process might be extremely time consuming. Similarly, in an airline's reservation system to access a passenger's reservation information sequentially, this might also be very time consuming. In such cases, the data retrieval must be efficient. A convenient way to do this is to be able to read the data randomly from a file, that is, randomly access any record in the file.

In the preceding section, you learned how to use the stream function `read` to read a specific number of bytes, and the function `write` to write a specific number of bytes.

The stream function `seekg` is used to move the read position to any byte in the file. The general syntax to use the function `seekg` is:

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```
fileVariableName.seekg(offset, position);
```

The stream function `seekp` is used to move the write position to any byte in the file. The general syntax to use the function `seekp` is:

```
fileVariableName.seekp(offset, position);
```

The `offset` specifies the number of bytes the reading/writing positions are to be moved, and `position` specifies where to begin the offset. The offset can be calculated from the beginning of the file, end of the file, or the current position in the file. Moreover, `offset` is a long integer representation of an offset. Table E-3 shows the values that can be used for `position`.

TABLE E-3 Values of `position`

`position`	Description
`ios::beg`	The offset is calculated from the beginning of the file.
`ios::cur`	The offset is calculated from the current position of the reading marker in the file.
`ios::end`	The offset is calculated from the end of the file.

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EXAMPLE E-3

Suppose you have the following line of text stored in a file, say, `digitsAndLetters.txt`:

```
0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

Also, suppose that `inFile` is an `ifstream` object and the file `digitsAndLetters.txt` has been opened using the object `inFile`. One byte is used to store each character of this line of text. Moreover, the position of the first character is `0`.

Statement	Explanation
`inFile.seekp(10L, ios::beg);`	Sets the reading position of `inFile` to the 11th byte (character), which is at position `10`. That is, it sets the reading position just after the digit `9` or just before the letter `A`.
`inFile.seekp(5L, ios::cur);`	Moves the reading position of `inFile` five bytes to the right of its current position.
`inFile.seekp(-6L, ios::end);`	Sets the reading position of `inFile` to the sixth byte (character) from the end. That is, it sets the reading position just before the letter `U`.

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The program in the following example further explains how the functions `seekg` and `seekp` work.

EXAMPLE E-4

```
#include <iostream>
#include <fstream>

using namespace std;

int main()
{
    char ch;                                              //Line 1
    ifstream inFile;                                      //Line 2

    inFile.open("digitsAndAlphabet.txt");                 //Line 3

    if (!inFile)                                          //Line 4
    {
       cout << "The input file does not exist. "
            << "The program terminates!!!!" << endl;     //Line 5
       return 1;                                          //Line 6
    }
```

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```
    inFile.get(ch);                                  //Line 7
    cout << "Line 8: The first byte: " << ch << endl; //Line 8

       //position the reading marker six bytes to the
       //right of its current position
    inFile.seekg(6L, ios::cur);                       //Line 9
    inFile.get(ch);   //read the character            //Line 10
    cout << "Line 11: Current byte read: " << ch
         << endl;                                     //Line 11

       //position the reading marker seven bytes
       //from the beginning
    inFile.seekg(7L, ios::beg);                       //Line 12
    inFile.get(ch);   //read the character            //Line 13
    cout << "Line 14: Seventh byte from the beginning: "
         << ch << endl;                               //Line 14

       //position the reading marker 26 bytes
       //from the end
    inFile.seekg(-26L, ios::end);                     //Line 15
    inFile.get(ch);   //read the character            //Line 16
    cout << "Line 17: Byte 26 from the end: " << ch
         << endl;                                     //Line 17

    return 0;                                         //Line 18
}
```

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Sample Run:

```
Line 8: The first byte: 0
Line 11: Current byte read: 7
Line 14: Seventh byte from the beginning: 7
Line 17: Byte 26 from the end: A
```

The input file contains the following line of text:

```
0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

The following program illustrates how the function `seekg` works with `struct`s.

EXAMPLE E-5

Suppose `customerType` is a `struct` defined as follows:

```
struct customerType
{
    char firstName[15];
    char lastName[15];
    int ID;
    double balance;
};
```

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The program in Example E-2 created the binary file customer.dat consisting of certain customers' data. You can use the function seekg to move the reading position of this file to any record. Suppose inFile is an ifstream object used to open the binary file customer.dat.

The following statement calculates the size of a customerType **struct** and stores it in the variable custSize:

```
long custSize = sizeof(cust);
```

We can use the value of the variable custSize to move the reading position to a specific record in the file. For example, consider the following statement:

```
inFile.seekg(6 * custSize, ios::beg);
```

This statement moves the reading position just after the sixth customer's record, that is, just before the seventh customer's record.

The following program further illustrates how the function seekg works with **struct**s.

EXAMPLE E-6

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```
//Reading a file randomly

#include <iostream>
#include <fstream>
#include <iomanip>

using namespace std;

struct customerType
{
    char firstName[15];
    char lastName[15];
    int ID;
    double balance;
};

void printCustData(const customerType& customer);

int main()
{
    customerType cust;                                   //Line 1
    ifstream inFile;                                     //Line 2

    long custSize = sizeof(cust);                        //Line 3

    inFile.open("customer.dat", ios::binary);            //Line 4
    if (!inFile)                                         //Line 5
```

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```
    {
        cout << "The input file does not exist. "
             << "The program terminates!!!!" << endl; //Line 6
        return 1;                                     //Line 7
    }

    cout << fixed << showpoint << setprecision(2);    //Line 8

        //randomly read the records and output them
    inFile.seekg(6 * custSize, ios::beg);             //Line 9
    inFile.read(reinterpret_cast<char *> (&cust),
                sizeof(cust));                        //Line 10
    cout << "Seventh customer's data: " << endl;      //Line 11
    printCustData(cust);                              //Line 12

    inFile.seekg(8 * custSize, ios::beg);             //Line 13
    inFile.read(reinterpret_cast<char *> (&cust),
                sizeof(cust));                        //Line 14
    cout << "Ninth customer's data: " << endl;        //Line 15
    printCustData(cust);

    inFile.seekg(-8 * custSize, ios::end);            //Line 16
    inFile.read(reinterpret_cast<char *> (&cust),
                sizeof(cust));                        //Line 17
    cout << "Eighth (from the end) customer's data: "
         << endl;                                     //Line 18
    printCustData(cust);                              //Line 19

    inFile.close();     //close the file              //Line 20

    return 0;                                         //Line 21
}

void printCustData(const customerType& customer)
{
    cout << "  ID: " << customer.ID <<endl
         << "  First Name: " << customer.firstName <<endl
         << "  Last Name: " << customer.lastName <<endl
         << "  Account Balance: $" << customer.balance
         << endl;
}
```

Sample Run:

```
Seventh customer's data:
  ID: 22222
  First Name: Jose
  Last Name: Ramey
  Account Balance: $25345.35
Ninth customer's data:
  ID: 55555
  First Name: Tommy
  Last Name: Pitts
```

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```
  Account Balance: $892.85
Eighth (from the end) customer's data:
  ID: 11111
  First Name: Rita
  Last Name: Gupta
  Account Balance: $14863.50
```

The program in Example E-6 illustrates how the function seekg works. Using the function seekg, the reading position in a file can be moved to any location in the file. Similarly, the function seekp can be used to move the write position in a file to any location. Furthermore, these functions can be used to create a binary file in which the data is organized according to the values of either a variable or a particular component of a struct. For example, suppose there are at most, say, 100 students in a class. Each student has a unique ID in the range 1 to 100. Using the students' IDs, we can create a random access binary file in such a way that in the file, a student's data is written at the location specified by its ID. This is like treating the file as an array. The advantage is that, once the file is created, a student's data from the file can be read, directly, using the student's ID. Another advantage is that in the file, the data is sorted according to the IDs.

Here, we are assuming that the student IDs are in the range 1 to 100. However, if you use, say, a three-, four-, or five-digit number as a student ID and there are only a few students in the class, the data in the file could be scattered. In other words, a lot of space could be used just to store only a few students' data. In such cases, more advanced techniques are used to organize the data so that it can be accessed efficiently.

The program in Example E-7 illustrates how to use the students' IDs to organize the data in a binary file. The program also shows how to output the file.

EXAMPLE E-7

```
//Creating and reading a random access file.

#include <iostream>
#include <fstream>
#include <iomanip>

using namespace std;

struct studentType
{
    char firstName[15];
    char lastName[15];
    int ID;
    double GPA;
};

void printStudentData(const studentType& student);
```

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```
int main()
{
    studentType st;                                     //Line 1
    ifstream inFile;                                    //Line 2
    ofstream outFile;                                   //Line 3

    long studentSize = sizeof(st);                      //Line 4

        //open the input file, which is a text file
    inFile.open("studentData.txt");                     //Line 5

    if (!inFile)                                        //Line 6
    {
        cout << "The input file does not exist. "
             << "The program terminates!!!!" << endl;   //Line 7
        return 1;                                       //Line 8
    }

        //open a binary output file
    outFile.open("student.dat", ios::binary);           //Line 9

    inFile >> st.ID >> st.firstName
           >> st.lastName >> st.GPA;                    //Line 10

    while (inFile)                                      //Line 11
    {
        outFile.seekp((st.ID - 1) * studentSize,
                      ios::beg);                        //Line 12
        outFile.write(reinterpret_cast<const char *> (&st),
                     sizeof(st));                       //Line 13
        inFile >> st.ID >> st.firstName
               >> st.lastName >> st.GPA;                //Line 14
    };

    inFile.close();                                     //Line 15
    inFile.clear();                                     //Line 16
    outFile.close();                                    //Line 17

    cout << left << setw(3) << "ID"
         << setw(16) << "First Name"
         << setw(16) << "Last Name"
         << setw(12) << "Current GPA" << endl;          //Line 18
    cout << fixed << showpoint << setprecision(2);      //Line 19

         //open the input file, which is a binary file
    inFile.open("student.dat", ios::binary);            //Line 20

    if (!inFile)                                        //Line 21
    {
       cout << "The input file does not exist. "
            << "The program terminates!!!!" << endl;    //Line 22
       return 1;                                        //Line 23
    }
```

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```
        //read the data at location 0 in the file
    inFile.read(reinterpret_cast<char *> (&st),
                sizeof(st));                               //Line 24
    while (inFile)                                         //Line 25
    {
        if (st.ID != 0)                                    //Line 26
            printStudentData(st);                          //Line 27

            //read the data at the current reading position
        inFile.read(reinterpret_cast<char *> (&st),
                    sizeof(st));                           //Line 28
    };

    return 0;                                              //Line 29
}

void printStudentData(const studentType& student)
{
    cout << left << setw(3) << student.ID
         << setw(16) << student.firstName
         << setw(16) << student.lastName
         << right << setw(10)<< student.GPA
         << endl;
}
```

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Sample Run:

```
ID First Name         Last Name          Current GPA
2  Sheila             Duffy                    4.00
10 Ajay               Kumar                    3.60
12 Ashley             White                    3.90
16 Tommy              Pitts                    2.40
23 Rita               Gupta                    3.40
34 Brad               Smith                    3.50
36 Salma              Quade                    3.90
41 Steve              Sharma                   3.50
45 Sheila             Robinson                 2.50
56 Lisa               Johnson                  2.90
67 Jose               Ramey                    3.80
75 Jennifer           Ackerman                 4.00
```

The data in the file studentData.txt is as follows:

```
12 Ashley White 3.9
34 Brad Smith 3.5
56 Lisa Johnson 2.9
45 Sheila Robinson 2.5
23 Rita Gupta 3.4
10 Ajay Kumar 3.6
67 Jose Ramey 3.8
2 Sheila Duffy 4.0
16 Tommy Pitts 2.4
```

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```
36 Salma Quade 3.9
75 Jennifer Ackerman 4.0
41 Steve Sharma 3.5
```

Naming Conventions of Header Files in ANSI/ISO Standard C++ and Standard C++

The programs in this book are written using ANSI/ISO Standard C++. As indicated in Chapter 1, there are two versions of C++—ANSI/ISO Standard C++ and Standard C++. For the most part, these two standards are the same. The header files in Standard C++ have the extension `.h`, while the header files in ANSI/ISO Standard C++ have no extension. Moreover, the names of certain header files, such as `math.h`, in ANSI/ISO Standard C++ start with the letter `c`. The language C++ evolved from C. Therefore, certain header files—such as `math.h`, `stdlib.h`, and `string.h`—were brought from C into C++. The header files—such as `iostream.h`, `iomanip.h`, and `fstream.h`—were specially designed for C++. Recall that when a header file is included in a program, the global identifiers of the header file also become the global identifiers of the program. In ANSI/ISO Standard C++, to take advantage of the **`namespace`** mechanism, all of the header files were modified so that the identifiers are declared within a **`namespace`**. Recall that the name of this **`namespace`** is `std`.

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In ANSI/ISO Standard C++, the extension `.h` of the header files that were specially designed for C++ was dropped. For the header files that were brought from C into C++, the extension `.h` was dropped and the names of these header files start with the letter `c`. Following are the names of the most commonly used header files in Standard C++ and ANSI/ISO Standard C++:

Standard C++ Header File Name	ANSI/ISO Standard C++ Header File Name
`assert.h`	`cassert`
`ctype.h`	`cctype`
`float.h`	`cfloat`
`fstream.h`	`fstream`
`iomanip.h`	`iomanip`
`iostream.h`	`iostream`
`limits.h`	`climits`
`math.h`	`cmath`
`stdlib.h`	`cstdlib`
`string.h`	`cstring`

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To include a header file, say, `iostream`, the following statement is required:

```
#include <iostream>
```

Furthermore, to use identifiers, such as `cin`, `cout`, `endl`, and so on, the program should use either the statement:

```
using namespace std;
```

or the prefix `std::` before the identifier.

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Appendix F
Header Files

The C++ standard library contains many predefined functions, named constants, and specialized data types. This appendix discusses some of the most widely used library routines (and several named constants). For additional explanation and information on functions, named constants, and so on, check your system documentation. The names of the Standard C++ header files are shown in parentheses.

Header File cassert (assert.h)

The following table describes the function `assert`. Its specification is contained in the header file `cassert` (`assert.h`).

`assert(expression)`	`expression` is any **`int`** `expression`; `expression` is usually a logical expression	• If the value of `expression` is nonzero (**`true`**), the program continues to execute. • If the value of `expression` is 0 (**`false`**), execution of the program terminates immediately. The expression, the name of the file containing the source code, and the line number in the source code are displayed.

NOTE To disable all the `assert` statements, place the preprocessor directive **`#define`** `NDEBUG` before the directive **`#include`** `<cassert>`.

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Header File cctype (ctype.h)

The following table shows various functions from the header file cctype (ctype.h).

Function Name and Parameters	Parameter(s) Types	Function Return Value
isalnum(ch)	ch is a char value	Function returns an int value as follows: • If ch is a letter or a digit character, that is ('A'-'Z', 'a'-'z', '0'-'9'), it returns a nonzero value (true) • 0 (false), otherwise
iscntrl(ch)	ch is a char value	Function returns an int value as follows: • If ch is a control character (in ASCII, a character value 0-31 or 127), it returns a nonzero value (true) • 0 (false), otherwise
isdigit(ch)	ch is a char value	Function returns an int value as follows: • If ch is a digit ('0'-'9'), it returns a nonzero value (true) • 0 (false), otherwise
islower(ch)	ch is a char value	Function returns an int value as follows: • If ch is lowercase ('a'-'z'), it returns a nonzero value (true) • 0 (false), otherwise
isprint(ch)	ch is a char value	Function returns an int value as follows: • If ch is a printable character, including blank (in ASCII, ' ' through '~'), it returns a nonzero value (true) • 0 (false), otherwise
ispunct(ch)	ch is a char value	Function returns an int value as follows: • If ch is a punctuation character, it returns a nonzero value (true) • 0 (false), otherwise
isspace(ch)	ch is a char value	Function returns an int value as follows: • If ch is a white space character (blank, newline, tab, carriage return, form feed), it returns a nonzero value (true) • 0 (false), otherwise

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Function Name and Parameters	Parameter(s) Types	Function Return Value
isupper(ch)	ch is a **char** value	Function returns an **int** value as follows: • If ch is an uppercase letter ('A'-'Z'), it returns a nonzero value (**true**) • 0 (**false**), otherwise
tolower(ch)	ch is a **char** value	Function returns an **int** value as follows: • If ch is an uppercase letter, it returns the ASCII value of the lowercase equivalent of ch • ASCII value of ch, otherwise
toupper(ch)	ch is a **char** value	Function returns an **int** value as follows: • If ch is a lowercase letter, it returns the ASCII value of the uppercase equivalent of ch • ASCII value of ch, otherwise

Header File cfloat (float.h)

In Chapter 2, we listed the largest and smallest values belonging to the floating-point data types. We also remarked that these values are system dependent. These largest and smallest values are stored in named constants. The header file cfloat contains many such named constants. The following table lists some of these constants.

Named Constant	Description
FLT_DIG	Approximate number of significant digits in a **float** value
FLT_MAX	Maximum positive **float** value
FLT_MIN	Minimum positive **float** value
DBL_DIG	Approximate number of significant digits in a **double** value
DBL_MAX	Maximum positive **double** value
DBL_MIN	Minimum positive **double** value
LDBL_DIG	Approximate number of significant digits in a **long double** value
LDBL_MAX	Maximum positive **long double** value
LDBL_MIN	Minimum positive **long double** value

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A program similar to the following can print the values of these named constants on your system:

```
#include <iostream>
#include <cfloat>

using namespace std;

int main()
{
    cout << "Approximate number of significant digits "
         << "in a float value " << FLT_DIG << endl;
    cout << "Maximum positive float value " << FLT_MAX
         << endl;
    cout << "Minimum positive float value " << FLT_MIN
         << endl;
    cout << "Approximate number of significant digits "
         << "in a double value " << DBL_DIG << endl;
    cout << "Maximum positive double value " << DBL_MAX
         << endl;
    cout << "Minimum positive double value " << DBL_MIN
         << endl;
    cout << "Approximate number of significant digits "
         << "in a long double value " << LDBL_DIG << endl;
    cout << "Maximum positive long double value " << LDBL_MAX
         << endl;
    cout << "Minimum positive long double value " << LDBL_MIN
         << endl;

    return 0;
}
```

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Header File climits (limits.h)

In Chapter 2, we listed the largest and smallest values belonging to the integral data types. We also remarked that these values are system dependent. These largest and smallest values are stored in named constants. The header file climits contains many such named constants. The following table lists some of these constants.

Named Constant	Description
CHAR_BIT	Number of bits in a byte
CHAR_MAX	Maximum char value
CHAR_MIN	Minimum char value
SHRT_MAX	Maximum short value
SHRT_MIN	Minimum short value

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Named Constant	Description
INT_MAX	Maximum int value
INT_MIN	Minimum int value
LONG_MAX	Maximum long value
LONG_MIN	Minimum long value
UCHAR_MAX	Maximum unsigned char value
USHRT_MAX	Maximum unsigned short value
UINT_MAX	Maximum unsigned int value
ULONG_MAX	Maximum unsigned long value

A program similar to the following can print the values of these named constants on your system:

```
#include <iostream>
#include <climits>

using namespace std;

int main()
{
    cout << "Number of bits in a byte " << CHAR_BIT << endl;
    cout << "Maximum char value " << CHAR_MAX << endl;
    cout << "Minimum char value " << CHAR_MIN << endl;
    cout << "Maximum short value " << SHRT_MAX << endl;
    cout << "Minimum short value " << SHRT_MIN << endl;
    cout << "Maximum int value " << INT_MAX << endl;
    cout << "Minimum int value " << INT_MIN << endl;
    cout << "Maximum long value " << LONG_MAX << endl;
    cout << "Minimum long value " << LONG_MIN << endl;
    cout << "Maximum unsigned char value " << UCHAR_MAX
         << endl;
    cout << "Maximum unsigned short value " << USHRT_MAX
         << endl;
    cout << "Maximum unsigned int value " << UINT_MAX << endl;
    cout << "Maximum unsigned long value " << ULONG_MAX
         << endl;

    return 0;
}
```

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Header File `cmath` (`math.h`)

The following table shows various math functions.

Function Name and Parameters	Parameter(s) Type	Function Return Value
`acos(x)`	`x` is a floating-point expression, $-1.0 \le x \le 1.0$	Arc cosine of `x`, a value between 0.0 and π
`asin(x)`	`x` is a floating-point expression, $-1.0 \le x \le 1.0$	Arc sine of `x`, a value between $-\pi/2$ and $\pi/2$
`atan(x)`	`x` is a floating-point expression	Arc tan of `x`, a value between $-\pi/2$ and $\pi/2$
`ceil(x)`	`x` is a floating-point expression	The smallest whole number $\ge$ `x`, ("ceiling" of `x`)
`cos(x)`	`x` is a floating-point expression, `x` is measured in radians	Trigonometric cosine of the angle
`cosh(x)`	`x` is a floating-point expression	Hyperbolic cosine of `x`
`exp(x)`	`x` is a floating-point expression	The value `e` raised to the power of `x`; `(e = 2.718...)`
`fabs(x)`	`x` is a floating-point expression	Absolute value of `x`
`floor(x)`	`x` is a floating-point expression	The largest whole number $\le$ x; ("floor" of x)
`log(x)`	`x` is a floating-point expression, where $x > 0.0$	Natural logarithm (base `e`) of `x`
`log10(x)`	`x` is a floating-point expression, where $x > 0.0$	Common logarithm (base `10`) of `x`
`pow(x,y)`	`x` and `y` are floating-point expressions. If $x = 0.0$, `y` must be positive; if $x \le 0.0$, `y` must be a whole number.	`x` raised to the power of `y`
`sin(x)`	`x` is a floating-point expression; `x` is measured in radians	Trigonometric sine of the angle
`sinh(x)`	`x` is a floating-point expression	Hyperbolic sine of `x`

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Function Name and Parameters	Parameter(s) Type	Function Return Value
`sqrt(x)`	`x` is a floating-point expression, where `x` ≥ `0.0`	Square root of `x`
`tan(x)`	`x` is a floating-point expression; `x` is measured in radians	Trigonometric tangent of the angle
`tanh(x)`	`x` is a floating-point expression	Hyperbolic tangent of `x`

Header File cstddef (stddef.h)

Among others, this header file contains the definition of the following symbolic constant:

`NULL`: The system-dependent null pointer (usually 0)

Header File cstring (string.h)

The following table shows various string functions.

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Function Name and Parameters	Parameter(s) Type	Function Return Value
`strcat(destStr, srcStr)`	`destStr` and `srcStr` are null-terminated **`char`** arrays; `destStr` must be large enough to hold the result	The base address of `destStr` is returned; `srcStr`, including the null character, is concatenated to the end of `destStr`
`strcmp(str1, str2)`	`str1` and `str2` are null terminated **`char`** arrays	The returned value is as follows: • An **`int`** value < 0, if `str1 < str2` • An **`int`** value 0, if `str1 = str2` • An **`int`** value > 0, if `str1 > str2`

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Function Name and Parameters	Parameter(s) Type	Function Return Value
`strcpy(destStr, srcStr)`	`destStr` and `srcStr` are null-terminated `char` arrays	The base address of `destStr` is returned; `srcStr` is copied into `destStr`
`strlen(str)`	`str` is a null-terminated `char` array	An integer value ≥ 0 specifying the length of the `str` (excluding the `'\0'`) is returned

HEADER FILE string

This header file—not to be confused with the header file `cstring`—supplies a programmer-defined data type named `string`. Associated with the `string` type are a data type `string::size_type` and a named constant `string::npos`. These are defined as follows:

`string::size_type`	An unsigned integer type
`string::npos`	The maximum value of type `string::size_type`

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Several functions are associated with the `string` type. The following table shows some of these functions. Unless stated otherwise, `str`, `str1`, and `str2` are variables (objects) of type `string`. The position of the first character in a `string` variable (such as `str`) is `0`, the second character is `1`, and so on.

Function Name and Parameters	Parameter(s) Type	Function Return Value
`str.c_str()`	None	The base address of a null-terminated C-string corresponding to the characters in `str`.
`getline(istreamVar,str)`	`istreamVar` is an input stream variable (of type `istream` or `ifstream`). `str` is a `string` object (variable).	Characters until the newline character are input from `istreamVar` and stored in `str`. (The newline character is read but not stored into `str`.) The value returned by this function is usually ignored.

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Function Name and Parameters	Parameter(s) Type	Function Return Value
str.empty()	None	Returns **true** if str is empty, that is, the number of characters in str is zero, **false** otherwise.
str.length()	None	A value of type string::size_type giving the number of characters in the string.
str.size()	None	A value of type string::size_type giving the number of characters in the string.
str.find(strExp)	str is a string object and strExp is a string expression evaluating to a string. The string expression, strExp, can also be a character.	The find function searches str to find the first occurrence of the string or the character specified by strExp. If the search is successful, the function find returns the position in str where the match begins. If the search is unsuccessful, the function returns the special value string::npos.
str.substr(pos, len)	Two unsigned integers, pos and len. pos, represent the starting position (of the substring in str), and len represents the length (of the substring). The value of pos must be less than str.length().	A temporary string object that holds a substring of str starting at pos. The length of the substring is, at most, len characters. If len is too large, it means "to the end" of the string in str.
str1.swap(str2);	One parameter of type string. str1 and str2 are string variables.	The contents of str1 and str2 are swapped.

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Function Name and Parameters	Parameter(s) Type	Function Return Value
`str.clear();`	None	Removes all the characters from `str`.
`str.erase();`	None	Removes all the characters from `str`.
`str.erase(m);`	One parameter of type `string::size_type`.	Removes all the characters from `str` starting at index `m`.
`str.erase(m, n);`	Two parameters of type **`int`**.	Starting at index `m`, removes the next `n` characters from `str`. If `n` > length of `str`, removes all the characters starting at the `m`th.
`str.insert(m, n, c);`	Parameters `m` and `n` are of type `string::size_type`; `c` is a character.	Inserts `n` occurrences of the character `c` at index `m` into `str`.
`str1.insert(m, str2);`	Parameter `m` is of type `string::size_type`.	Inserts all the characters of `str2` at index `m` into `str1`.
`str1.replace(m,n,str2);`	Parameters `m` and `n` are of type `string::size_type`.	Starting at index `m`, replaces the next `n` characters of `str1` with all the characters of `str2`. If `n` > length of `str1`, then all the characters until the end of `str1` are replaced.

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Appendix G
Memory Size on a System and Random Number Generator

A program similar to the following prints the memory size of the built-in data types on your system. (The output of the program shows the size of the built-in data type on which this program was run.)

```
#include <iostream>

using namespace std;

int main()
{
   cout << "Size of char = " << sizeof(char) << endl;
   cout << "Size of int = " << sizeof(int) << endl;
   cout << "Size of short = " << sizeof(short) << endl;
   cout << "Size of unsigned int = " << sizeof(unsigned int)
        << endl;
   cout << "Size of long = " << sizeof(long) << endl;
   cout << "Size of bool = " << sizeof(bool) << endl;
   cout << "Size of float = " << sizeof(float) << endl;
   cout << "Size of double = " << sizeof(double) << endl;
   cout << "Size of long double = " << sizeof(long double)
        << endl;
   cout << "Size of unsigned short = "
        << sizeof(unsigned short) << endl;
   cout << "Size of unsigned long = "
        << sizeof(unsigned long) << endl;

   return 0;
}
```

Sample Run:

```
Size of char = 1
Size of int = 4
Size of short = 2
Size of unsigned int = 4
Size of long = 4
Size of bool = 1
Size of float = 4
Size of double = 8
Size of long double = 8
Size of unsigned short = 2
Size of unsigned long = 4
```

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Random Number Generator

To generate a random number, you can use the C++ function rand. To use the function rand, the program must include the header file cstdlib. The header file cstdlib also contains the constant RAND_MAX. Typically, the value of RAND_MAX is 32767. To find the exact value of RAND_MAX, check your system's documentation. The function rand generates an integer between 0 and RAND_MAX. The following program illustrates how to use the function rand. It also prints the value of RAND_MAX:

```
#include <iostream>
#include <cstdlib>
#include <iomanip>

using namespace std;

int main()
{
    cout << fixed << showpoint << setprecision(5);
      cout << "The value of RAND_MAX: " << RAND_MAX << endl;
    cout << "A random number: " << rand() << endl;
    cout << "A random number between 0 and 9: "
         << rand() % 10 << endl;
    cout << "A random number between 0 and 1: "
         << static_cast<double> (rand())
              / static_cast<double>(RAND_MAX)
         << endl;

    return 0;
}
```

Sample Run:

```
The value of RAND_MAX: 32767
A random number: 41
A random number between 0 and 9: 7
A random number between 0 and 1: 0.19330
```

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Appendix H
References

1. G. Booch, *Object-Oriented Analysis and Design*, Second Edition, Addison-Wesley, 1995.
2. E. Horowitz, S. Sahni, and S. Rajasekaran, *Computer Algorithms C++*, Computer Science Press, 1997.
3. N.M. Josuttis, *The C++ Standard Library: A Tutorial and Reference*, Addison-Wesley, Reading, MA, 1999.
4. D.E. Knuth, *The Art of Computer Programming*, Vols. 1-3, Addison-Wesley, 1973, 1969, 1973.
5. S.B. Lippman and J. Lajoie, *C++ Primer*, Third Edition, Addison-Wesley, Reading, MA, 1998.
6. D.S. Malik and M.K. Sen, *Discrete Mathematical Structures: Theory and Applications*, Course Technology, Boston, MA, 2004.
7. E.M. Reingold and W.J. Hensen, *Data Structures in Pascal*, Little Brown and Company, Boston, MA, 1986.
8. R. Sedgewick, *Algorithms in C*, Third Edition, Addison-Wesley, Reading, MA, Parts 1-4, 1998; Part 5, 2002.
9. B. Stroustrup, *The Design and Evolution of C++*, Addison-Wesley, Reading, MA, 1994.

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