CHAPTER

3

Selections

Objectives

- To declare `boolean` variables and write Boolean expressions using relational operators (§3.2).
- To implement selection control using one-way `if` statements (§3.3).
- To implement selection control using two-way `if-else` statements (§3.4).
- To implement selection control using nested `if` and multi-way `if` statements (§3.5).
- To avoid common errors and pitfalls in `if` statements (§3.6).
- To generate random numbers using the `Math.random()` method (§3.7).
- To program using selection statements for a variety of examples (`SubtractionQuiz`, `BMI`, `ComputeTax`) (§§3.7–3.9).
- To combine conditions using logical operators (`!`, `&&`, `||`, and `^`) (§3.10).
- To program using selection statements with combined conditions (`LeapYear`, `Lottery`) (§§3.11 and 3.12).
- To implement selection control using `switch` statements (§3.13).
- To write expressions using the conditional operator (§3.14).
- To examine the rules governing operator precedence and associativity (§3.15).
- To apply common techniques to debug errors (§3.16).

3.1 Introduction

The program can decide which statements to execute based on a condition.

problem

Key Point

If you enter a negative value for `radius` in Listing 2.2, ComputeAreaWithConsoleInput.java, the program displays an invalid result. If the radius is negative, you don't want the program to compute the area. How can you deal with this situation?

selection statements

Like all high-level programming languages, Java provides *selection statements*: statements that let you choose actions with alternative courses. You can use the following selection statement to replace lines 12–17 in Listing 2.2:

```
if (radius < 0) {
  System.out.println("Incorrect input");
}
else {
  double area = radius * radius * 3.14159;
  System.out.println("Area is " + area);
}
```

Boolean expression

Boolean value

Selection statements use conditions that are Boolean expressions. A *Boolean expression* is an expression that evaluates to a *Boolean value*: `true` or `false`. We now introduce the `boolean` type and relational operators.

3.2 `boolean` Data Type, Values, and Expressions

The `boolean` data type declares a variable with the value either `true` or `false`.

Key Point

`boolean` data type

relational operators

How do you compare two values, such as whether a radius is greater than `0`, equal to `0`, or less than `0`? Java provides six *relational operators* (also known as *comparison operators*), shown in Table 3.1, which can be used to compare two values (assume radius is `5` in the table).

TABLE 3.1 Relational Operators

Java Operator	*Mathematics Symbol*	*Name*	*Example (radius is 5)*	*Result*
`<`	<	Less than	`radius < 0`	`false`
`<=`	≤	Less than or equal to	`radius <= 0`	`false`
`>`	>	Greater than	`radius > 0`	`true`
`>=`	≥	Greater than or equal to	`radius >= 0`	`true`
`==`	=	Equal to	`radius == 0`	`false`
`!=`	≠	Not equal to	`radius != 0`	`true`

`== vs. =`

Caution

The equality testing operator is two equal signs (`==`), not a single equal sign (`=`). The latter symbol is for assignment.

The result of the comparison is a Boolean value: `true` or `false`. For example, the following statement displays `true`:

```
double radius = 1;
System.out.println(radius > 0);
```

Boolean variable

A variable that holds a Boolean value is known as a *Boolean variable*. The `boolean` data type is used to declare Boolean variables. A `boolean` variable can hold one of the two values: `true` or `false`. For example, the following statement assigns `true` to the variable `lightsOn`:

```
boolean lightsOn = true;
```

Boolean literals

`true` and `false` are literals, just like a number such as `10`. They are not keywords, but are reserved words and cannot be used as identifiers in the program.

VideoNote
Program addition quiz

Suppose you want to develop a program to let a first-grader practice addition. The program randomly generates two single-digit integers, `number1` and `number2`, and displays to the student a question such as "What is 1 + 7?," as shown in the sample run in Listing 3.1. After the student types the answer, the program displays a message to indicate whether it is true or false.

There are several ways to generate random numbers. For now, generate the first integer using `System.currentTimeMillis() % 10` (i.e., the last digit in the current time) and the second using `System.currentTimeMillis() / 10 % 10` (i.e., the second last digit in the current time). Listing 3.1 gives the program. Lines 5–6 generate two numbers, `number1` and `number2`. Line 14 obtains an answer from the user. The answer is graded in line 18 using a Boolean expression `number1 + number2 == answer`.

LISTING 3.1 AdditionQuiz.java

```
 1  import java.util.Scanner;
 2
 3  public class AdditionQuiz {
 4    public static void main(String[] args) {
 5      int number1 = (int)(System.currentTimeMillis() % 10);
 6      int number2 = (int)(System.currentTimeMillis() / 10 % 10);
 7
 8      // Create a Scanner
 9      Scanner input = new Scanner(System.in);
10
11      System.out.print(
12        "What is " + number1 + " + " + number2 + "? ");
13
14      int answer = input.nextInt();
15
16      System.out.println(
17        number1 + " + " + number2 + " = " + answer + " is " +
18        (number1 + number2 == answer));
19    }
20  }
```

generate number1
generate number2
show question
receive answer
display result

```
What is 1 + 7? 8 ↵Enter
1 + 7 = 8 is true
```

```
What is 4 + 8? 9 ↵Enter
4 + 8 = 9 is false
```

line#	number1	number2	answer	output
5	4			
6		8		
14			9	
16				4 + 8 = 9 is false

Check Point

3.2.1 List six relational operators.

3.2.2 Assuming `x` is `1`, show the result of the following Boolean expressions:

```
(x > 0)
(x < 0)
(x != 0)
(x >= 0)
(x != 1)
```

3.2.3 Can the following conversions involving casting be allowed? Write a test program to verify it.

```
boolean b = true;
i = (int)b;

int i = 1;
boolean b = (boolean)i;
```

3.3 `if` Statements

Key Point

An `if` statement is a construct that enables a program to specify alternative paths of execution.

why `if` statement?

The preceding program displays a message such as "6 + 2 = 7 is false." If you wish the message to be "6 + 2 = 7 is incorrect," you have to use a selection statement to make this minor change.

Java has several types of selection statements: one-way `if` statements, two-way `if-else` statements, nested `if` statements, multi-way `if-else` statements, `switch` statements, and conditional operators.

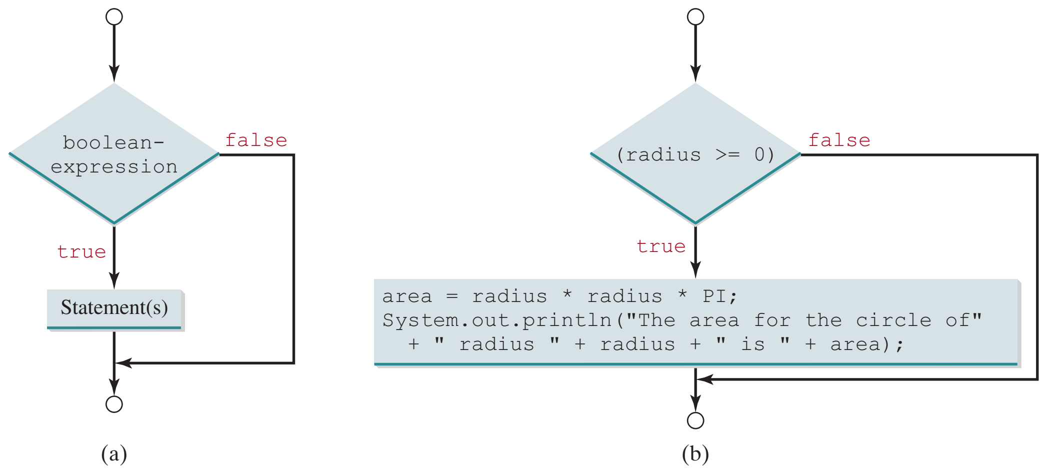
A one-way `if` statement executes an action if and only if the condition is `true`. The syntax for a one-way `if` statement is as follows:

`if` statement?

```
if (boolean-expression) {
  statement(s);
}
```

flowchart

The flowchart in Figure 3.1a illustrates how Java executes the syntax of an `if` statement. A *flowchart* is a diagram that describes an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting these with arrows. Process operations are represented in these boxes, and the arrows connecting them represent the flow of control. A diamond box denotes a Boolean condition, and a rectangle box represents statements.



```
area = radius * radius * PI;
System.out.println("The area for the circle of"
  + " radius " + radius + " is " + area);
```

FIGURE 3.1 An `if` statement executes statements if the `boolean-expression` evaluates to `true`.

If the `boolean-expression` evaluates to `true`, the statements in the block are executed. As an example, see the following code:

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("The area for the circle of radius " +
    radius + " is " + area);
}
```

The flowchart of the preceding statement is shown in Figure 3.1b. If the value of `radius` is greater than or equal to `0`, then the `area` is computed and the result is displayed; otherwise, the two statements in the block will not be executed.

The `boolean-expression` is enclosed in parentheses. For example, the code in (a) is wrong. It should be corrected, as shown in (b).

```
if  i > 0  {
  System.out.println("i is positive");
}
```

(a) Wrong

```
if (i > 0) {
  System.out.println("i is positive");
}
```

(b) Correct

The block braces can be omitted if they enclose a single statement. For example, the following statements are equivalent:

```
if (i > 0) {
  System.out.println("i is positive");
}
```

(a)

Equivalent

```
if (i > 0)
  System.out.println("i is positive");
```

(b)

Caution

Omitting braces makes the code shorter, but it is prone to errors. It is a common mistake to forget the braces when you go back to modify the code that omits the braces.

Omitting braces or not

Listing 3.2 gives a program that prompts the user to enter an integer. If the number is a multiple of `5`, the program displays `HiFive`. If the number is divisible by `2`, it displays `HiEven`.

LISTING 3.2 SimpleIfDemo.java

```
import java.util.Scanner;

public class SimpleIfDemo {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);
    System.out.print("Enter an integer: ");
    int number = input.nextInt();                         enter input

    if (number % 5 == 0)                                  check 5
      System.out.println("HiFive");

    if (number % 2 == 0)                                  check even
      System.out.println("HiEven");
  }
}
```

```
Enter an integer: 4 ↵Enter
HiEven
```

```
Enter an integer: 30 ↵Enter
HiFive
HiEven
```

The program prompts the user to enter an integer (lines 6–7) and displays `HiFive` if it is divisible by `5` (lines 9–10) and `HiEven` if it is divisible by `2` (lines 12–13).

Check Point

3.3.1 Write an `if` statement that assigns `1` to `x` if `y` is greater than `0`.

3.3.2 Write an `if` statement that increases pay by 3% if `score` is greater than `90`.

3.3.3 What is wrong in the following code?

```
if radius >= 0
{
  area = radius * radius * PI;
  System.out.println("The area for the circle of " +
    " radius " + radius + " is " + area);
}
```

3.4 Two-Way `if-else` Statements

Key Point

An `if-else` statement decides the execution path based on whether the condition is true or false.

A one-way `if` statement performs an action if the specified condition is `true`. If the condition is `false`, nothing is done. But what if you want to take alternative actions when the condition is `false`? You can use a two-way `if-else` statement. The actions that a two-way `if-else` statement specifies differ based on whether the condition is `true` or `false`.

Here is the syntax for a two-way `if-else` statement:

```
if (boolean-expression) {
  statement(s)-for-the-true-case;
}
else {
  statement(s)-for-the-false-case;
}
```

The flowchart of the statement is shown in Figure 3.2.

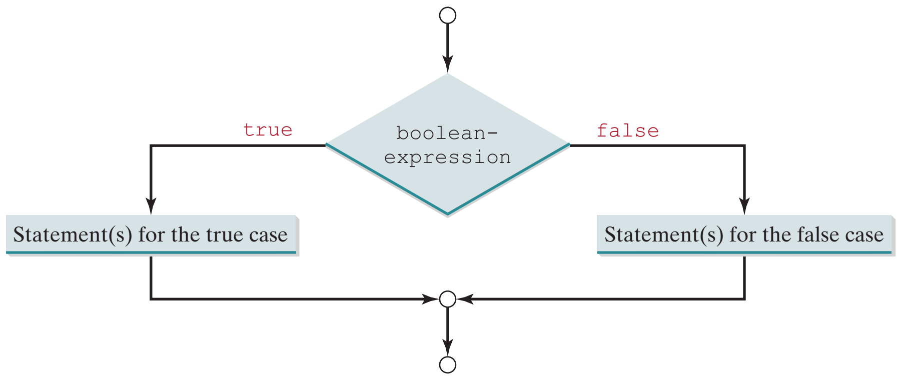

true
boolean-expression
false
Statement(s) for the true case
Statement(s) for the false case

FIGURE 3.2 An `if-else` statement executes statements for the true case if the `boolean-expression` evaluates to `true`; otherwise, statements for the `false` case are executed.

If the boolean-expression evaluates to true, the statement(s) for the true case are executed; otherwise, the statement(s) for the false case are executed. For example, consider the following code:

two-way if-else statement

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("The area for the circle of radius " +
    radius + " is " + area);
}
else {
  System.out.println("Negative input");
}
```

If radius >= 0 is true, area is computed and displayed; if it is false, the message "Negative input" is displayed.

As usual, the braces can be omitted if there is only one statement within them. The braces enclosing the System.out.println("Negative input") statement can therefore be omitted in the preceding example.

Here is another example of using the if-else statement. The example checks whether a number is even or odd, as follows:

```
if (number % 2 == 0)
  System.out.println(number + " is even.");
else
  System.out.println(number + " is odd.");
```

Check Point

3.4.1 Write an if statement that increases pay by 3% if score is greater than 90, otherwise increases pay by 1%.

3.4.2 What is the output of the code in (a) and (b) if number is 30? What if number is 35?

```
if (number % 2 == 0)
  System.out.println(number
    + "is even.");

System.out.println(number
    + "is odd");
```

(a)

```
if (number % 2 == 0)
  System.out.println(number
    + "is even.");
else
System.out.println(number
    + "is odd");
```

(b)

3.5 Nested if and Multi-Way if-else Statements

An if statement can be inside another if statement to form a nested if statement.

Key Point

nested if statement

The statement in an if or if-else statement can be any legal Java statement, including another if or if-else statement. The inner if statement is said to be *nested* inside the outer if statement. The inner if statement can contain another if statement; in fact, there is no limit to the depth of the nesting. For example, the following is a nested if statement:

```
if (i > k) {
  if (j > k)
    System.out.println("i and j are greater than k");
}
else
  System.out.println("i is less than or equal to k");
```

The if (j > k) statement is nested inside the if (i > k) statement.

The nested if statement can be used to implement multiple alternatives. The statement given in Figure 3.3a, for instance, prints a letter grade according to the score, with multiple alternatives.

```
if (score >= 90)
  System.out.print("A");
else
  if (score >= 80)
    System.out.print("B");
  else
    if (score >= 70)
      System.out.print("C");
    else
      if (score >= 60)
        System.out.print("D");
      else
        System.out.print("F");
```

(a)

Equivalent

This is better

```
if (score >= 90)
  System.out.print("A");
else if (score >= 80)
  System.out.print("B");
else if (score >= 70)
  System.out.print("C");
else if (score >= 60)
  System.out.print("D");
else
  System.out.print("F");
```

(b)

FIGURE 3.3 A preferred format for multiple alternatives is shown in (b) using a multi-way `if-else` statement.

The execution of this `if` statement proceeds as shown in Figure 3.4. The first condition `(score >= 90)` is tested. If it is `true`, the grade is `A`. If it is `false`, the second condition `(score >= 80)` is tested. If the second condition is `true`, the grade is `B`. If that condition is `false`, the third condition and the rest of the conditions (if necessary) are tested until a condition is met or all of the conditions prove to be `false`. If all of the conditions are `false`, the grade is `F`. Note a condition is tested only when all of the conditions that come before it are `false`.

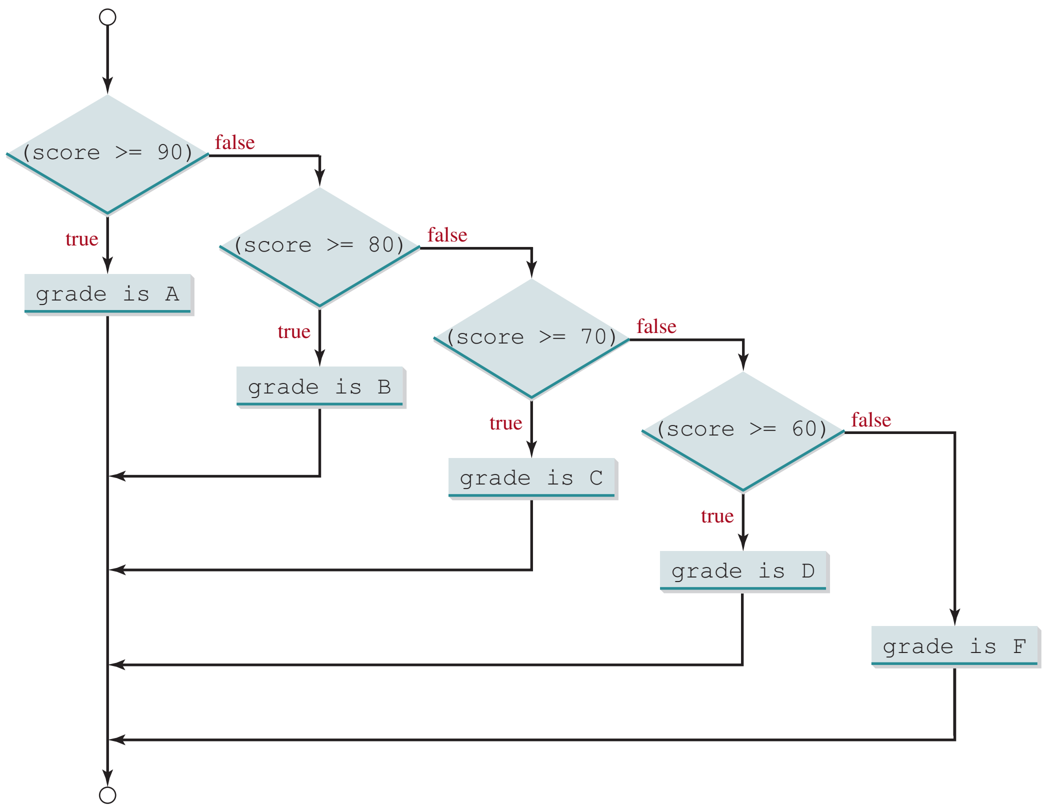


FIGURE 3.4 You can use a multi-way `if-else` statement to assign a grade.

The if statement in Figure 3.3a is equivalent to the if statement in Figure 3.3b. In fact, Figure 3.3b is the preferred coding style for multiple alternative if statements. This style, called *multi-way* **if-else** *statements*, avoids deep indentation and makes the program easy to read.

multi-way if statement

Check Point

3.5.1 Suppose x = 3 and y = 2; show the output, if any, of the following code. What is the output if x = 3 and y = 4? What is the output if x = 2 and y = 2? Draw a flowchart of the code.

```
if (x > 2) {
  if (y > 2) {
    z = x + y;
    System.out.println("z is " + z);
  }
}
else
  System.out.println("x is " + x);
```

3.5.2 Suppose x = 2 and y = 3. Show the output, if any, of the following code. What is the output if x = 3 and y = 2? What is the output if x = 3 and y = 3?

```
if (x > 2)
  if (y > 2) {
    int z = x + y;
      System.out.println("z is " + z);
  }
else
  System.out.println("x is " + x);
```

3.5.3 What is wrong in the following code?

```
if (score >= 60)
  System.out.println("D");
else if (score >= 70)
  System.out.println("C");
else if (score >= 80)
  System.out.println("B");
else if (score >= 90)
  System.out.println("A");
else
  System.out.println("F");
```

3.6 Common Errors and Pitfalls

Key Point

Forgetting necessary braces, ending an **if** *statement in the wrong place, mistaking* **==** *for* **=**, *and dangling* **else** *clauses are common errors in selection statements. Duplicated statements in* **if-else** *statements and testing equality of double values are common pitfalls.*

The following errors are common among new programmers.

Common Error 1: Forgetting Necessary Braces

The braces can be omitted if the block contains a single statement. However, forgetting the braces when they are needed for grouping multiple statements is a common programming error. If you modify the code by adding new statements in an if statement without braces, you will have to insert the braces. For example, the following code in (a) is wrong. It should be written with braces to group multiple statements, as shown in (b).

```
if (radius >= 0)
  area = radius * radius * PI;
  System.out.println("The area "
    + " is " + area);
```

(a) Wrong

```
if (radius >= 0) {
  area = radius * radius * PI;
  System.out.println("The area "
    + " is " + area);
}
```

(b) Correct

In (a), the console output statement is not part of the `if` statement. It is the same as the following code:

```
if (radius >= 0)
  area = radius * radius * PI;

System.out.println(“The area "
  + “ is " + area);
```

Regardless of the condition in the `if` statement, the console output statement is always executed.

Common Error 2: Wrong Semicolon at the `if` Line

Adding a semicolon at the end of an `if` line, as shown in (a) below, is a common mistake.

Logic error

```
if (radius >= 0);
{
  area = radius * radius * PI;
  System.out.println("The area "
    + " is " + area);
}
```

(a)

Equivalent

Empty block

```
if (radius >= 0) { };
{
  area = radius * radius * PI;
  System.out.println("The area "
    + " is " + area);
}
```

(b)

This mistake is hard to find, because it is neither a compile error nor a runtime error; it is a logic error. The code in (a) is equivalent to that in (b) with an empty block.

This error often occurs when you use the next-line block style. Using the end-of-line block style can help prevent this error.

Common Error 3: Redundant Testing of Boolean Values

To test whether a `boolean` variable is `true` or `false` in a test condition, it is redundant to use the equality testing operator like the code in (a):

```
if (even == true)
  System.out.println(
    "It is even.");
```

(a)

Equivalent

This is better

```
if (even)
  System.out.println(
    "It is even.");
```

(b)

Instead, it is better to test the `boolean` variable directly, as shown in (b). Another good reason for doing this is to avoid errors that are difficult to detect. Using the `=` operator instead of the `==` operator to compare the equality of two items in a test condition is a common error. It could lead to the following erroneous statement:

```
if (even = true)
  System.out.println("It is even.");
```

This statement does not have compile errors. It assigns `true` to `even`, so `even` is always `true`.

Common Error 4: Dangling `else` Ambiguity

dangling else ambiguity

The code in (a) below has two `if` clauses and one `else` clause. Which `if` clause is matched by the `else` clause? The indentation indicates that the `else` clause matches the first `if` clause. However, the `else` clause actually matches the second `if` clause. This situation is known as the *dangling else ambiguity*. The `else` clause always matches the most recent unmatched `if` clause in the same block. Therefore, the statement in (a) is equivalent to the code in (b).

```
int i = 1, j = 2, k = 3;

if (i > j)
  if (i > k)
     System.out.println("A");
else
     System.out.println("B");
```

(a)

Equivalent

This is better with correct indentation

```
int i = 1, j = 2, k = 3;

if (i > j)
  if (i > k)
    System.out.println("A");
  else
    System.out.println("B");
```

(b)

Since `(i > j)` is false, nothing is displayed from the statements in (a) and (b). To force the `else` clause to match the first `if` clause, you must add a pair of braces:

```
int i = 1, j = 2, k = 3;

if (i > j) {
  if (i > k)
    System.out.println("A");
}
else
  System.out.println("B");
```

This statement displays `B`.

Common Error 5: Equality Test of Two Floating-Point Values

As discussed in Common Error 3 in Section 2.19, floating-point numbers have a limited precision and calculations; involving floating-point numbers can introduce round-off errors. Therefore, equality test of two floating-point values is not reliable. For example, you expect the following code to display `true`, but surprisingly, it displays `false`:

```
double x = 1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1;
System.out.println(x == 0.5);
```

Here, `x` is not exactly `0.5`, but is `0.5000000000000001`. You cannot reliably test equality of two floating-point values. However, you can compare whether they are close enough by testing whether the difference of the two numbers is less than some threshold. That is, two numbers x and y are very close if $|x - y| < \varepsilon$, for a very small value, ε. ε, a Greek letter pronounced "epsilon", is commonly used to denote a very small value. Normally, you set ε to 10^{-14} for comparing two values of the `double` type, and to 10^{-7} for comparing two values of the `float` type. For example, the following code

```
final double EPSILON = 1E-14;
double x = 1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1;
if (Math.abs(x - 0.5) < EPSILON)
  System.out.println(x + " is approximately 0.5");
```

will display

```
0.5000000000000001 is approximately 0.5.
```

The `Math.abs(a)` method can be used to return the absolute value of `a`.

Common Pitfall 1: Simplifying Boolean Variable Assignment

Often, new programmers write the code that assigns a test condition to a `boolean` variable like the code in (a):

```
if (number % 2 == 0)
  even = true;
else
  even = false;
```

(a)

Equivalent

This is better

```
boolean even
  = number % 2 == 0;
```

(b)

This is not an error, but it should be better written as shown in (b).

Common Pitfall 2: Avoiding Duplicate Code in Different Cases

Often, new programmers write the duplicate code in different cases that should be combined in one place. For example, the highlighted code in the following statement is duplicated:

```
if (inState) {
  tuition = 5000;
  System.out.println("The tuition is " + tuition);
}
else {
  tuition = 15000;
  System.out.println("The tuition is " + tuition);
}
```

This is not an error, but it should be better written as follows:

```
if (inState) {
  tuition = 5000;
}
else {
  tuition = 15000;
}
System.out.println("The tuition is " + tuition);
```

The new code removes the duplication and makes the code easy to maintain, because you only need to change in one place if the print statement is modified.

Check Point

3.6.1 Which of the following statements are equivalent? Which ones are correctly indented?

```
if (i > 0) if
(j > 0)
x = 0; else
if (k > 0) y = 0;
else z = 0;
```

(a)

```
if (i > 0) {
  if (j > 0)
    x = 0;
  else if (k > 0)
    y = 0;
}
else
  z = 0;
```

(b)

```
if (i > 0)
  if (j > 0)
    x = 0;
   else if (k > 0)
    y = 0;
   else
    z = 0;
```

(c)

```
if (i > 0)
  if (j > 0)
    x = 0;
  else if (k > 0)
    y = 0;
else
  z = 0;
```

(d)

3.6.2 Rewrite the following statement using a Boolean expression:

```
if (count % 10 == 0)
  newLine = true;
else
  newLine = false;
```

3.6.3 Are the following statements correct? Which one is better?

```
if (age < 16)
  System.out.println
    ("Cannot get a driver's license");
if (age >= 16)
  System.out.println
    ("Can get a driver's license");
```

(a)

```
if (age < 16)
  System.out.println
    ("Cannot get a driver's license");
else
  System.out.println
    ("Can get a driver's license");
```

(b)

3.6.4 What is the output of the following code if `number` is `14`, `15`, or `30`?

```
if (number % 2 == 0)
  System.out.println
    (number +  " is even");
if (number % 5 == 0)
  System.out.println
    (number +  " is multiple of 5");
```

(a)

```
if (number % 2 == 0)
  System.out.println
    (number +  " is even");
else if (number % 5 == 0)
  System.out.println
    (number +  " is multiple of 5");
```

(b)

3.7 Generating Random Numbers

Key Point

You can use `Math.random()` to obtain a random double value between `0.0` and `1.0`, excluding `1.0`.

VideoNote

Program subtraction quiz

Suppose you want to develop a program for a first-grader to practice subtraction. The program randomly generates two single-digit integers, `number1` and `number2`, with `number1 >= number2`, and it displays to the student a question such as "What is 9 − 2?" After the student enters the answer, the program displays a message indicating whether it is correct.

The previous programs generate random numbers using `System.currentTimeMillis()`. A better approach is to use the `random()` method in the `Math` class. Invoking this method returns a random double value `d` such that $0.0 \leq d < 1.0$. Thus, `(int)(Math.random() * 10)` returns a random single-digit integer (i.e., a number between `0` and `9`).

`random()` method

The program can work as follows:

1. Generate two single-digit integers into `number1` and `number2`.
2. If `number1 < number2`, swap `number1` with `number2`.
3. Prompt the student to answer, `"What is number1 – number2?"`
4. Check the student's answer and display whether the answer is correct.

The complete program is given in Listing 3.3.

Listing 3.3 SubtractionQuiz.java

```
import java.util.Scanner;

public class SubtractionQuiz {
  public static void main(String[] args) {
    // 1. Generate two random single-digit integers
    int number1 = (int)(Math.random() * 10);
    int number2 = (int)(Math.random() * 10);

    // 2. If number1 < number2, swap number1 with number2
    if (number1 < number2) {
      int temp = number1;
```

random number

get answer

check the answer

```
12        number1 = number2;
13        number2 = temp;
14      }
15
16      // 3. Prompt the student to answer "What is number1 – number2?"
17      System.out.print
18        ("What is " + number1 + " - " + number2 + "? ");
19      Scanner input = new Scanner(System.in);
20      int answer = input.nextInt();
21
22      // 4. Grade the answer and display the result
23      if (number1 - number2 == answer)
24        System.out.println("You are correct!");
25      else {
26        System.out.println("Your answer is wrong.");
27        System.out.println(number1 + " - " + number2 +
28          " should be " + (number1 - number2));
29      }
30    }
31  }
```

```
What is 6 - 6? 0 ↵Enter
You are correct!
```

```
What is 9 - 2? 5 ↵Enter
Your answer is wrong
9 - 2 is 7
```

line#	number1	number2	temp	answer	output
6	2				
7		9			
11			2		
12	9				
13		2			
20				5	
26					Your answer is wrong 9 - 2 should be 7

To swap two variables **number1** and **number2**, a temporary variable temp (line 11) is used to first hold the value in **number1**. The value in **number2** is assigned to **number1** (line 12), and the value in **temp** is assigned to **number2** (line 13).

Check Point

3.7.1 Which of the following is a possible output from invoking `Math.random()`?

`323.4`, `0.5`, `34`, `1.0`, `0.0`, `0.234`

3.7.2 a. How do you generate a random integer `i` such that $0 \leq i < 20$?

b. How do you generate a random integer `i` such that $10 \leq i < 20$?

c. How do you generate a random integer `i` such that $10 \leq i \leq 50$?

d. Write an expression that returns `0` or `1` randomly.

3.8 Case Study: Computing Body Mass Index

You can use nested `if` *statements to write a program that interprets body mass index.*

Key Point

Body mass index (BMI) is a measure of health based on height and weight. It can be calculated by taking your weight in kilograms and dividing it by the square of your height in meters. The interpretation of BMI for people 20 years or older is as follows:

BMI	Interpretation
$\text{BMI} < 18.5$	Underweight
$18.5 \leq \text{BMI} < 25.0$	Normal
$25.0 \leq \text{BMI} < 30.0$	Overweight
$30.0 \leq \text{BMI}$	Obese

Write a program that prompts the user to enter a weight in pounds and height in inches and displays the BMI. Note that one pound is `0.45359237` kilograms, and one inch is `0.0254` meters. Listing 3.4 gives the program.

LISTING 3.4 `ComputeAndInterpretBMI.java`

```java
import java.util.Scanner;

public class ComputeAndInterpretBMI {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter weight in pounds
    System.out.print("Enter weight in pounds: ");
    double weight = input.nextDouble();

    // Prompt the user to enter height in inches
    System.out.print("Enter height in inches: ");
    double height = input.nextDouble();

    final double KILOGRAMS_PER_POUND = 0.45359237; // Constant
    final double METERS_PER_INCH = 0.0254; // Constant

    // Compute BMI
    double weightInKilograms = weight * KILOGRAMS_PER_POUND;
    double heightInMeters = height * METERS_PER_INCH;
    double bmi = weightInKilograms /
      (heightInMeters * heightInMeters);

    // Display result
    System.out.println("BMI is " + bmi);
    if (bmi < 18.5)
      System.out.println("Underweight");
    else if (bmi < 25)
      System.out.println("Normal");
    else if (bmi < 30)
      System.out.println("Overweight");
    else
      System.out.println("Obese");
  }
}
```

input weight

input height

compute bmi

display output

```
Enter weight in pounds: 146 ↵Enter
Enter height in inches: 70 ↵Enter
BMI is 20.948603801493316
Normal
```

```
line# weight  height  weightInKilograms   heightInMeters  bmi       output
  9   146
 13           70
 19                   66.22448602
 20                                       1.778
 21                                                        20.9486
 25                                                                  BMI is
                                                                     20.95
 29                                                                  Normal
```

The constants **KILOGRAMS_PER_POUND** and **METERS_PER_INCH** are defined in lines 15–16. Using constants here makes programs easy to read.

You should test the input that covers all possible cases for BMI to ensure that the program works for all cases.

3.9 Case Study: Computing Taxes

Key Point

You can use nested `if` *statements to write a program for computing taxes.*

VideoNote
Use multi-way `if-else` statements

The U.S. federal personal income tax is calculated based on filing status and taxable income. There are four filing statuses: single filers, married filing jointly or qualified widow(er), married filing separately, and head of household. The tax rates vary every year. Table 3.2 shows the rates for 2009. If you are single with a taxable income of $10,000, for example, the first $8,350 is taxed at 10% and the other $1,650 is taxed at 15%, so your total tax is $1,082.50.

TABLE 3.2 2009 U.S. Federal Personal Tax Rates

Marginal Tax Rate	*Single*	*Married Filing Jointly or Qualifying Widow(er)*	*Married Filing Separately*	*Head of Household*
10%	$0–$8,350	$0–$16,700	$0–$8,350	$0–$11,950
15%	$8,351–$33,950	$16,701–$67,900	$8,351–$33,950	$11,951–$45,500
25%	$33,951–$82,250	$67,901–$137,050	$33,951–$68,525	$45,501–$117,450
28%	$82,251–$171,550	$137,051–$208,850	$68,526–$104,425	$117,451–$190,200
33%	$171,551–$372,950	$208,851–$372,950	$104,426–$186,475	$190,201–$372,950
35%	$372,951+	$372,951+	$186,476+	$372,951+

You are to write a program to compute personal income tax. Your program should prompt the user to enter the filing status and taxable income and compute the tax. Enter **0** for single filers, **1** for married filing jointly or qualified widow(er), **2** for married filing separately, and **3** for head of household.

Your program computes the tax for the taxable income based on the filing status. The filing status can be determined using `if` statements outlined as follows:

```
if (status == 0) {
  // Compute tax for single filers
}
else if (status == 1) {
  // Compute tax for married filing jointly or qualifying widow(er)
}
else if (status == 2) {
  // Compute tax for married filing separately
}
else if (status == 3) {
  // Compute tax for head of household
}
else  {
  // Display wrong status
}
```

For each filing status there are six tax rates. Each rate is applied to a certain amount of taxable income. For example, of a taxable income of $400,000 for single filers, $8,350 is taxed at 10%, (33,950 − 8,350) at 15%, (82,250 − 33,950) at 25%, (171,550 − 82,250) at 28%, (372,950 − 171,550) at 33%, and (400,000 − 372,950) at 35%.

Listing 3.5 gives the solution for computing taxes for single filers. The complete solution is left as an exercise.

LISTING 3.5 ComputeTax.java

```
import java.util.Scanner;

public class ComputeTax {
  public static void main(String[] args) {
    // Create a Scanner
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter filing status
    System.out.print("(0-single filer, 1-married jointly or " +
      "qualifying widow(er), 2-married separately, 3-head of " +
      "household) Enter the filing status: ");

    int status = input.nextInt();

    // Prompt the user to enter taxable income
    System.out.print("Enter the taxable income: ");
    double income = input.nextDouble();

    // Compute tax
    double tax = 0;

    if (status == 0) { // Compute tax for single filers
      if (income <= 8350)
        tax = income * 0.10;
      else if (income <= 33950)
        tax = 8350 * 0.10 + (income - 8350) * 0.15;
      else if (income <= 82250)
        tax = 8350 * 0.10 + (33950 - 8350) * 0.15 +
          (income - 33950) * 0.25;
      else if (income <= 171550)
        tax = 8350 * 0.10 + (33950 - 8350) * 0.15 +
          (82250 - 33950) * 0.25 + (income - 82250) * 0.28;
```

input status

input income

compute tax

```
33        else if (income <= 372950)
34          tax = 8350 * 0.10 + (33950 - 8350) * 0.15 +
35            (82250 - 33950) * 0.25 + (171550 - 82250) * 0.28 +
36            (income - 171550) * 0.33;
37        else
38          tax = 8350 * 0.10 + (33950 - 8350) * 0.15 +
39            (82250 - 33950) * 0.25 + (171550 - 82250) * 0.28 +
40            (372950 - 171550) * 0.33 + (income - 372950) * 0.35;
41      }
42      else if (status == 1) { // Left as an exercise
43        // Compute tax for married file jointly or qualifying widow(er)
44      }
45      else if (status == 2) { // Compute tax for married separately
46        // Left as an exercise in Programming Exercise 3.13
47      }
48      else if (status == 3) { // Compute tax for head of household
49        // Left as an exercise in Programming Exercise 3.13
50      }
51      else {
52        System.out.println("Error: invalid status");
53        System.exit(1);
54      }
55
56      // Display the result
57      System.out.println("Tax is " + (int)(tax * 100) / 100.0);
58    }
59  }
```

exit program

display output

```
(0-single filer, 1-married jointly or qualifying widow(er),
2-married separately, 3-head of household)
Enter the filing status: 0 ↵Enter
Enter the taxable income: 400000 ↵Enter
Tax is 117683.5
```

line#	status	income	Tax	output
13	0			
17		400000		
20			0	
38			117683.5	
57				Tax is 117683.5

The program receives the filing status and taxable income. The multi-way `if-else` statements (lines 22, 42, 45, 48, and 51) check the filing status and compute the tax based on the filing status.

`System.exit(status)`

`System.exit(status)` (line 53) is defined in the `System` class. Invoking this method terminates the program. The status `0` indicates that the program is terminated normally. A nonzero status code indicates abnormal termination.

An initial value of `0` is assigned to `tax` (line 20). A compile error would occur if it had no initial value, because all of the other statements that assign values to `tax` are within the `if` statement. The compiler thinks these statements may not be executed, and therefore reports a compile error.

To test a program, you should provide the input that covers all cases. For this program, your input should cover all statuses (0, 1, 2, 3). For each status, test the tax for each of the six brackets. Thus, there are a total of 24 cases.

test all cases

Tip

For all programs, you should write a small amount of code and test it before moving on to add more code. This is called *incremental development and testing*. This approach makes testing easier, because the errors are likely in the new code you just added.

incremental development and testing

Check Point

3.9.1 Are the following two statements equivalent?

```
if (income <= 10000)
  tax = income * 0.1;
else if (income <= 20000)
  tax = 1000 +
    (income - 10000) * 0.15;
```

```
if (income <= 10000)
  tax = income * 0.1;
else if (income > 10000 &&
          income <= 20000)
  tax = 1000 +
    (income - 10000) * 0.15;
```

3.10 Logical Operators

The logical operators **!**, **&&**, **||**, *and* **^** *can be used to create a compound Boolean expression.*

Key Point

Sometimes, whether a statement is executed is determined by a combination of several conditions. You can use logical operators to combine these conditions to form a compound Boolean expression. *Logical operators*, also known as *Boolean operators*, operate on Boolean values to create a new Boolean value. Table 3.3 lists the Boolean operators. Table 3.4 defines the not (!) operator, which negates true to false and false to true. Table 3.5 defines the and (&&) operator. The and (&&) of two Boolean operands is true if and only if both the operands are true. Table 3.6 defines the or (||) operator. The or (||) of two Boolean operands is true if at least one of the operands is true. Table 3.7 defines the exclusive or (^) operator. The exclusive or (^) of two Boolean operands is true if and only if the two operands have different Boolean values. Note p1 ^ p2 is the same as p1 != p2.

TABLE 3.3 Boolean Operators

Operator	*Name*	*Description*
!	not	Logical negation
&&	and	Logical conjunction
||	or	Logical disjunction
^	exclusive or	Logical exclusion

TABLE 3.4 Truth Table for Operator !

p	!p	*Example (assume* age = 24, weight = 140*)*
true	false	!(age > 18) is false, because (age > 18) is true.
false	true	!(weight == 150) is true, because (weight == 150) is false.

TABLE 3.5 Truth Table for Operator &&

p_1	p_2	p_1 && p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	
`false`	`true`	`false`	`(age > 28) && (weight <= 140)` is `false`, because `(age > 28)` is `false`.
`true`	`false`	`false`	
`true`	`true`	`true`	`(age > 18) && (weight >= 140)` is `true`, because `(age > 18)` and `(weight >= 140)` are both `true`.

TABLE 3.6 Truth Table for Operator ||

p_1	p_2	p_1 || p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	`(age > 34) || (weight >= 150)` is `false`, because `(age > 34)` and `(weight >= 150)` are both `false`.
`false`	`true`	`true`	
`true`	`false`	`true`	`(age > 18) || (weight < 140)` is `true`, because `(age > 18)` is `true`.
`true`	`true`	`true`	

TABLE 3.7 Truth Table for Operator ^

p_1	p_2	p_1 ^ p_2	*Example (assume* `age = 24, weight = 140`*)*
`false`	`false`	`false`	`(age > 34) ^ (weight > 140)` is `false`, because `(age > 34)` and `(weight > 140)` are both `false`.
`false`	`true`	`true`	`(age > 34) ^ (weight >= 140)` is `true`, because `(age > 34)` is `false` but `(weight >= 140)` is `true`.
`true`	`false`	`true`	
`true`	`true`	`false`	

Listing 3.6 gives a program that checks whether a number is divisible by 2 and 3, by 2 or 3, and by 2 or 3 but not both.

LISTING 3.6 TestBooleanOperators.java

import class

input

and

```
import java.util.Scanner;

public class TestBooleanOperators {
  public static void main(String[] args) {
    // Create a Scanner
    Scanner input = new Scanner(System.in);

    // Receive an input
    System.out.print("Enter an integer: ");
    int number = input.nextInt();

    if (number % 2 == 0 && number % 3 == 0)
      System.out.println(number + " is divisible by 2 and 3.");

15      if (number % 2 == 0 || number % 3 == 0)
16        System.out.println(number + " is divisible by 2 or 3.");
17
18      if (number % 2 == 0 ^ number % 3 == 0)
19        System.out.println(number +
20          " is divisible by 2 or 3, but not both.");
21    }
22  }
```

or

exclusive or

```
Enter an integer: 4 ↵Enter
4 is divisible by 2 or 3.
4 is divisible by 2 or 3, but not both.
```

```
Enter an integer: 18 ↵Enter
18 is divisible by 2 and 3.
18 is divisible by 2 or 3.
```

(number % 2 == 0 && number % 3 == 0) (line 12) checks whether the number is divisible by both **2** and **3**. **(number % 2 == 0 || number % 3 == 0)** (line 15) checks whether the number is divisible by **2** or by **3**. **(number % 2 == 0 ^ number % 3 == 0)** (line 18) checks whether the number is divisible by **2** or **3**, but not both.

Caution

In mathematics, the expression

```
28 <= numberOfDaysInAMonth <= 31
```

is correct. However, it is incorrect in Java, because **28 <= numberOfDaysInAMonth** is evaluated to a **boolean** value, which cannot be compared with **31**. Here, two operands (a **boolean** value and a numeric value) are *incompatible*. The correct expression in Java is

incompatible operands

```
28 <= numberOfDaysInAMonth && numberOfDaysInAMonth <= 31
```

Note

De Morgan's law, named after Indian-born British mathematician and logician Augustus De Morgan (1806–1871), can be used to simplify Boolean expressions. The law states the following:

De Morgan's law

`!(condition1 && condition2)` is the same as
  `!condition1 || !condition2`
`!(condition1 || condition2)` is the same as
  `!condition1 && !condition2`

For example,

```
!(number % 2 == 0 && number % 3 == 0)
```

can be simplified using an equivalent expression:

```
number % 2 != 0 || number % 3 != 0
```

As another example,

```
!(number == 2 || number == 3)
```

is better written as

```
number != 2 && number != 3
```

If one of the operands of an `&&` operator is `false`, the expression is `false`; if one of the operands of an `||` operator is `true`, the expression is `true`. Java uses these properties to improve the performance of these operators. When evaluating `p1 && p2`, Java first evaluates `p1` then, if `p1` is `true`, evaluates `p2`; if `p1` is `false`, it does not evaluate `p2`. When evaluating `p1 || p2`, Java first evaluates `p1` then, if `p1` is `false`, evaluates `p2`; if `p1` is `true`, it does not evaluate `p2`. In programming language terminology, `&&` and `||` are known as the *short-circuit* or *lazy operators*. Java also provides the `&` and `|` operators, which are covered in Supplement III.C for advanced readers.

short-circuit operator
lazy operator

Check Point

3.10.1 Assuming that `x` is `1`, show the result of the following Boolean expressions:

```
(true) && (3 > 4)
!(x > 0) && (x > 0)
(x > 0) || (x < 0)
(x != 0) || (x == 0)
(x >= 0) || (x < 0)
(x != 1) == !(x == 1)
```

3.10.2 (a) Write a Boolean expression that evaluates to `true` if a number stored in variable `num` is between `1` and `100`. (b) Write a Boolean expression that evaluates to `true` if a number stored in variable `num` is between `1` and `100` or the number is negative.

3.10.3 (a) Write a Boolean expression for $|x - 5| < 4.5$. (b) Write a Boolean expression for $|x - 5| > 4.5$.

3.10.4 Assume `x` and `y` are `int` type. Which of the following are legal Java expressions?

```
x > y > 0
x = y && y
x /= y
x or y
x and y
(x != 0) || (x = 0)
```

3.10.5 Are the following two expressions the same?

(a) `x % 2 == 0 && x % 3 == 0`

(b) `x % 6 == 0`

3.10.6 What is the value of the expression `x >= 50 && x <= 100` if `x` is `45`, `67`, or `101`?

3.10.7 Suppose, when you run the following program, you enter the input `2 3 6` from the console. What is the output?

```java
public class Test {
  public static void main(String[] args) {
    java.util.Scanner input = new java.util.Scanner(System.in);
    double x = input.nextDouble();
    double y = input.nextDouble();
    double z = input.nextDouble();

    System.out.println("(x < y && y < z) is " + (x < y && y < z));
    System.out.println("(x < y || y < z) is " + (x < y || y < z));
    System.out.println("!(x < y) is " + !(x < y));
    System.out.println("(x + y < z) is " + (x + y < z));
    System.out.println("(x + y > z) is " + (x + y > z));
  }
}
```

3.10.8 Write a Boolean expression that evaluates to `true` if `age` is greater than `13` and less than `18`.

3.10.9 Write a Boolean expression that evaluates to `true` if `weight` is greater than `50` pounds or height is greater than `60` inches.

3.10.10 Write a Boolean expression that evaluates to `true` if `weight` is greater than `50` pounds and height is greater than `60` inches.

3.10.11 Write a Boolean expression that evaluates to `true` if either `weight` is greater than `50` pounds or height is greater than `60` inches, but not both.

3.11 Case Study: Determining Leap Year

Key Point

A year is a leap year if it is divisible by **4** *but not by* **100***, or if it is divisible by* **400***.*

A leap year has 366 days. The February of a leap year has 29 days. You can use the following Boolean expressions to check whether a year is a leap year:

```
// A leap year is divisible by 4
boolean isLeapYear = (year % 4 == 0);

// A leap year is divisible by 4 but not by 100
isLeapYear = isLeapYear && (year % 100 != 0);

// A leap year is divisible by 4 but not by 100 or divisible by 400
isLeapYear = isLeapYear || (year % 400 == 0);
```

Or you can combine all these expressions into one as follows:

```
isLeapYear = (year % 4 == 0 && year % 100 != 0) || (year % 400 == 0);
```

Listing 3.7 gives the program that lets the user enter a year and checks whether it is a leap year.

LISTING 3.7 LeapYear.java

```
import java.util.Scanner;

public class LeapYear {
  public static void main(String[] args) {
    // Create a Scanner
    Scanner input = new Scanner(System.in);
    System.out.print("Enter a year: ");
    int year = input.nextInt();                                      input

    // Check if the year is a leap year
    boolean isLeapYear =                                             leap year?
      (year % 4 == 0 && year % 100 != 0) || (year % 400 == 0);

    // Display the result
    System.out.println(year + " is a leap year? " + isLeapYear);    display result
  }
}
```

```
Enter a year: 2008 ↵Enter
2008 is a leap year? true
```

```
Enter a year: 1900 ↵Enter
1900 is a leap year? false
```

```
Enter a year: 2002 ↵Enter
2002 is a leap year? false
```

Check Point

3.11.1 How many days in the February of a leap year? Which of the following is a leap year? 500, 1000, 2000, 2016, and 2020?

3.12 Case Study: Lottery

Key Point

The lottery program involves generating random numbers, comparing digits, and using Boolean operators.

Suppose you want to develop a program to play lottery. The program randomly generates a lottery of a two-digit number, prompts the user to enter a two-digit number, and determines whether the user wins according to the following rules:

1. If the user input matches the lottery number in the exact order, the award is $10,000.
2. If all digits in the user input match all digits in the lottery number, the award is $3,000.
3. If one digit in the user input matches a digit in the lottery number, the award is $1,000.

Note the digits of a two-digit number may be **0**. If a number is less than **10**, we assume that the number is preceded by a **0** to form a two-digit number. For example, number **8** is treated as **08**, and number **0** is treated as **00** in the program. Listing 3.8 gives the complete program.

LISTING 3.8 Lottery.java

generate a lottery number

enter a guess

exact match?

match all digits?

match one digit?

```
import java.util.Scanner;

public class Lottery {
  public static void main(String[] args) {
    // Generate a lottery number
    int lottery = (int)(Math.random() * 100);

    // Prompt the user to enter a guess
    Scanner input = new Scanner(System.in);
    System.out.print("Enter your lottery pick (two digits): ");
    int guess = input.nextInt();

    // Get digits from lottery
    int lotteryDigit1 = lottery / 10;
    int lotteryDigit2 = lottery % 10;

    // Get digits from guess
    int guessDigit1 = guess / 10;
    int guessDigit2 = guess % 10;

    System.out.println("The lottery number is " + lottery);

    // Check the guess
    if (guess == lottery)
      System.out.println("Exact match: you win $10,000");
    else if (guessDigit2 == lotteryDigit1
            && guessDigit1 == lotteryDigit2)
      System.out.println("Match all digits: you win $3,000");
    else if (guessDigit1 == lotteryDigit1
           || guessDigit1 == lotteryDigit2
           || guessDigit2 == lotteryDigit1
           || guessDigit2 == lotteryDigit2)
33          System.out.println("Match one digit: you win $1,000");
34        else
35          System.out.println("Sorry, no match");
36      }
37    }
```

```
Enter your lottery pick (two digits): 15 ↵Enter
The lottery number is 15
Exact match: you win $10,000
```

```
Enter your lottery pick (two digits): 45 ↵Enter
The lottery number is 54
Match all digits: you win $3,000
```

```
Enter your lottery pick: 23 ↵Enter
The lottery number is 34
Match one digit: you win $1,000
```

```
Enter your lottery pick: 23 ↵Enter
The lottery number is 14
Sorry: no match
```

line# / variable	6	11	14	15	18	19	33
`lottery`	34						
`guess`		23					
`lotteryDigit1`			3				
`lotteryDigit2`				4			
`guessDigit1`					2		
`guessDigit2`						3	
`Output`							`Match one digit: you win $1,000`

The program generates a lottery using the `random()` method (line 6) and prompts the user to enter a guess (line 11). Note `guess % 10` obtains the last digit from `guess` and `guess /10` obtains the first digit from `guess`, since `guess` is a two-digit number (lines 18 and 19).

The program checks the guess against the lottery number in this order:

1. First, check whether the guess matches the lottery exactly (line 24).
2. If not, check whether the reversal of the guess matches the lottery (lines 26 and 27).
3. If not, check whether one digit is in the lottery (lines 29–32).
4. If not, nothing matches and display `"Sorry, no match"` (lines 34 and 35).

Check Point

3.12.1 What happens if you enter an integer as `05`?

3.13 switch Statements

Key Point

*A **switch** statement executes statements based on the value of a variable or an expression.*

The **if** statement in Listing 3.5, ComputeTax.java, makes selections based on a single **true** or **false** condition. There are four cases for computing taxes, which depend on the value of **status**. To fully account for all the cases, nested **if** statements were used. Overuse of nested **if** statements makes a program difficult to read. Java provides a **switch** statement to simplify coding for multiple conditions. You can write the following **switch** statement to replace the nested **if** statement in Listing 3.5:

```
switch (status) {
  case 0:  compute tax for single filers;
           break;
  case 1:  compute tax for married jointly or qualifying widow(er);
           break;
  case 2:  compute tax for married filing separately;
           break;
  case 3:  compute tax for head of household;
           break;
  default: System.out.println("Error: invalid status");
           System.exit(1);
}
```

The flowchart of the preceding **switch** statement is shown in Figure 3.5.

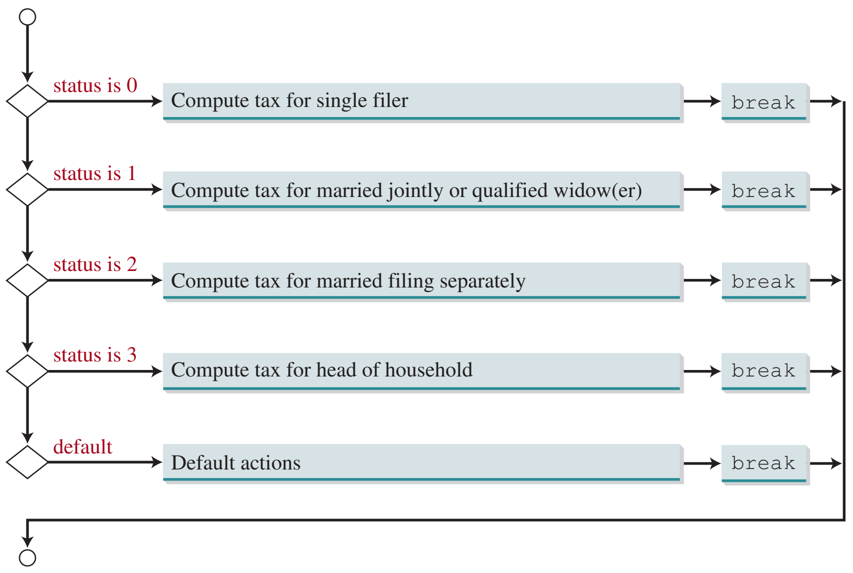

status is 0
Compute tax for single filer
break
status is 1
Compute tax for married jointly or qualified widow(er)
break
status is 2
Compute tax for married filing separately
break
status is 3
Compute tax for head of household
break
default
Default actions
break

FIGURE 3.5 The **switch** statement checks all cases and executes the statements in the matched case.

This statement checks to see whether the status matches the value **0**, **1**, **2**, or **3**, in that order. If matched, the corresponding tax is computed; if not matched, a message is displayed. Here is the full syntax for the **switch** statement:

switch statement

```
switch (switch-expression) {
  case value1: statement(s)1;
               break;
  case value2: statement(s)2;
               break;
  ...
  case valueN: statement(s)N;
               break;
  default:    statement(s)-for-default;
}
```

The switch statement observes the following rules:

- The switch-expression must yield a value of char, byte, short, int, or String type and must always be enclosed in parentheses. (The char and String types will be introduced in Chapter 4.)
- The value1, ..., and valueN must have the same data type as the value of the switch-expression. Note that value1, ..., and valueN are constant expressions, meaning they cannot contain variables, such as 1 + x.
- When the value in a case statement matches the value of the switch-expression, the statements *starting from this case* are executed until either a break statement or the end of the switch statement is reached.
- The default case, which is optional, can be used to perform actions when none of the specified cases matches the switch-expression.
- The keyword break is optional. The break statement immediately ends the switch statement.

Caution

without break

Do not forget to use a break statement when one is needed. Once a case is matched, the statements starting from the matched case are executed until a break statement or the end of the switch statement is reached. This is referred to as *fall-through behavior*. For example, the following code displays Weekday for days 1–5 and Weekend for day 0 and day 6.

fall-through behavior

```
switch (day) {
  case 1:
  case 2:
  case 3:
  case 4:
  case 5: System.out.println("Weekday"); break;
  case 0:
  case 6: System.out.println("Weekend");
}
```

Tip

To avoid programming errors and improve code maintainability, it is a good idea to put a comment in a case clause if break is purposely omitted.

Now let us write a program to find out the Chinese Zodiac sign for a given year. The Chinese Zodiac is based on a 12-year cycle, with each year represented by an animal—monkey, rooster, dog, pig, rat, ox, tiger, rabbit, dragon, snake, horse, or sheep—in this cycle, as shown in Figure 3.6.

Note year % 12 determines the Zodiac sign. 1900 is the year of the rat because 1900 % 12 is 4. Listing 3.9 gives a program that prompts the user to enter a year and displays the animal for the year.

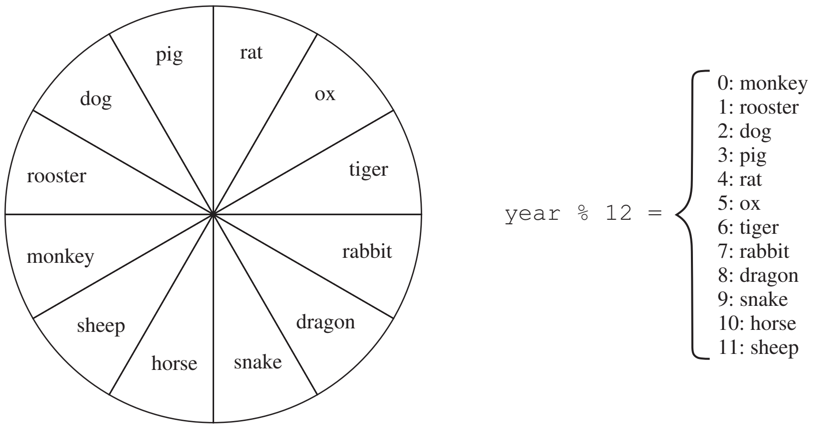


Figure 3.6 The Chinese Zodiac is based on a 12-year cycle.

Listing 3.9 ChineseZodiac.java

```java
import java.util.Scanner;

public class ChineseZodiac {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    System.out.print("Enter a year: ");
    int year = input.nextInt();                          // enter year

    switch (year % 12) {                                 // determine Zodiac sign
      case 0: System.out.println("monkey"); break;
      case 1: System.out.println("rooster"); break;
      case 2: System.out.println("dog"); break;
      case 3: System.out.println("pig"); break;
      case 4: System.out.println("rat"); break;
      case 5: System.out.println("ox"); break;
      case 6: System.out.println("tiger"); break;
      case 7: System.out.println("rabbit"); break;
      case 8: System.out.println("dragon"); break;
      case 9: System.out.println("snake"); break;
      case 10: System.out.println("horse"); break;
      case 11: System.out.println("sheep");
    }
  }
}
```

```
Enter a year: 1963 ↵Enter
rabbit
```

```
Enter a year: 1877 ↵Enter
ox
```

Check Point

3.13.1 What data types are required for a `switch` variable? If the keyword `break` is not used after a case is processed, what is the next statement to be executed? Can you convert a `switch` statement to an equivalent `if` statement, or vice versa? What are the advantages of using a `switch` statement?

3.13.2 What is `y` after the following `switch` statement is executed? Rewrite the code using an `if-else` statement.

```
x = 3; y = 3;
switch (x +  3) {
  case 6: y = 1;
  default: y += 1;
}
```

3.13.3 What is `x` after the following `if-else` statement is executed? Use a `switch` statement to rewrite it and draw the flowchart for the new `switch` statement.

```
int x = 1, a = 3;
if (a == 1)
  x += 5;
else if (a == 2)
  x += 10;
else if (a == 3)
  x += 16;
else if (a == 4)
  x += 34;
```

3.13.4 Write a `switch` statement that displays Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, if `day` is `0`, `1`, `2`, `3`, `4`, `5`, `6`, respectively.

3.13.5 Rewrite Listing 3.9 using an `if-else` statement.

3.14 Conditional Operators

A conditional operator evaluates an expression based on a condition.

Key Point

You might want to assign a value to a variable that is restricted by certain conditions. For example, the following statement assigns `1` to `y` if `x` is greater than `0` and `-1` to `y` if `x` is less than or equal to `0`:

```
if (x > 0)
  y = 1;
else
  y = -1;
```

Alternatively, as in the following example, you can use a *conditional operator* to achieve the same result.

conditional operator

```
y = (x > 0)? 1: -1;
```

The symbols `?` and `:` appearing together is called a conditional operator (also known as a *ternary operator* because it uses three operands. It is the only ternary operator in Java. The conditional operator is in a completely different style, with no explicit `if` in the statement. The syntax to use the operator is as follows:

ternary operator

```
boolean-expression? expression1: expression2
```

The result of this expression is `expression1` if `boolean-expression` is true; otherwise the result is `expression2`.

Suppose you want to assign the larger number of variable `num1` and `num2` to `max`. You can simply write a statement using the conditional operator:

```
max = (num1 > num2)? num1: num2;
```

For another example, the following statement displays the message "num is even" if `num` is even, and otherwise displays "num is odd."

```
System.out.println((num % 2 == 0)? "num is even": "num is odd");
```

As you can see from these examples, the conditional operator enables you to write short and concise code.

Conditional expressions can be embedded. For example, the following code assigns `1`, `0`, or `-1` to status if `n1 > n1`, `n1 == n2`, or `n1 < n2`:

```
status = n1 > n2? 1: (n1 == n2? 0: -1);
```

Check Point

3.14.1 Suppose when you run the following program, you enter the input `2 3 6` from the console. What is the output?

```
public class Test {
  public static void main(String[] args) {
    java.util.Scanner input = new java.util.Scanner(System.in);
    double x = input.nextDouble();
    double y = input.nextDouble();
    double z = input.nextDouble();

    System.out.println((x < y && y < z)? "sorted": "not sorted");
  }
}
```

3.14.2 Rewrite the following `if` statements using the conditional operator.

```
if (ages >= 16)
  ticketPrice = 20;
else
  ticketPrice = 10;
```

3.14.3 Rewrite the following codes using `if-else` statements.

a. `score = (x > 10)? 3 * scale: 4 * scale;`
b. `tax = (income > 10000)? income * 0.2: income * 0.17 + 1000;`
c. `System.out.println((number % 3 == 0)? i: j);`

3.14.4 Write an expression using a conditional operator that returns randomly `-1` or `1`.

3.15 Operator Precedence and Associativity

Key Point

Operator precedence and associativity determine the order in which operators are evaluated.

Section 2.11 introduced operator precedence involving arithmetic operators. This section discusses operator precedence in more detail. Suppose you have this expression:

```
3 + 4 * 4 > 5 * (4 + 3) – 1 && (4 – 3 > 5)
```

What is its value? What is the execution order of the operators?

The expression within parentheses is evaluated first. (Parentheses can be nested, in which case the expression within the inner parentheses is executed first.) When evaluating an expression without parentheses, the operators are applied according to the precedence rule and the associativity rule.

operator precedence

The precedence rule defines precedence for operators, as shown in Table 3.8, which contains the operators you have learned so far. Operators are listed in decreasing order of precedence from top to bottom. The logical operators have lower precedence than the relational operators, and the relational operators have lower precedence than the arithmetic operators. Operators with the same precedence appear in the same group. (See Appendix C, *Operator Precedence Chart*, for a complete list of Java operators and their precedence.)

TABLE 3.8 Operator Precedence Chart

Precedence	*Operator*
	`var++` and `var--` (Postfix)
	`+`, `-` (Unary plus and minus), `++var` and `--var` (Prefix)
	(type) (Casting)
	`!`(Not)
	`*`, `/`, `%` (Multiplication, division, and remainder)
	`+`, `-` (Binary addition and subtraction)
	`<`, `<=`, `>`, `>=` (Relational)
	`==`, `!=` (Equality)
	`^` (Exclusive OR)
	`&&` (AND)
	`||` (OR)
	`?:` (Ternary operator)
	`=`, `+=`, `-=`, `*=`, `/=`, `%=` (Assignment operators)

If operators with the same precedence are next to each other, their *associativity* determines the order of evaluation. All binary operators except assignment operators are *left associative*. For example, since `+` and `-` are of the same precedence and are left associative, the expression

operator associativity

`a - b + c - d` is equivalent to `((a - b) + c) - d`

Assignment operators are *right associative*. Therefore, the expression

`a = b += c = 5` is equivalent to `a = (b += (c = 5))`

Suppose `a`, `b`, and `c` are `1` before the assignment; after the whole expression is evaluated, `a` becomes `6`, `b` becomes `6`, and `c` becomes `5`. Note that left associativity for the assignment operator would not make sense.

Note

Java has its own way to evaluate an expression internally. The result of a Java evaluation is the same as that of its corresponding arithmetic evaluation. Advanced readers may refer to Supplement III.B for more discussions on how an expression is evaluated in Java *behind the scenes*.

behind the scenes

Check Point

3.15.1 List the precedence order of the Boolean operators. Evaluate the following expressions:

```
true || true && false
true && true || false
```

3.15.2 True or false? All the binary operators except `=` are left associative.

3.15.3 Evaluate the following expressions:

```
2 * 2 - 3 > 2 && 4 - 2 > 5
2 * 2 - 3 > 2 || 4 - 2 > 5
```

3.15.4 Is `(x > 0 && x < 10)` the same as `((x > 0) && (x < 10))`?

Is `(x > 0 || x < 10)` the same as `((x > 0) || (x < 10))`?

Is `(x > 0 || x < 10 && y < 0)` the same as `(x > 0 || (x < 10 && y < 0))`?

3.16 Debugging

Key Point

Debugging is the process of finding and fixing errors in a program.

As mentioned in Section 1.10, syntax errors are easy to find and easy to correct because the compiler gives indications as to where the errors came from and why they are there. Runtime errors are not difficult to find either, because the Java interpreter displays them on the console when the program aborts. Finding logic errors, on the other hand, can be very challenging.

bugs
hand-traces
debugging

Logic errors are called *bugs*. The process of finding and correcting errors is called *debugging*. A common approach to debugging is to use a combination of methods to help pinpoint the part of the program where the bug is located. You can *hand-trace* the program (i.e., catch errors by reading the program), or you can insert print statements in order to show the values of the variables or the execution flow of the program. These approaches might work for debugging a short, simple program, but for a large, complex program, the most effective approach is to use a debugger utility.

JDK includes a command-line debugger, jdb, which is invoked with a class name. jdb is itself a Java program, running its own copy of Java interpreter. All the Java IDE tools, such as Eclipse and NetBeans, include integrated debuggers. The debugger utilities let you follow the execution of a program. They vary from one system to another, but they all support most of the following helpful features.

- *Executing a single statement at a time:* The debugger allows you to execute one statement at a time so that you can see the effect of each statement.
- *Tracing into or stepping over a method:* If a method is being executed, you can ask the debugger to enter the method and execute one statement at a time in the method, or you can ask it to step over the entire method. You should step over the entire method if you know that the method works. For example, always step over system-supplied methods, such as `System.out.println`.
- **Setting breakpoints:** You can also set a breakpoint at a specific statement. Your program pauses when it reaches a breakpoint. You can set as many breakpoints as you want. Breakpoints are particularly useful when you know where your programming error starts. You can set a breakpoint at that statement, and have the program execute until it reaches the breakpoint.
- **Displaying variables:** The debugger lets you select several variables and display their values. As you trace through a program, the content of a variable is continuously updated.
- **Displaying call stacks:** The debugger lets you trace all of the method calls. This feature is helpful when you need to see a large picture of the program-execution flow.
- **Modifying variables:** Some debuggers enable you to modify the value of a variable when debugging. This is convenient when you want to test a program with different samples, but do not want to leave the debugger.

debugging in IDE

Tip

If you use an IDE such as Eclipse or NetBeans, please refer to *Learning Java Effectively with Eclipse/NetBeans* in Supplements II.C and II.E on the Companion Website. The supplement shows you how to use a debugger to trace programs, and how debugging can help in learning Java effectively.

Key Terms

boolean data type, 78
Boolean expression, 78
Boolean value, 78
conditional operator, 105
dangling else ambiguity, 87
debugging, 108
fall-through behavior, 103
flowchart, 80
lazy operator, 98
operator associativity, 107
operator precedence, 106
selection statement, 78
short-circuit operator, 98

Chapter Summary

1. A `boolean`-type variable can store a `true` or `false` value.

2. The relational operators (`<`, `<=`, `==`, `!=`, `>`, and `>=`) yield a Boolean value.

3. *Selection statements* are used for programming with alternative courses of actions. There are several types of selection statements: one-way `if` statements, two-way `if-else` statements, nested `if` statements, multi-way `if-else` statements, `switch` statements, and conditional operators.

4. The various `if` statements all make control decisions based on a *Boolean expression*. Based on the `true` or `false` evaluation of the expression, these statements take one of the two possible courses.

5. The Boolean operators `&&`, `||`, `!`, and `^` operate with Boolean values and variables.

6. When evaluating `p1 && p2`, Java first evaluates `p1` then evaluates `p2` if `p1` is `true`; if `p1` is `false`, it does not evaluate `p2`. When evaluating `p1 || p2`, Java first evaluates `p1` then evaluates `p2` if `p1` is `false`; if `p1` is `true`, it does not evaluate `p2`. Therefore, `&&` is referred to as the *short-circuit* or *lazy AND operator*, and `||` is referred to as the *short-circuit* or *lazy OR operator*.

7. The `switch` statement makes control decisions based on a switch expression of type `char`, `byte`, `short`, `int`, or `String`.

8. The keyword `break` is optional in a `switch` statement, but it is normally used at the end of each case in order to skip the remainder of the `switch` statement. If the `break` statement is not present, the next `case` statement will be executed.

9. The operators in expressions are evaluated in the order determined by the rules of parentheses, *operator precedence*, and *operator associativity*.

10. Parentheses can be used to force the order of evaluation to occur in any sequence.

11. Operators with higher precedence are evaluated earlier. For operators of the same precedence, their associativity determines the order of evaluation.

12. All binary operators except assignment operators are left associative; assignment operators are right associative.

Quiz

Answer the quiz for this chapter online at the Companion Website.

MyLab Programming™

Programming Exercises

think before coding

Pedagogical Note
For each exercise, carefully analyze the problem requirements and design strategies for solving the problem before coding.

learn from mistakes

Debugging Tip
Before you ask for help, read and explain the program to yourself, and trace it using several representative inputs by hand or using an IDE debugger. You learn how to program by debugging your own mistakes.

Section 3.2

***3.1** (*Algebra: solve quadratic equations*) The two roots of a quadratic equation $ax^2 + bx + c = 0$ can be obtained using the following formula:

$$r_1 = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad \text{and} \quad r_2 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

$b^2 - 4ac$ is called the discriminant of the quadratic equation. If it is positive, the equation has two real roots. If it is zero, the equation has one root. If it is negative, the equation has no real roots.

Write a program that prompts the user to enter values for a, b, and c and displays the result based on the discriminant. If the discriminant is positive, display two roots. If the discriminant is `0`, display one root. Otherwise, display "The equation has no real roots."

Note you can use `Math.pow(x, 0.5)` to compute $\sqrt{x}$. Here are some sample runs:

```
Enter a, b, c: 1.0 3 1 ↵Enter
The equation has two roots -0.381966 and -2.61803
```

```
Enter a, b, c: 1 2.0 1 ↵Enter
The equation has one root -1.0
```

```
Enter a, b, c: 1 2 3 ↵Enter
The equation has no real roots
```

3.2 (*Game: add three numbers*) The program in Listing 3.1, AdditionQuiz.java, generates two integers and prompts the user to enter the sum of these two integers. Revise the program to generate three single-digit integers and prompt the user to enter the sum of these three integers.

Sections 3.3–3.7

***3.3** (*Algebra: solve* 2 × 2 *linear equations*) A linear equation can be solved using Cramer's rule given in Programming Exercise 1.13. Write a program that prompts the user to enter *a*, *b*, *c*, *d*, *e*, and *f* and displays the result. If $ad - bc$ is **0**, report that "The equation has no solution."

```
Enter a, b, c, d, e, f: 9.0 4.0 3.0 -5.0 -6.0 -21.0 ↵Enter
x is -2.0 and y is 3.0
```

```
Enter a, b, c, d, e, f: 1.0 2.0 2.0 4.0 4.0 5.0 ↵Enter
The equation has no solution
```

****3.4** (*Random month*) Write a program that randomly generates an integer between 1 and 12 and displays the English month names January, February, . . . , December for the numbers 1, 2, . . . , 12, accordingly.

***3.5** (*Find future dates*) Write a program that prompts the user to enter an integer for today's day of the week (Sunday is 0, Monday is 1, . . . , and Saturday is 6). Also prompt the user to enter the number of days after today for a future day and display the future day of the week. Here is a sample run:

```
Enter today's day: 1 ↵Enter
Enter the number of days elapsed since today: 3 ↵Enter
Today is Monday and the future day is Thursday
```

```
Enter today's day: 0
Enter the number of days elapsed since today: 31 ↵Enter
Today is Sunday and the future day is Wednesday
```

***3.6** (*Health application: BMI*) Revise Listing 3.4, ComputeAndInterpretBMI.java, to let the user enter weight, feet, and inches. For example, if a person is 5 feet and 10 inches, you will enter **5** for feet and **10** for inches. Here is a sample run:

```
Enter weight in pounds: 140 ↵Enter
Enter feet: 5 ↵Enter
Enter inches: 10 ↵Enter
BMI is 20.087702275404553
Normal
```

3.7 (*Financial application: monetary units*) Modify Listing 2.10, ComputeChange.java, to display the nonzero denominations only, using singular words for single units such as 1 dollar and 1 penny, and plural words for more than one unit such as 2 dollars and 3 pennies.

VideoNote
Sort three integers

***3.8** (*Sort three integers*) Write a program that prompts the user to enter three integers and display the integers in non-decreasing order.

****3.9** (*Business: check ISBN-10*) An ISBN-10 (International Standard Book Number) consists of 10 digits: $d_1d_2d_3d_4d_5d_6d_7d_8d_9d_{10}$. The last digit, d_{10}, is a checksum, which is calculated from the other 9 digits using the following formula:

$$(d_1 \times 1 + d_2 \times 2 + d_3 \times 3 + d_4 \times 4 + d_5 \times 5 + \\ d_6 \times 6 + d_7 \times 7 + d_8 \times 8 + d_9 \times 9)\%11$$

If the checksum is **10**, the last digit is denoted as X according to the ISBN-10 convention. Write a program that prompts the user to enter the first 9 digits and displays the 10-digit ISBN (including leading zeros). Your program should read the input as an integer. Here are sample runs:

```
Enter the first 9 digits of an ISBN as integer: 013601267 ↵Enter
The ISBN-10 number is 0136012671
```

```
Enter the first 9 digits of an ISBN as integer: 013031997 ↵Enter
The ISBN-10 number is 013031997X
```

3.10 (*Game: addition quiz*) Listing 3.3, SubtractionQuiz.java, randomly generates a subtraction question. Revise the program to randomly generate an addition question with two integers less than 100.

Sections 3.8–3.16

***3.11** (*Find the number of days in a month*) Write a program that prompts the user to enter the month and year and displays the number of days in the month. For example, if the user entered month **2** and year **2012**, the program should display that February 2012 has 29 days. If the user entered month **3** and year **2015**, the program should display that March 2015 has 31 days.

3.12 (*Palindrome integer*) Write a program that prompts the user to enter a three-digit integer and determines whether it is a palindrome *integer*. An *integer* is palindrome if it reads the same from right to left and from left to right. A negative integer is treated the same as a positive integer. Here are sample runs of this program:

```
Enter a three-digit integer: 121 ↵Enter
121 is a palindrome
```

```
Enter a three-digit integer: 123 ↵Enter
123 is not a palindrome
```

***3.13** (*Financial application: compute taxes*) Listing 3.5, ComputeTax.java, gives the source code to compute taxes for single filers. Complete this program to compute taxes for all filing statuses.

3.14 (*Game: heads or tails*) Write a program that lets the user guess whether the flip of a coin results in heads or tails. The program randomly generates an integer **0** or **1**, which represents head or tail. The program prompts the user to enter a guess, and reports whether the guess is correct or incorrect.

****3.15** (*Game: lottery*) Revise Listing 3.8, Lottery.java, to generate a lottery of a three-digit integer. The program prompts the user to enter a three-digit integer and determines whether the user wins according to the following rules:

1. If the user input matches the lottery number in the exact order, the award is $10,000.
2. If all digits in the user input match all digits in the lottery number, the award is $3,000.
3. If one digit in the user input matches a digit in the lottery number, the award is $1,000.

3.16 (*Random point*) Write a program that displays a random coordinate in a rectangle. The rectangle is centered at (0, 0) with width 100 and height 200.

***3.17** (*Game: scissor, rock, paper*) Write a program that plays the popular scissor–rock–paper game. (A scissor can cut a paper, a rock can knock a scissor, and a paper can wrap a rock.) The program randomly generates a number `0`, `1`, or `2` representing scissor, rock, and paper. The program prompts the user to enter a number `0`, `1`, or `2` and displays a message indicating whether the user or the computer wins, loses, or draws. Here are sample runs:

```
scissor (0), rock (1), paper (2): 1 ↵Enter
The computer is scissor. You are rock. You won
```

```
scissor (0), rock (1), paper (2): 2 ↵Enter
The computer is paper. You are paper too. It is a draw
```

***3.18** (*Cost of shipping*) A shipping company uses the following function to calculate the cost (in dollars) of shipping based on the weight of the package (in pounds).

$$c(w) = \begin{cases} 3.5, \text{ if } 0 < w <= 1 \\ 5.5, \text{ if } 1 < w <= 3 \\ 8.5, \text{ if } 3 < w <= 10 \\ 10.5, \text{ if } 10 < w <= 20 \end{cases}$$

Write a program that prompts the user to enter the weight of the package and displays the shipping cost. If the weight is negative or zero, display a message "Invalid input." If the weight is greater than 20, display a message "The package cannot be shipped."

****3.19** (*Compute the perimeter of a triangle*) Write a program that reads three edges for a triangle and computes the perimeter if the input is valid. Otherwise, display that the input is invalid. The input is valid if the sum of every pair of two edges is greater than the remaining edge.

***3.20** (*Science: wind-chill temperature*) Programming Exercise 2.17 gives a formula to compute the wind-chill temperature. The formula is valid for temperatures in the range between −58°F and 41°F and wind speed greater than or equal to `2`. Write a program that prompts the user to enter a temperature and a wind speed. The program displays the wind-chill temperature if the input is valid; otherwise, it displays a message indicating whether the temperature and/or wind speed is invalid.

Comprehensive

****3.21** (*Science: day of the week*) Zeller's congruence is an algorithm developed by Christian Zeller to calculate the day of the week. The formula is

$$h = \left(q + \frac{26(m + 1)}{10} + k + \frac{k}{4} + \frac{j}{4} + 5j\right)\%7$$

where

- `h` is the day of the week (0: Saturday, 1: Sunday, 2: Monday, 3: Tuesday, 4: Wednesday, 5: Thursday, and 6: Friday).
- `q` is the day of the month.
- `m` is the month (3: March, 4: April, ..., 12: December). January and February are counted as months 13 and 14 of the previous year.
- `j` is $\frac{year}{100}$.
- `k` is the year of the century (i.e., *year* % 100).

Note all divisions in this exercise perform an integer division. Write a program that prompts the user to enter a year, month, and day of the month, and displays the name of the day of the week. Here are some sample runs:

```
Enter year: (e.g., 2012): 2015 ↵Enter
Enter month: 1-12: 1 ↵Enter
Enter the day of the month: 1-31: 25 ↵Enter
Day of the week is Sunday
```

```
Enter year: (e.g., 2012): 2012 ↵Enter
Enter month: 1-12: 5 ↵Enter
Enter the day of the month: 1-31: 12 ↵Enter
Day of the week is Saturday
```

(*Hint*: January and February are counted as 13 and 14 in the formula, so you need to convert the user input 1 to 13 and 2 to 14 for the month and change the year to the previous year. For example, if the user enters 1 for `m` and 2015 for year, `m` will be 13 and `year` will be 2014 used in the formula.)

VideoNote
Check point location

****3.22** (*Geometry: point in a circle?*) Write a program that prompts the user to enter a point (`x`, `y`) and checks whether the point is within the circle centered at (`0`, `0`) with radius `10`. For example, (`4`, `5`) is inside the circle and (`9`, `9`) is outside the circle, as shown in Figure 3.7a.

(*Hint*: A point is in the circle if its distance to (`0`, `0`) is less than or equal to `10`. The formula for computing the distance is $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$. Test your program to cover all cases.) Two sample runs are shown below:

```
Enter a point with two coordinates: 4 5 ↵Enter
Point (4.0, 5.0) is in the circle
```

```
Enter a point with two coordinates: 9 9 ↵Enter
Point (9.0, 9.0) is not in the circle
```

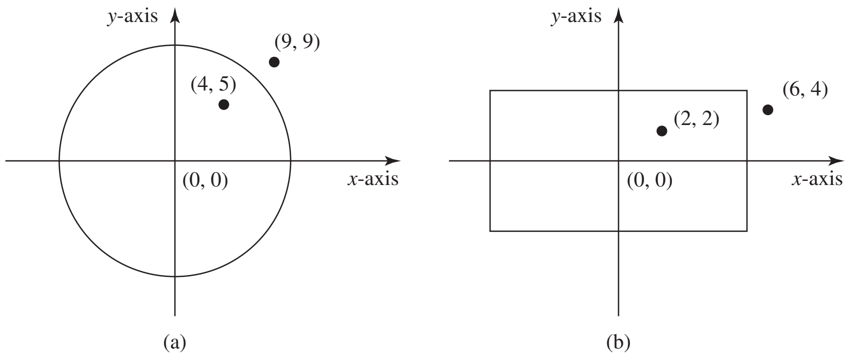


FIGURE 3.7 (a) Points inside and outside of the circle. (b) Points inside and outside of the rectangle.

****3.23** (*Geometry: point in a rectangle?*) Write a program that prompts the user to enter a point `(x, y)` and checks whether the point is within the rectangle centered at (`0`, `0`) with width `10` and height `5`. For example, (`2`, `2`) is inside the rectangle and (`6`, `4`) is outside the rectangle, as shown in Figure 3.7b. (*Hint*: A point is in the rectangle if its horizontal distance to (`0`, `0`) is less than or equal to `10 / 2` and its vertical distance to (`0`, `0`) is less than or equal to `5.0 / 2`. Test your program to cover all cases.) Here are two sample runs:

```
Enter a point with two coordinates: -4.9 2.49 ↵Enter
Point (-4.9, 2.49) is in the rectangle
```

```
Enter a point with two coordinates: -5.1 -2.4 ↵Enter
Point (-5.1, -2.4) is not in the rectangle
```

****3.24** (*Game: pick a card*) Write a program that simulates picking a card from a deck of `52` cards. Your program should display the rank (`Ace`, `2`, `3`, `4`, `5`, `6`, `7`, `8`, `9`, `10`, `Jack`, `Queen`, `King`) and suit (`Clubs`, `Diamonds`, `Hearts`, `Spades`) of the card. Here is a sample run of the program:

```
The card you picked is Jack of Hearts
```

***3.25** (*Geometry: intersecting point*) Two points on line 1 are given as (`x1`, `y1`) and (`x2`, `y2`) and on line 2 as (`x3`, `y3`) and (`x4`, `y4`), as shown in Figure 3.8a and b.

The intersecting point of the two lines can be found by solving the following linear equations:

$$(y_1 - y_2)x - (x_1 - x_2)y = (y_1 - y_2)x_1 - (x_1 - x_2)y_1$$
$$(y_3 - y_4)x - (x_3 - x_4)y = (y_3 - y_4)x_3 - (x_3 - x_4)y_3$$

This linear equation can be solved using Cramer's rule (see Programming Exercise 3.3). If the equation has no solutions, the two lines are parallel (see

Figure 3.8c). Write a program that prompts the user to enter four points and displays the intersecting point. Here are sample runs:

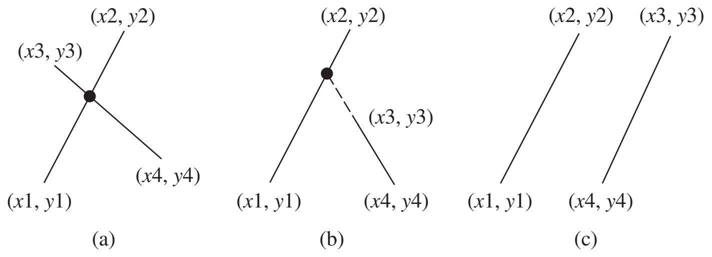


FIGURE 3.8 Two lines intersect in (a and b) and two lines are parallel in (c).

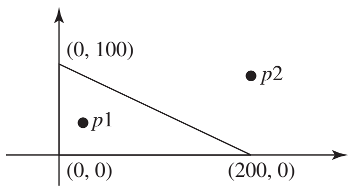
```
Enter x1, y1, x2, y2, x3, y3, x4, y4: 2 2 5 -1.0 4.0 2.0 -1.0 -2.0 Enter
The intersecting point is at (2.88889, 1.1111)
```

```
Enter x1, y1, x2, y2, x3, y3, x4, y4: 2 2 7 6.0 4.0 2.0 -1.0 -2.0 Enter
The two lines are parallel
```

3.26 (*Use the* **&&**, **||**, *and* **^** *operators*) Write a program that prompts the user to enter an integer and determines whether it is divisible by 5 and 6, whether it is divisible by 5 or 6, and whether it is divisible by 5 or 6, but not both. Here is a sample run of this program:

```
Enter an integer: 10 Enter
Is 10 divisible by 5 and 6? false
Is 10 divisible by 5 or 6? true
Is 10 divisible by 5 or 6, but not both? true
```

****3.27** (*Geometry: points in triangle?*) Suppose a right triangle is placed in a plane as shown below. The right-angle point is placed at (0, 0), and the other two points are placed at (200, 0) and (0, 100). Write a program that prompts the user to enter a point with *x*- and *y*-coordinates and determines whether the point is inside the triangle. Here are the sample runs:



```
Enter a point's x- and y-coordinates: 100.5 25.5 Enter
The point is in the triangle
```

```
Enter a point's x- and y-coordinates: 100.5 50.5 ↵Enter
The point is not in the triangle
```

****3.28** (*Geometry: two rectangles*) Write a program that prompts the user to enter the center *x*-, *y*-coordinates, width, and height of two rectangles and determines whether the second rectangle is inside the first or overlaps with the first, as shown in Figure 3.9. Test your program to cover all cases.

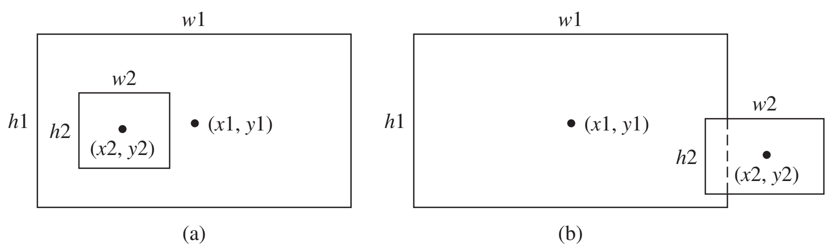


FIGURE 3.9 (a) A rectangle is inside another one. (b) A rectangle overlaps another one.

Here are the sample runs:

```
Enter r1's center x-, y-coordinates, width, and height: 2.5 4 2.5 43 ↵Enter
Enter r2's center x-, y-coordinates, width, and height: 1.5 5 0.5 3 ↵Enter
r2 is inside r1
```

```
Enter r1's center x-, y-coordinates, width, and height: 1 2 3 5.5 ↵Enter
Enter r2's center x-, y-coordinates, width, and height: 3 4 4.5 5 ↵Enter
r2 overlaps r1
```

```
Enter r1's center x-, y-coordinates, width, and height: 1 2 3 3 ↵Enter
Enter r2's center x-, y-coordinates, width, and height: 40 45 3 2 ↵Enter
r2 does not overlap r1
```

****3.29** (*Geometry: two circles*) Write a program that prompts the user to enter the center coordinates and radii of two circles and determines whether the second circle is inside the first or overlaps with the first, as shown in Figure 3.10. (*Hint*: `circle2` is inside `circle1` if the distance between the two centers <= `r1 - r2` and `circle2` overlaps `circle1` if the distance between the two centers <= `r1 + r2`. Test your program to cover all cases.)

Here are the sample runs:

```
Enter circle1's center x-, y-coordinates, and radius: 0.5 5.1 13 ↵Enter
Enter circle2's center x-, y-coordinates, and radius: 1 1.7 4.5 ↵Enter
circle2 is inside circle1
```

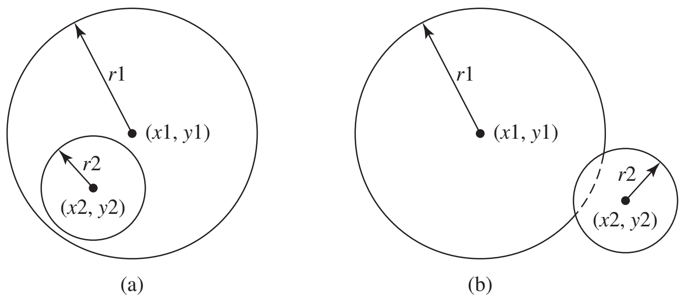


FIGURE 3.10 (a) A circle is inside another circle. (b) A circle overlaps another circle.

```
Enter circle1's center x-, y-coordinates, and radius: 3.4 5.7 5.5 ↵Enter
Enter circle2's center x-, y-coordinates, and radius: 6.7 3.5 3 ↵Enter
circle2 overlaps circle1
```

```
Enter circle1's center x-, y-coordinates, and radius: 3.4 5.5 1 ↵Enter
Enter circle2's center x-, y-coordinates, and radius: 5.5 7.2 1 ↵Enter
circle2 does not overlap circle1
```

***3.30** (*Current time*) Revise Programming Exercise 2.8 to display the hour using a 12-hour clock. Here is a sample run:

```
Enter the time zone offset to GMT: -5 ↵Enter
The current time is 4:50:34 AM
```

***3.31** (*Financials: currency exchange*) Write a program that prompts the user to enter the exchange rate from currency in U.S. dollars to Chinese RMB. Prompt the user to enter **0** to convert from U.S. dollars to Chinese RMB and **1** to convert from Chinese RMB to U.S. dollars. Prompt the user to enter the amount in U.S. dollars or Chinese RMB to convert it to Chinese RMB or U.S. dollars, respectively. Here are the sample runs:

```
Enter the exchange rate from dollars to RMB: 6.81 ↵Enter
Enter 0 to convert dollars to RMB and 1 vice versa: 0 ↵Enter
Enter the dollar amount: 100 ↵Enter
$100.0 is 681.0 yuan
```

```
Enter the exchange rate from dollars to RMB: 6.81 ↵Enter
Enter 0 to convert dollars to RMB and 1 vice versa: 1 ↵Enter
Enter the RMB amount: 10000
10000.0 yuan is $1468.43
```

```
Enter the exchange rate from dollars to RMB: 6.81 ↵Enter
Enter 0 to convert dollars to RMB and 1 vice versa: 5 ↵Enter
CIncorrect input
```

***3.32** (*Geometry: point position*) Given a directed line from point *p*0(*x*0, *y*0) to *p*1(*x*1, *y*1), you can use the following condition to decide whether a point *p*2(*x*2, *y*2) is on the left of the line, on the right, or on the same line (see Figure 3.11):

$$(x1 - x0)*(y2 - y0) - (x2 - x0)*(y1 - y0) \begin{cases} >0 \text{ p2 is on the left side of the line} \\ =0 \text{ p2 is on the same line} \\ <0 \text{ p2 is on the right side of the line} \end{cases}$$

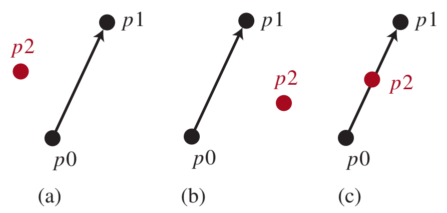


FIGURE 3.11 (a) *p*2 is on the left of the line. (b) *p*2 is on the right of the line. (c) *p*2 is on the same line.

Write a program that prompts the user to enter the three points for *p*0, *p*1, and *p*2 and displays whether *p*2 is on the left of the line from *p*0 to *p*1, to the right, or on the same line. Here are some sample runs:

```
Enter three points for p0, p1, and p2: 4.4 2 6.5 9.5 -5 4 ↵Enter
p2 is on the left side of the line
```

```
Enter three points for p0, p1, and p2: 1 1 5 5 2 2 ↵Enter
p2 is on the same line
```

```
Enter three points for p0, p1, and p2: 3.4 2 6.5 9.5 5 2.5 ↵Enter
p2 is on the right side of the line
```

***3.33** (*Financial: compare costs*) Suppose you shop for rice in two different packages. You would like to write a program to compare the cost. The program prompts the user to enter the weight and price of each package and displays the one with the better price. Here is a sample run:

```
Enter weight and price for package 1: 50 24.59 ↵Enter
Enter weight and price for package 2: 25 11.99 ↵Enter
Package 2 has a better price.
```

```
Enter weight and price for package 1: 50 25 ↵Enter
Enter weight and price for package 2: 25 12.5 ↵Enter
Two packages have the same price.
```

***3.34** (*Geometry: point on line segment*) Exercise 3.32 shows how to test whether a point is on an unbounded line. Revise Exercise 3.32 to test whether a point is on a line segment. Write a program that prompts the user to enter the three points for $p0$, $p1$, and $p2$ and displays whether $p2$ is on the line segment from $p0$ to $p1$. Here are some sample runs:

```
Enter three points for p0, p1, and p2: 1 1 2.5 2.5 1.5 1.5 ↵Enter
(1.5, 1.5) is on the line segment from (1.0, 1.0) to (2.5, 2.5)
```

```
Enter three points for p0, p1, and p2: 1 1 2 2 3.5 3.5 ↵Enter
(3.5, 3.5) is not on the line segment from (1.0, 1.0) to (2.0, 2.0)
```

Note

More than 200 additional programming exercises with solutions are provided to the instructors on the Instructor Resource Website.