

ELEMENTARY PROGRAMMING

Objectives

- To write Java programs to perform simple computations (§2.2).
- To obtain input from the console using the `Scanner` class (§2.3).
- To use identifiers to name variables, constants, methods, and classes (§2.4).
- To use variables to store data (§§2.5 and 2.6).
- To program with assignment statements and assignment expressions (§2.6).
- To use constants to store permanent data (§2.7).
- To name classes, methods, variables, and constants by following their naming conventions (§2.8).
- To explore Java numeric primitive data types: `byte`, `short`, `int`, `long`, `float`, and `double` (§2.9).
- To read a `byte`, `short`, `int`, `long`, `float`, or `double` value from the keyboard (§2.9.1).
- To perform operations using operators `+`, `-`, `*`, `/`, and `%` (§2.9.2).
- To perform exponent operations using `Math.pow(a, b)` (§2.9.3).
- To write integer literals, floating-point literals, and literals in scientific notation (§2.10).
- To use JShell to quickly test Java code (§2.11).
- To write and evaluate numeric expressions (§2.12).
- To obtain the current system time using `System.currentTimeMillis()` (§2.13).
- To use augmented assignment operators (§2.14).
- To distinguish between postincrement and preincrement and between postdecrement and predecrement (§2.15).
- To cast the value of one type to another type (§2.16).
- To describe the software development process and apply it to develop the loan payment program (§2.17).
- To write a program that converts a large amount of money into smaller units (§2.18).
- To avoid common errors and pitfalls in elementary programming (§2.19).



2.1 Introduction



The focus of this chapter is on learning elementary programming techniques to solve problems.

In Chapter 1, you learned how to create, compile, and run very basic Java programs. You will learn how to solve problems by writing programs. Through these problems, you will learn elementary programming using primitive data types, variables, constants, operators, expressions, and input and output.

Suppose, for example, you need to take out a student loan. Given the loan amount, loan term, and annual interest rate, can you write a program to compute the monthly payment and total payment? This chapter shows you how to write programs like this. Along the way, you will learn the basic steps that go into analyzing a problem, designing a solution, and implementing the solution by creating a program.

2.2 Writing a Simple Program



Writing a program involves designing a strategy for solving the problem then using a programming language to implement that strategy.

problem

algorithm

pseudocode

Let's first consider the simple *problem* of computing the area of a circle. How do we write a program for solving this problem?

Writing a program involves designing algorithms and translating algorithms into programming instructions, or code. An *algorithm* lists the steps you can follow to solve a problem. Algorithms can help the programmer plan a program before writing it in a programming language. Algorithms can be described in natural languages or in *pseudocode* (natural language mixed with some programming code). The algorithm for calculating the area of a circle can be described as follows:

1. Read in the circle's radius.
2. Compute the area using the following formula:

$$\text{area} = \text{radius} \times \text{radius} \times \pi$$

3. Display the result.



Tip

It's always a good practice to outline your program (or its underlying problem) in the form of an algorithm before you begin coding.

When you *code*—that is, when you write a program—you translate an algorithm into a program. You already know every Java program begins with a class definition in which the keyword **class** is followed by the class name. Assume you have chosen **ComputeArea** as the class name. The outline of the program would look as follows:

```
public class ComputeArea {
    // Details to be given later
}
```

As you know, every Java program must have a **main** method where program execution begins. The program is then expanded as follows:

```
public class ComputeArea {
    public static void main(String[] args) {
        // Step 1: Read in radius

        // Step 2: Compute area
```

```
// Step 3: Display the area
}
}
```

The program needs to read the radius entered by the user from the keyboard. This raises two important issues:

- Reading the radius
- Storing the radius in the program

Let's address the second issue first. In order to store the radius, the program needs to declare a symbol called a *variable*. A variable represents a value stored in the computer's memory.

Rather than using **x** and **y** as variable names, choose *descriptive names*: in this case, **radius** for radius and **area** for area. To let the compiler know what **radius** and **area** are, specify their *data types*. That is the kind of data stored in a variable, whether an integer, real number, or something else. This is known as *declaring variables*. Java provides simple data types for representing integers, real numbers, characters, and Boolean types. These types are known as *primitive data types* or *fundamental types*.

Real numbers (i.e., numbers with a decimal point) are represented using a method known as *floating-point* in computers. Therefore, the real numbers are also called *floating-point numbers*. In Java, you can use the keyword **double** to declare a floating-point variable. Declare **radius** and **area** as **double**. The program can be expanded as follows:

```
public class ComputeArea {
    public static void main(String[] args) {
        double radius;
        double area;

        // Step 1: Read in radius

        // Step 2: Compute area

        // Step 3: Display the area
    }
}
```

The program declares **radius** and **area** as variables. The keyword **double** indicates that **radius** and **area** are floating-point values stored in the computer.

The first step is to prompt the user to designate the circle's **radius**. You will soon learn how to prompt the user for information. For now, to learn how variables work, you can assign a fixed value to **radius** in the program as you write the code. Later, you'll modify the program to prompt the user for this value.

The second step is to compute **area** by assigning the result of the expression **radius * radius * 3.14159** to **area**.

In the final step, the program will display the value of **area** on the console by using the **System.out.println** method.

Listing 2.1 shows the complete program, and a sample run of the program is shown in Figure 2.1.

LISTING 2.1 ComputeArea.java

```
1  public class ComputeArea {
2      public static void main(String[] args) {
3          double radius; // Declare radius
4          double area; // Declare area
5
6          // Assign a radius
7          radius = 20; // radius is now 20
```

variable
descriptive names

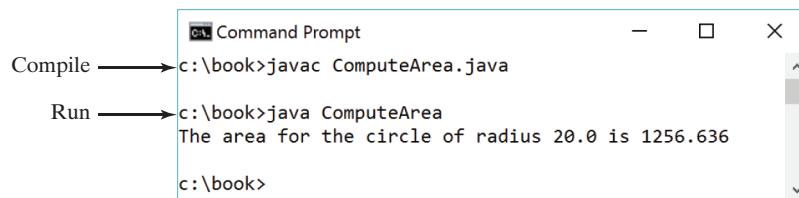
data type
declare variables

primitive data types

floating-point numbers

```

8
9      // Compute area
10     area = radius * radius * 3.14159;
11
12     // Display results
13     System.out.println("The area for the circle of radius " +
14         radius + " is " + area);
15 }
16 }
```



The screenshot shows a Windows Command Prompt window titled 'Command Prompt'. It has three arrows pointing to specific parts of the window:

- A blue arrow labeled 'Compile' points to the command 'c:\book>javac ComputeArea.java'.
- A red arrow labeled 'Run' points to the command 'c:\book>java ComputeArea' and its output 'The area for the circle of radius 20.0 is 1256.636'.
- A green arrow points to the directory 'c:\book>' at the bottom.

FIGURE 2.1 The program displays the area of a circle.

declare variable
assign value

tracing program

Variables such as `radius` and `area` correspond to memory locations. Every variable has a name, a type, and a value. Line 3 declares that `radius` can store a `double` value. The value is not defined until you assign a value. Line 7 assigns `20` into the variable `radius`. Similarly, line 4 declares the variable `area`, and line 10 assigns a value into `area`. The following table shows the value in the memory for `area` and `radius` as the program is executed. Each row in the table shows the values of variables after the statement in the corresponding line in the program is executed. This method of reviewing how a program works is called *tracing a program*. Tracing programs are helpful for understanding how programs work, and they are useful tools for finding errors in programs.



line#	radius	area
3	no value	
4		no value
7	20	
10		1256.636

concatenate strings

concatenate strings with
numbers

The plus sign (`+`) has two meanings: one for addition, and the other for concatenating (combining) strings. The plus sign (`+`) in lines 13–14 is called a *string concatenation operator*. It combines two strings into one. If a string is combined with a number, the number is converted into a string and concatenated with the other string. Therefore, the plus signs (`+`) in lines 13–14 concatenate strings into a longer string, which is then displayed in the output. Strings and string concatenation will be discussed further in Chapter 4.



Caution

A string cannot cross lines in the source code. Thus, the following statement would result in a compile error:

```
System.out.println("Introduction to Java Programming,
by Y. Daniel Liang");
```

To fix the error, break the string into separate substrings, and use the concatenation operator (`+`) to combine them:

```
System.out.println("Introduction to Java Programming, " +
"by Y. Daniel Liang");
```

break a long string

2.2.1 Identify and fix the errors in the following code:



```

1 public class Test {
2     public void main(string[] args) {
3         double i = 50.0;
4         double k = i + 50.0;
5         double j = k + 1;
6
7         System.out.println("j is " + j + " and
8             k is " + k);
9     }
10 }
```

2.3 Reading Input from the Console

Reading input from the console enables the program to accept input from the user.

In Listing 2.1, the radius is fixed in the source code. To use a different radius, you have to modify the source code and recompile it. Obviously, this is not convenient, so instead you can use the **Scanner** class for console input.

Java uses **System.out** to refer to the standard output device, and **System.in** to the standard input device. By default, the output device is the display monitor, and the input device is the keyboard. To perform console output, you simply use the **println** method to display a primitive value or a string to the console. To perform console input, you need to use the **Scanner** class to create an object to read input from **System.in**, as follows:

```
Scanner input = new Scanner(System.in);
```

The syntax **new Scanner(System.in)** creates an object of the **Scanner** type. The syntax **Scanner input** declares that **input** is a variable whose type is **Scanner**. The whole line **Scanner input = new Scanner(System.in)** creates a **Scanner** object and assigns its reference to the variable **input**. An object may invoke its methods. To invoke a method on an object is to ask the object to perform a task. You can invoke the **nextDouble()** method to read a **double** value as follows:

```
double radius = input.nextDouble();
```

This statement reads a number from the keyboard and assigns the number to **radius**.

Listing 2.2 rewrites Listing 2.1 to prompt the user to enter a radius.



VideoNote
Obtain Input

LISTING 2.2 ComputeAreaWithConsoleInput.java

```

1 import java.util.Scanner; // Scanner is in the java.util package           import class
2
3 public class ComputeAreaWithConsoleInput {
4     public static void main(String[] args) {
5         // Create a Scanner object
6         Scanner input = new Scanner(System.in);                                create a Scanner
7
8         // Prompt the user to enter a radius
9         System.out.print("Enter a number for radius: ");
10        double radius = input.nextDouble();                                     read a double
11
12        // Compute area
13        double area = radius * radius * 3.14159;
14
15        // Display results
16        System.out.println("The area for the circle of radius " +
```

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```
17     radius + " is " + area);
18 }
19 }
```



```
Enter a number for radius: 2.5 ↵Enter
The area for the circle of radius 2.5 is 19.6349375
```



```
Enter a number for radius: 23 ↵Enter
The area for the circle of radius 23.0 is 1661.90111
```

prompt

The `Scanner` class is in the `java.util` package. It is imported in line 1. Line 6 creates a `Scanner` object. Note the `import` statement can be omitted if you replace `Scanner` by `java.util.Scanner` in line 6.

Line 9 displays a string "`Enter a number for radius:`" to the console. This is known as a *prompt*, because it directs the user to enter an input. Your program should always tell the user what to enter when expecting input from the keyboard.

Recall that the `print` method in line 9 is identical to the `println` method, except that `println` moves to the beginning of the next line after displaying the string, but `print` does not advance to the next line when completed.

Line 6 creates a `Scanner` object. The statement in line 10 reads input from the keyboard.

```
double radius = input.nextDouble();
```

After the user enters a number and presses the *Enter* key, the program reads the number and assigns it to `radius`.

More details on objects will be introduced in Chapter 9. *For the time being, simply accept that this is how we obtain input from the console.*

specific import

The `Scanner` class is in the `java.util` package. It is imported in line 1. There are two types of `import` statements: *specific import* and *wildcard import*. The *specific import* specifies a single class in the import statement. For example, the following statement imports `Scanner` from the package `java.util`.

```
import java.util.Scanner;
```

wildcard import

The *wildcard import* imports all the classes in a package by using the asterisk as the wildcard. For example, the following statement imports all the classes from the package `java.util`.

```
import java.util.*;
```

no performance difference

The information for the classes in an imported package is not read in at compile time or runtime unless the class is used in the program. The import statement simply tells the compiler where to locate the classes. There is no performance difference between a specific import and a wildcard import declaration.

Listing 2.3 gives an example of reading multiple inputs from the keyboard. The program reads three numbers and displays their average.

LISTING 2.3 ComputeAverage.java

import class

```
1 import java.util.Scanner; // Scanner is in the java.util package
2
3 public class ComputeAverage {
4     public static void main(String[] args) {
5         // Create a Scanner object
6         Scanner input = new Scanner(System.in);
7
8         // Prompt the user to enter three numbers
9         System.out.print("Enter three numbers: ");
```

create a Scanner

```

10  double number1 = input.nextDouble();
11  double number2 = input.nextDouble();
12  double number3 = input.nextDouble();
13
14  // Compute average
15  double average = (number1 + number2 + number3) / 3;
16
17  // Display results
18  System.out.println("The average of " + number1 + " " + number2
19    + " " + number3 + " is " + average);
20 }
21 }
```

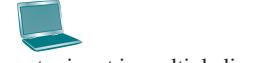
read a double

Enter three numbers: 1 2 3 ↵Enter
The average of 1.0 2.0 3.0 is 2.0



enter input in one line

Enter three numbers: 10.5 ↵Enter
11 ↵Enter
11.5 ↵Enter
The average of 10.5 11.0 11.5 is 11.0



enter input in multiple lines

The codes for importing the **Scanner** class (line 1) and creating a **Scanner** object (line 6) are the same as in the preceding example, as well as in all new programs you will write for reading input from the keyboard.

Line 9 prompts the user to enter three numbers. The numbers are read in lines 10–12. You may enter three numbers separated by spaces, then press the *Enter* key, or enter each number followed by a press of the *Enter* key, as shown in the sample runs of this program.

If you entered an input other than a numeric value, a runtime error would occur. In Chapter 12, you will learn how to handle the exception so the program can continue to run.

runtime error



Note

Most of the programs in the early chapters of this book perform three steps—input, process, and output—called **IPO**. Input is receiving input from the user; process is producing results using the input; and output is displaying the results.

IPO

Note

If you use an IDE such as Eclipse or NetBeans, you will get a warning to ask you to close the input for preventing a potential resource leak. Ignore the warning for the time being because the input is automatically closed when your program is terminated. In this case, there will be no resource leaking.

Warning in IDE

- 2.3.1** How do you write a statement to let the user enter a double value from the keyboard? What happens if you entered **5a** when executing the following code?

```
double radius = input.nextDouble();
```



Check Point

- 2.3.2** Are there any performance differences between the following two **import** statements?

```
import java.util.Scanner;
import java.util.*;
```



2.4 Identifiers

Identifiers are the names that identify the elements such as classes, methods, and variables in a program.

identifiers
identifier naming rules

As you see in Listing 2.3, `ComputeAverage`, `main`, `input`, `number1`, `number2`, `number3`, and so on are the names of things that appear in the program. In programming terminology, such names are called *identifiers*. All identifiers must obey the following rules:

- An identifier is a sequence of characters that consists of letters, digits, underscores (_), and dollar signs (\$).
- An identifier must start with a letter, an underscore (_), or a dollar sign (\$). It cannot start with a digit.
- An identifier cannot be a reserved word. See Appendix A for a list of reserved words. Reserved words have specific meaning in the Java language. Keywords are reserved words.
- An identifier can be of any length.

For example, `$2`, `ComputeArea`, `area`, `radius`, and `print` are legal identifiers, whereas `2A` and `d+4` are not because they do not follow the rules. The Java compiler detects illegal identifiers and reports syntax errors.



Note

Since Java is case sensitive, `area`, `Area`, and `AREA` are all different identifiers.

case sensitive



Tip

Identifiers are for naming variables, methods, classes, and other items in a program. Descriptive identifiers make programs easy to read. Avoid using abbreviations for identifiers. Using complete words is more descriptive. For example, `numberOfStudents` is better than `numStuds`, `numOfStuds`, or `numOfStudents`. We use descriptive names for complete programs in the text. However, we will occasionally use variable names such as `i`, `j`, `k`, `x`, and `y` in the code snippets for brevity. These names also provide a generic tone to the code snippets.



Tip

Do not name identifiers with the \$ character. By convention, the \$ character should be used only in mechanically generated source code.



2.4.1 Which of the following identifiers are valid? Which are Java keywords?

`miles`, `Test`, `a++`, `--a`, `4#R`, `$4`, `#44`, `apps`
`class`, `public`, `int`, `x`, `y`, `radius`

the \$ character



2.5 Variables

Variables are used to represent values that may be changed in the program.

why called variables?

As you see from the programs in the preceding sections, variables are used to store values to be used later in a program. They are called variables because their values can be changed. In the program in Listing 2.2, `radius` and `area` are variables of the `double` type. You can assign any numerical value to `radius` and `area`, and the values of `radius` and `area` can be reassigned. For example, in the following code, `radius` is initially `1.0` (line 2) then changed to `2.0` (line 7), and `area` is set to `3.14159` (line 3) then reset to `12.56636` (line 8).

```

1 // Compute the first area
2 radius = 1.0;                                radius: 1.0
3 area = radius * radius * 3.14159;            area: 3.14159
4 System.out.println("The area is " + area + " for radius " + radius);
5
6 // Compute the second area
7 radius = 2.0;                                radius: 2.0
8 area = radius * radius * 3.14159;            area: 12.56636
9 System.out.println("The area is " + area + " for radius " + radius);

```

Variables are for representing data of a certain type. To use a variable, you declare it by telling the compiler its name as well as what type of data it can store. The *variable declaration* tells the compiler to allocate appropriate memory space for the variable based on its data type. The syntax for declaring a variable is

```
datatype variableName;
```

Here are some examples of variable declarations:

declare variable

```

int count;           // Declare count to be an integer variable
double radius;     // Declare radius to be a double variable
double interestRate; // Declare interestRate to be a double variable

```

These examples use the data types **int** and **double**. Later you will be introduced to additional data types, such as **byte**, **short**, **long**, **float**, **char**, and **boolean**.

If variables are of the same type, they can be declared together, as follows:

```
datatype variable1, variable2, ..., variablen;
```

The variables are separated by commas. For example,

```
int i, j, k; // Declare i, j, and k as int variables
```

Variables often have initial values. You can declare a variable and initialize it in one step. Consider, for instance, the following code:

initialize variables

```
int count = 1;
```

This is equivalent to the next two statements:

```

int count;
count = 1;

```

You can also use a shorthand form to declare and initialize variables of the same type together. For example,

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



Tip

A variable must be declared before it can be assigned a value. A variable declared in a method must be assigned a value before it can be used.

Whenever possible, declare a variable and assign its initial value in one step. This will make the program easy to read and avoid programming errors.

Every variable has a scope. The *scope of a variable* is the part of the program where the variable can be referenced. The rules that define the scope of a variable will be gradually introduced later in the book. For now, all you need to know is that a variable must be declared and initialized before it can be used.



2.5.1 Identify and fix the errors in the following code:

```

1 public class Test {
2     public static void main(String[] args) {
3         int i = k + 2;
4         System.out.println(i);
5     }
6 }
```



assignment statement
assignment operator

expression

2.6 Assignment Statements and Assignment Expressions

An assignment statement assigns a value to a variable. An assignment statement can also be used as an expression in Java.

After a variable is declared, you can assign a value to it by using an *assignment statement*. In Java, the equal sign (`=`) is used as the *assignment operator*. The syntax for assignment statements is as follows:

```
variable = expression;
```

An *expression* represents a computation involving values, variables, and operators that, taking them together, evaluates to a value. In an assignment statement, the expression on the right-hand side of the assignment operator is evaluated, and then the value is assigned to the variable on the left-hand side of the assignment operator. For example, consider the following code:

```

int y = 1;           // Assign 1 to variable y
double radius = 1.0; // Assign 1.0 to variable radius
int x = 5 * (3 / 2); // Assign the value of the expression to x
x = y + 1;          // Assign the addition of y and 1 to x
double area = radius * radius * 3.14159; // Compute area
```

You can use a variable in an expression. A variable can also be used in both sides of the `=` operator. For example,

```
x = x + 1;
```

In this assignment statement, the result of `x + 1` is assigned to `x`. If `x` is `1` before the statement is executed, then it becomes `2` after the statement is executed.

To assign a value to a variable, you must place the variable name to the left of the assignment operator. Thus, the following statement is wrong:

```
1 = x; // Wrong
```



Note

In mathematics, `x = 2 * x + 1` denotes an equation. However, in Java, `x = 2 * x + 1` is an assignment statement that evaluates the expression `2 * x + 1` and assigns the result to `x`.

assignment expression

In Java, an assignment statement is essentially an expression that evaluates to the value to be assigned to the variable on the left side of the assignment operator. For this reason, an assignment statement is also known as an *assignment expression*. For example, the following statement is correct:

```
System.out.println(x = 1);
```

which is equivalent to

```

x = 1;
System.out.println(x);
```

If a value is assigned to multiple variables, you can use chained assignments like this:

```
i = j = k = 1;
```

which is equivalent to

```
k = 1;
j = k;
i = j;
```



Note

In an assignment statement, the data type of the variable on the left must be compatible with the data type of the value on the right. For example, `int x = 1.0` would be illegal, because the data type of `x` is `int`. You cannot assign a `double` value (`1.0`) to an `int` variable without using type casting. Type casting will be introduced in Section 2.15.

2.6.1 Identify and fix the errors in the following code:

```
1 public class Test {
2     public static void main(String[] args) {
3         int i = j = k = 2;
4         System.out.println(i + " " + j + " " + k);
5     }
6 }
```



Check Point

2.7 Named Constants

A named constant is an identifier that represents a permanent value.

The value of a variable may change during the execution of a program, but a *named constant*, or simply *constant*, represents permanent data that never changes. A constant is also known as a *final variable* in Java. In our `ComputeArea` program, π is a constant. If you use it frequently, you don't want to keep typing `3.14159`; instead, you can declare a constant for π . Here is the syntax for declaring a constant:

```
final datatype CONSTANTNAME = value;
```

A constant must be declared and initialized in the same statement. The word `final` is a Java keyword for declaring a constant. By convention, all letters in a constant are in uppercase. For example, you can declare π as a constant and rewrite Listing 2.2, as in Listing 2.4.



Key Point

constant

final keyword

LISTING 2.4 ComputeAreaWithConstant.java

```
1 import java.util.Scanner; // Scanner is in the java.util package
2
3 public class ComputeAreaWithConstant {
4     public static void main(String[] args) {
5         final double PI = 3.14159; // Declare a constant
6
7         // Create a Scanner object
8         Scanner input = new Scanner(System.in);
9
10        // Prompt the user to enter a radius
11        System.out.print("Enter a number for radius: ");
12        double radius = input.nextDouble();
13
14        // Compute area
15        double area = radius * radius * PI;
16
17        // Display result
```

```

18     System.out.println("The area for the circle of radius " +
19         radius + " is " + area);
20     }
21 }
```

benefits of constants

There are three benefits of using constants: (1) you don't have to repeatedly type the same value if it is used multiple times; (2) if you have to change the constant value (e.g., from **3.14** to **3.14159** for **PI**), you need to change it only in a single location in the source code; and (3) a descriptive name for a constant makes the program easy to read.



2.7.1 What are the benefits of using constants? Declare an **int** constant **SIZE** with value **20**.

2.7.2 Translate the following algorithm into Java code:

Step 1: Declare a **double** variable named **miles** with an initial value **100**.

Step 2: Declare a **double** constant named **KILOMETERS_PER_MILE** with value **1.609**.

Step 3: Declare a **double** variable named **kilometers**, multiply **miles** and **KILOMETERS_PER_MILE**, and assign the result to **kilometers**.

Step 4: Display **kilometers** to the console.

What is **kilometers** after Step 4?

2.8 Naming Conventions

Sticking with the Java naming conventions makes your programs easy to read and avoids errors.



name variables and methods

Make sure you choose descriptive names with straightforward meanings for the variables, constants, classes, and methods in your program. As mentioned earlier, names are case sensitive. Listed below are the conventions for naming variables, methods, and classes.

- Use lowercase for variables and methods—for example, the variables **radius** and **area**, and the method **print**. If a name consists of several words, concatenate them into one, making the first word lowercase and capitalizing the first letter of each subsequent word—for example, the variable **numberOfStudents**. This naming style is known as the *camelCase* because the uppercase characters in the name resemble a camel's humps.
- Capitalize the first letter of each word in a class name—for example, the class names **ComputeArea** and **System**.
- Capitalize every letter in a constant, and use underscores between words—for example, the constants **PI** and **MAX_VALUE**.

It is important to follow the naming conventions to make your programs easy to read.



Caution

Do not choose class names that are already used in the Java library. For example, since the **System** class is defined in Java, you should not name your class **System**.



2.8.1 What are the naming conventions for class names, method names, constants, and variables? Which of the following items can be a constant, a method, a variable, or a class according to the Java naming conventions?

MAX_VALUE, Test, read, readDouble

2.9 Numeric Data Types and Operations

*Java has six numeric types for integers and floating-point numbers with operators +, −, *, /, and %.*



Every data type has a range of values. The compiler allocates memory space for each variable or constant according to its data type. Java provides eight primitive data types for numeric values, characters, and Boolean values. This section introduces numeric data types and operators.

Table 2.1 lists the six numeric data types, their ranges, and their storage sizes.

TABLE 2.1 Numeric Data Types

Name	Range	Storage Size	
byte	-2^7 to $2^7 - 1$ (-128 to 127)	8-bit signed	byte type
short	-2^{15} to $2^{15} - 1$ (-32768 to 32767)	16-bit signed	short type
int	-2^{31} to $2^{31} - 1$ (-2147483648 to 2147483647)	32-bit signed	int type
long	-2^{63} to $2^{63} - 1$ (i.e., -9223372036854775808 to 9223372036854775807)	64-bit signed	long type
float	Negative range: $-3.4028235E + 38$ to $-1.4E - 45$ Positive range: $1.4E - 45$ to $3.4028235E+38$ 6–9 significant digits	32-bit IEEE 754	float type
double	Negative range: $-1.7976931348623157E+308$ to $-4.9E - 324$ Positive range: $4.9E - 324$ to $1.7976931348623157E+308$ 15–17 significant digits	64-bit IEEE 754	double type



Note

IEEE 754 is a standard approved by the Institute of Electrical and Electronics Engineers for representing floating-point numbers on computers. The standard has been widely adopted. Java uses the 32-bit **IEEE 754** for the **float** type and the 64-bit **IEEE 754** for the **double** type. The **IEEE 754** standard also defines special floating-point values, which are listed in Appendix E.

Java uses four types for integers: **byte**, **short**, **int**, and **long**. Choose the type that is most appropriate for your variable. For example, if you know an integer stored in a variable is within a range of a byte, declare the variable as a **byte**. For simplicity and consistency, we will use **int** for integers most of the time in this book.

integer types

Java uses two types for floating-point numbers: **float** and **double**. The **double** type is twice as big as **float**, so the **double** is known as *double precision*, and **float** as *single precision*. Normally, you should use the **double** type, because it is more accurate than the **float** type.

floating-point types

2.9.1 Reading Numbers from the Keyboard

You know how to use the **nextDouble()** method in the **Scanner** class to read a double value from the keyboard. You can also use the methods listed in Table 2.2 to read a number of the **byte**, **short**, **int**, **long**, and **float** type.

TABLE 2.2 Methods for **Scanner** Objects

Method	Description
nextByte()	reads an integer of the byte type.
nextShort()	reads an integer of the short type.
nextInt()	reads an integer of the int type.
nextLong()	reads an integer of the long type.
nextFloat()	reads a number of the float type.
nextDouble()	reads a number of the double type.

Here are examples for reading values of various types from the keyboard:

```

1 Scanner input = new Scanner(System.in);
2 System.out.print("Enter a byte value: ");
3 byte byteValue = input.nextByte();
4
5 System.out.print("Enter a short value: ");
6 short shortValue = input.nextShort();
7
8 System.out.print("Enter an int value: ");
9 int intValue = input.nextInt();
10
11 System.out.print("Enter a long value: ");
12 long longValue = input.nextLong();
13
14 System.out.print("Enter a float value: ");
15 float floatValue = input.nextFloat();

```

If you enter a value with an incorrect range or format, a runtime error would occur. For example, if you enter a value **128** for line 3, an error would occur because **128** is out of range for a **byte** type integer.

2.9.2 Numeric Operators

operators +, -, *, /, and %

operands

The operators for numeric data types include the standard arithmetic operators: addition (**+**), subtraction (**-**), multiplication (*****), division (**/**), and remainder (**%**), as listed in Table 2.3. The *operands* are the values operated by an operator.

TABLE 2.3 Numeric Operators

Name	Meaning	Example	Result
+	Addition	34 + 1	35
-	Subtraction	34.0 - 0.1	33.9
*	Multiplication	300*30	9000
/	Division	1.0 / 2.0	0.5
%	Remainder	20 % 3	2

integer division

When both operands of a division are integers, the result of the division is the quotient and the fractional part is truncated. For example, **5 / 2** yields **2**, not **2.5**, and **-5 / 2** yields **-2**, not **-2.5**. To perform a floating-point division, one of the operands must be a floating-point number. For example, **5.0 / 2** yields **2.5**.

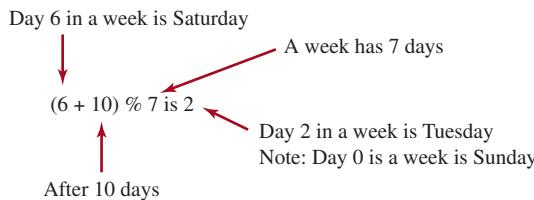
The **%** operator, known as *remainder*, yields the remainder after division. The operand on the left is the dividend, and the operand on the right is the divisor. Therefore, **7 % 3** yields **1**, **3 % 7** yields **3**, **12 % 4** yields **0**, **26 % 8** yields **2**, and **20 % 13** yields **7**.

The diagram illustrates several division operations:

- $\frac{2}{3} \overline{)7}$ results in $\frac{6}{1}$
- $\frac{0}{7} \overline{)3}$ results in $\frac{3}{0}$
- $\frac{3}{4} \overline{)12}$ results in $\frac{12}{0}$
- $\frac{3}{8} \overline{)26}$ results in $\frac{24}{2}$
- A general division structure: $\text{Divisor} \xrightarrow{\longrightarrow} \frac{1}{13} \overline{)20}$ results in $\frac{13}{7}$, labeled with "Quotient" above 1, "Dividend" next to 20, and "Remainder" next to 7.

The `%` operator is often used for positive integers, but it can also be used with negative integers and floating-point values. The remainder is negative only if the dividend is negative. For example, `-7 % 3` yields `-1`, `-12 % 4` yields `0`, `-26 % -8` yields `-2`, and `20 % -13` yields `7`.

Remainder is very useful in programming. For example, an even number `% 2` is always `0` and a positive odd number `% 2` is always `1`. Thus, you can use this property to determine whether a number is even or odd. If today is Saturday, it will be Saturday again in 7 days. Suppose you and your friends are going to meet in 10 days. What will be the day in 10 days? You can find that the day is Tuesday using the following expression:



The program in Listing 2.5 obtains minutes and remaining seconds from an amount of time in seconds. For example, `500` seconds contains `8` minutes and `20` seconds.

LISTING 2.5 DisplayTime.java

```

1 import java.util.Scanner;                                import Scanner
2
3 public class DisplayTime {                               create a Scanner
4     public static void main(String[] args) {
5         Scanner input = new Scanner(System.in);
6         // Prompt the user for input
7         System.out.print("Enter an integer for seconds: ");
8         int seconds = input.nextInt();                      read an integer
9
10        int minutes = seconds / 60; // Find minutes in seconds
11        int remainingSeconds = seconds % 60; // Seconds remaining
12        System.out.println(seconds + " seconds is " + minutes +
13            " minutes and " + remainingSeconds + " seconds"); divide
14    }                                                       remainder
15 }
```

Enter an integer for seconds: 500
 500 seconds is 8 minutes and 20 seconds



line#	seconds	minutes	remainingSeconds
8	500		
10		8	
11			20



The `nextInt()` method (line 8) reads an integer for `seconds`. Line 10 obtains the minutes using `seconds / 60`. Line 11 (`seconds % 60`) obtains the remaining seconds after taking away the minutes.

unary operator
binary operator

Math.pow(a, b) method

The `+` and `-` operators can be both unary and binary. A *unary operator* has only one operand; a *binary operator* has two. For example, the `-` operator in `-5` is a unary operator to negate number `5`, whereas the `-` operator in `4 - 5` is a binary operator for subtracting `5` from `4`.

2.9.3 Exponent Operations

The `Math.pow(a, b)` method can be used to compute a^b . The `pow` method is defined in the `Math` class in the Java API. You invoke the method using the syntax `Math.pow(a, b)` (e.g., `Math.pow(2, 3)`), which returns the result of a^b (2^3). Here, `a` and `b` are parameters for the `pow` method and the numbers `2` and `3` are actual values used to invoke the method. For example,

```
System.out.println(Math.pow(2, 3)); // Displays 8.0
System.out.println(Math.pow(4, 0.5)); // Displays 2.0
System.out.println(Math.pow(2.5, 2)); // Displays 6.25
System.out.println(Math.pow(2.5, -2)); // Displays 0.16
```

Chapter 6 introduces more details on methods. For now, all you need to know is how to invoke the `pow` method to perform the exponent operation.



- 2.9.1** Find the largest and smallest `byte`, `short`, `int`, `long`, `float`, and `double`. Which of these data types requires the least amount of memory?

- 2.9.2** Show the result of the following remainders:

<code>56</code>	<code>%</code>	<code>6</code>
<code>78</code>	<code>%</code>	<code>-4</code>
<code>-34</code>	<code>%</code>	<code>5</code>
<code>-34</code>	<code>%</code>	<code>-5</code>
<code>5</code>	<code>%</code>	<code>1</code>
<code>1</code>	<code>%</code>	<code>5</code>

- 2.9.3** If today is Tuesday, what will be the day in 100 days?

- 2.9.4** What is the result of `25 / 4`? How would you rewrite the expression if you wished the result to be a floating-point number?

- 2.9.5** Show the result of the following code:

```
System.out.println(2 * (5 / 2 + 5 / 2));
System.out.println(2 * 5 / 2 + 2 * 5 / 2);
System.out.println(2 * (5 / 2));
System.out.println(2 * 5 / 2);
```

- 2.9.6** Are the following statements correct? If so, show the output.

```
System.out.println("25 / 4 is " + 25 / 4);
System.out.println("25 / 4.0 is " + 25 / 4.0);
System.out.println("3 * 2 / 4 is " + 3 * 2 / 4);
System.out.println("3.0 * 2 / 4 is " + 3.0 * 2 / 4);
```

- 2.9.7** Write a statement to display the result of $2^{3.5}$.

- 2.9.8** Suppose `m` and `r` are integers. Write a Java expression for mr^2 to obtain a floating-point result.



2.10 Numeric Literals

A *literal* is a constant value that appears directly in a program.

literal

For example, `34` and `0.305` are literals in the following statements:

```
int numberOfYears = 34;
double weight = 0.305;
```

2.10.1 Integer Literals

An integer literal can be assigned to an integer variable as long as it can fit into the variable. A compile error will occur if the literal is too large for the variable to hold. The statement `byte b = 128`, for example, will cause a compile error, because `128` cannot be stored in a variable of the `byte` type. (Note the range for a byte value is from `-128` to `127`.)

An integer literal is assumed to be of the `int` type, whose value is between -2^{31} (`-2147483648`) and $2^{31} - 1$ (`2147483647`). To denote an integer literal of the `long` type, append the letter `L` or `l` to it. For example, to write integer `2147483648` in a Java program, you have to write it as `2147483648L` or `2147483648l`, because `2147483648` exceeds the range for the `int` value. `L` is preferred because `l` (lowercase `L`) can easily be confused with `1` (the digit one).



Note

By default, an integer literal is a decimal integer number. To denote a binary integer literal, use a leading `0b` or `0B` (zero B); to denote an octal integer literal, use a leading `0` (zero); and to denote a hexadecimal integer literal, use a leading `0x` or `0X` (zero X). For example,

```
System.out.println(0B1111); // Displays 15
System.out.println(07777); // Displays 4095
System.out.println(0xFFFF); // Displays 65535
```

Hexadecimal numbers, binary numbers, and octal numbers will be introduced in Appendix F.

binary, octal, and hex literals

2.10.2 Floating-Point Literals

Floating-point literals are written with a decimal point. By default, a floating-point literal is treated as a `double` type value. For example, `5.0` is considered a `double` value, not a `float` value. You can make a number a `float` by appending the letter `f` or `F`, and you can make a number a `double` by appending the letter `d` or `D`. For example, you can use `100.2f` or `100.2F` for a `float` number, and `100.2d` or `100.2D` for a `double` number.

suffix f or F
suffix d or D



Note

The `double` type values are more accurate than the `float` type values. For example,

```
System.out.println("1.0 / 3.0 is " + 1.0 / 3.0);
displays 1.0 / 3.0 is 0.3333333333333333
          ↑
          16 digits

System.out.println("1.0F / 3.0F is " + 1.0F / 3.0F);
displays 1.0F / 3.0F is 0.33333334
          ↑
          8 digits
```

double vs. float

A float value has **6–9** numbers of significant digits, and a double value has **15–17** numbers of significant digits.



Note

To improve readability, Java allows you to use underscores to separate two digits in a number literal. For example, the following literals are correct.

```
long value = 232_45_4519;
double amount = 23.24_4545_4519_3415;
```

However, `45_` or `_45` is incorrect. The underscore must be placed between two digits.

underscores in numbers

2.10.3 Scientific Notation

Floating-point literals can be written in scientific notation in the form of $a \times 10^b$. For example, the scientific notation for 123.456 is 1.23456×10^2 and for 0.0123456 is 1.23456×10^{-2} . A special syntax is used to write scientific notation numbers. For example, 1.23456×10^2 is written as **1.23456E2** or **1.23456E+2** and 1.23456×10^{-2} as **1.23456E-2**. **E** (or **e**) represents an exponent, and can be in either lowercase or uppercase.



Note

The **float** and **double** types are used to represent numbers with a decimal point.

Why are they called *floating-point numbers*? These numbers are stored in scientific notation internally. When a number such as **50.534** is converted into scientific notation, such as **5.0534E+1**, its decimal point is moved (i.e., floated) to a new position.



why called floating-point?

2.10.1 How many accurate digits are stored in a **float** or **double** type variable?

2.10.2 Which of the following are correct literals for floating-point numbers?

12.3, 12.3e+2, 23.4e-2, -334.4, 20.5, 39F, 40D

2.10.3 Which of the following are the same as **52.534**?

5.2534e+1, 0.52534e+2, 525.34e-1, 5.2534e+0

2.10.4 Which of the following are correct literals?

5_2534e+1, _2534, 5_2, 5_



2.11 JShell

JShell is a command line tool for quickly evaluating an expression and executing a statement.

JShell is a command line interactive tool introduced in Java 9. JShell enables you to type a single Java statement and get it executed to see the result right away without having to write a complete class. This feature is commonly known as REPL (Read-Evaluate-Print Loop), which evaluates expressions and executes statements as they are entered and shows the result immediately. To use JShell, you need to install JDK 9 or higher. Make sure that you set the correct path on the Windows environment if you use Windows. Open a Command Window and type `jshell` to launch JShell as shown in Figure 2.2.

```
c:\book>jshell
| Welcome to JShell -- Version 11.0.1
| For an introduction type: /help intro
jshell>
```

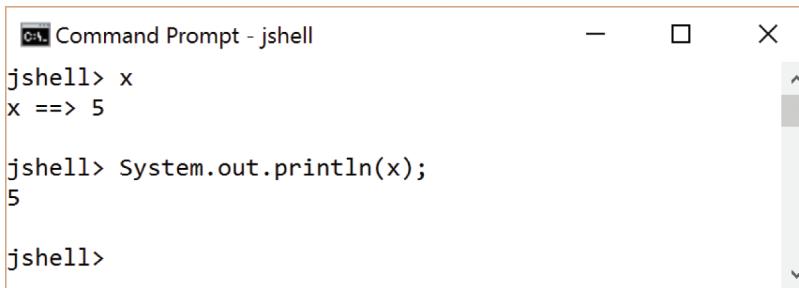
FIGURE 2.2 JShell is launched.

You can enter a Java statement from the `jshell` prompt. For example, enter `int x = 5`, as shown in Figure 2.3.

```
jshell> int x = 5;
x ==> 5
jshell> -
```

FIGURE 2.3 Enter a Java statement at the `jshell` command prompt

To print the variable, simply type `x`. Alternatively, you can type `System.out.println(x)`, as shown in Figure 2.4.



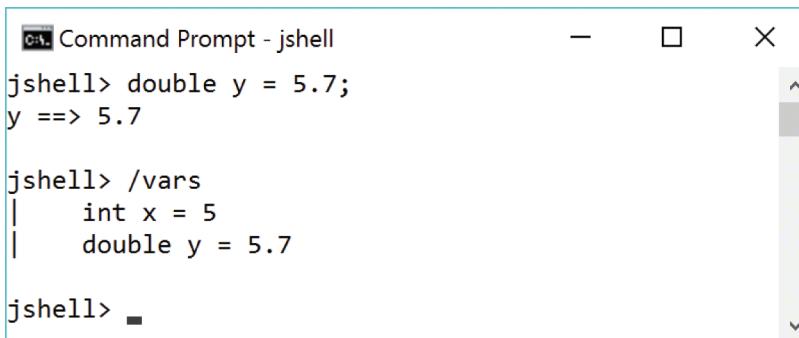
```
Command Prompt - jshell
jshell> x
x ==> 5

jshell> System.out.println(x);
5

jshell>
```

FIGURE 2.4 Print a variable

You can list all the declared variables using the `/vars` command as shown in Figure 2.5.



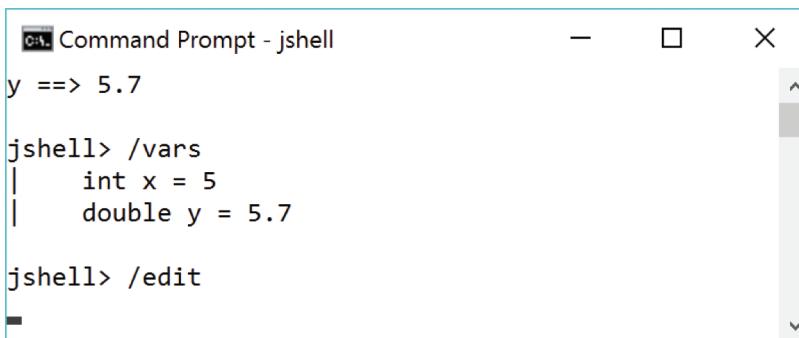
```
Command Prompt - jshell
jshell> double y = 5.7;
y ==> 5.7

jshell> /vars
|   int x = 5
|   double y = 5.7

jshell> ■
```

FIGURE 2.5 List all variables

You can use the `/edit` command to edit the code you have entered from the jshell prompt, as shown in Figure 2.6a. This command opens up an edit pane. You can also add/delete the code from the edit pane, as shown in Figure 2.6b. After finishing editing, click the Accept button to make the change in JShell and click the Exit button to exit the edit pane.

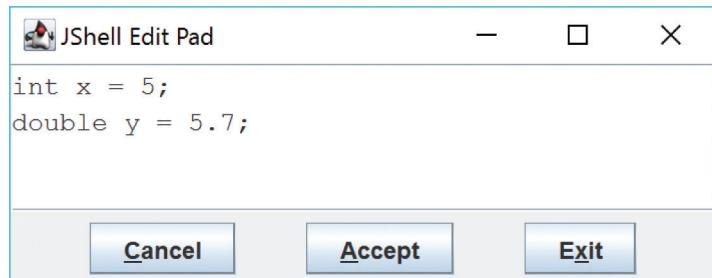


```
Command Prompt - jshell
y ==> 5.7

jshell> /vars
|   int x = 5
|   double y = 5.7

jshell> /edit
■
```

(a)



(b)

FIGURE 2.6 The /edit command opens up the edit pane

In JShell, if you don't specify a variable for a value, JShell will automatically create a variable for the value. For example, if you type 6.8 from the jshell prompt, you will see variable \$7 is automatically created for 6.8, as shown in Figure 2.7.

The image shows a window titled "Command Prompt - jshell". Inside the window, the following interaction is visible:

```
jshell> 6.9
$7 ==> 6.9

jshell> /vars
|   int x = 5
|   double y = 5.7
|   double $7 = 6.9

jshell>
```

FIGURE 2.7 A variable is automatically created for a value.

To exit JShell, enter /exit.

For more information on JShell, see <https://docs.oracle.com/en/java/javase/11/jshell/>.



2.11.1 What does REPL stand for? How do you launch JShell?



2.12 Evaluating Expressions and Operator Precedence

Java expressions are evaluated in the same way as arithmetic expressions.

Writing a numeric expression in Java involves a straightforward translation of an arithmetic expression using Java operators. For example, the arithmetic expression

$$\frac{3 + 4x}{5} - \frac{10(y - 5)(a + b + c)}{x} + 9\left(\frac{4}{x} + \frac{9 + x}{y}\right)$$

can be translated into a Java expression as follows:

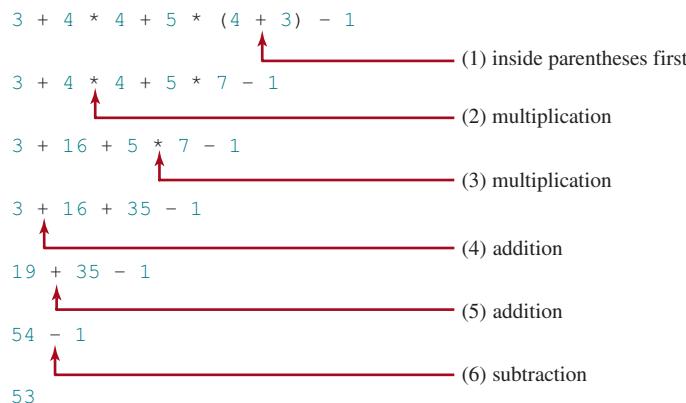
```
(3 + 4 * x) / 5 - 10 * (y - 5) * (a + b + c) / x +
9 * (4 / x + (9 + x) / y)
```

Although Java has its own way to evaluate an expression behind the scene, the result of a Java expression and its corresponding arithmetic expression is the same. Therefore, you can safely apply the arithmetic rule for evaluating a Java expression. Operators contained within pairs of parentheses are evaluated first. Parentheses can be nested, in which case the expression in the

inner parentheses is evaluated first. When more than one operator is used in an expression, the following operator precedence rule is used to determine the order of evaluation:

- Multiplication, division, and remainder operators are applied first. If an expression contains several multiplication, division, and remainder operators, they are applied from left to right.
- Addition and subtraction operators are applied last. If an expression contains several addition and subtraction operators, they are applied from left to right.

Here is an example of how an expression is evaluated:



Listing 2.6 gives a program that converts a Fahrenheit degree to Celsius using the formula $\text{Celsius} = \left(\frac{5}{9}\right)(\text{Fahrenheit} - 32)$.

LISTING 2.6 FahrenheitToCelsius.java

```

1 import java.util.Scanner;
2
3 public class FahrenheitToCelsius {
4     public static void main(String[] args) {
5         Scanner input = new Scanner(System.in);
6
7         System.out.print("Enter a degree in Fahrenheit: ");
8         double fahrenheit = input.nextDouble();
9
10        // Convert Fahrenheit to Celsius
11        double celsius = (5.0 / 9) * (fahrenheit - 32);           divide
12        System.out.println("Fahrenheit " + fahrenheit + " is " +
13            celsius + " in Celsius");
14    }
15 }
```

Enter a degree in Fahrenheit: 100

Fahrenheit 100.0 is 37.77777777777778 in Celsius



line#	fahrenheit	celsius
8	100	
11		37.77777777777778



integer vs. floating-point division

Be careful when applying division. Division of two integers yields an integer in Java. $\frac{5}{9}$ is coded `5.0 / 9` instead of `5 / 9` in line 11, because `5 / 9` yields `0` in Java.



2.12.1 How would you write the following arithmetic expressions in Java?

a. $\frac{4}{3(r + 34)} - 9(a + bc) + \frac{3 + d(2 + a)}{a + bd}$

b. $5.5 \times (r + 2.5)^{2.5+t}$

2.13 Case Study: Displaying the Current Time



You can invoke `System.currentTimeMillis()` to return the current time.



VideoNote

Use operators / and %

currentTimeMillis

UNIX epoch

The problem is to develop a program that displays the current time in GMT (Greenwich Mean Time) in the format hour:minute:second, such as 13:19:8.

The `currentTimeMillis` method in the `System` class returns the current time in milliseconds elapsed since the time midnight, January 1, 1970 GMT, as shown in Figure 2.8. This time is known as the *UNIX epoch*. The epoch is the point when time starts, and 1970 was the year when the UNIX operating system was formally introduced.

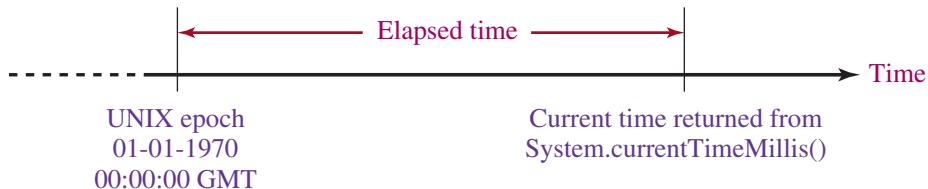


FIGURE 2.8 The `System.currentTimeMillis()` returns the number of milliseconds since the UNIX epoch.

You can use this method to obtain the current time, then compute the current second, minute, and hour as follows:

1. Obtain the total milliseconds since midnight, January 1, 1970, in `totalMilliseconds` by invoking `System.currentTimeMillis()` (e.g., `1203183068328` milliseconds).
2. Obtain the total seconds `totalSeconds` by dividing `totalMilliseconds` by `1000` (e.g., `1203183068328` milliseconds / `1000` = `1203183068` seconds).
3. Compute the current second from `totalSeconds % 60` (e.g., `1203183068` seconds % `60` = `8`, which is the current second).
4. Obtain the total minutes `totalMinutes` by dividing `totalSeconds` by `60` (e.g., `1203183068` seconds / `60` = `20053051` minutes).
5. Compute the current minute from `totalMinutes % 60` (e.g., `20053051` minutes % `60` = `31`, which is the current minute).
6. Obtain the total hours `totalHours` by dividing `totalMinutes` by `60` (e.g., `20053051` minutes / `60` = `334217` hours).
7. Compute the current hour from `totalHours % 24` (e.g., `334217` hours % `24` = `17`, which is the current hour).

Listing 2.7 gives the complete program.

LISTING 2.7 ShowCurrentTime.java

```

1  public class ShowcurrentTime {
2      public static void main(String[] args) {
3          // Obtain the total milliseconds since midnight, Jan 1, 1970
4          long totalMilliseconds = System.currentTimeMillis();           totalMilliseconds
5
6          // Obtain the total seconds since midnight, Jan 1, 1970
7          long totalSeconds = totalMilliseconds / 1000;                 totalSeconds
8
9          // Compute the current second in the minute in the hour
10         long currentSecond = totalSeconds % 60;                      currentSecond
11
12         // Obtain the total minutes
13         long totalMinutes = totalSeconds / 60;                        totalMinutes
14
15         // Compute the current minute in the hour
16         long currentMinute = totalMinutes % 60;                      currentMinute
17
18         // Obtain the total hours
19         long totalHours = totalMinutes / 60;                          totalHours
20
21         // Compute the current hour
22         long currentHour = totalHours % 24;                         currentHour
23
24         // Display results
25         System.out.println("Current time is " + currentHour + ":"        display output
26             + currentMinute + ":" + currentSecond + " GMT");
27     }
28 }
```

Current time is 17:31:8 GMT



Line 4 invokes `System.currentTimeMillis()` to obtain the current time in milliseconds as a `long` value. Thus, all the variables are declared as the long type in this program. The seconds, minutes, and hours are extracted from the current time using the `/` and `%` operators (lines 6–22).

variables	line#	4	7	10	13	16	19	22
<code>totalMilliseconds</code>								
<code>totalSeconds</code>								
<code>currentSecond</code>								
<code>totalMinutes</code>								
<code>currentMinute</code>								
<code>totalHours</code>								
<code>currentHour</code>								



In the sample run, a single digit 8 is displayed for the second. The desirable output would be 08. This can be fixed by using a method that formats a single digit with a prefix 0 (see Programming Exercise 6.37).

The hour displayed in this program is in GMT. Programming Exercise 2.8 enables to display the hour in any time zone.

nanoTime



Java also provides the `System.nanoTime()` method that returns the elapse time in nanoseconds. `nanoTime()` is more precise and accurate than `currentTimeMillis()`.

2.13.1 How do you obtain the current second, minute, and hour?

2.14 Augmented Assignment Operators

*The operators +, -, *, /, and % can be combined with the assignment operator to form augmented operators.*

Very often, the current value of a variable is used, modified, then reassigned back to the same variable. For example, the following statement increases the variable `count` by 1:

```
count = count + 1;
```

Java allows you to combine assignment and addition operators using an augmented (or compound) assignment operator. For example, the preceding statement can be written as

```
count += 1;
```

addition assignment operator

The `+=` is called the *addition assignment operator*. Table 2.4 shows other augmented assignment operators.

TABLE 2.4 Augmented Assignment Operators

Operator	Name	Example	Equivalent
<code>+=</code>	Addition assignment	<code>i += 8</code>	<code>i = i + 8</code>
<code>-=</code>	Subtraction assignment	<code>i -= 8</code>	<code>i = i - 8</code>
<code>*=</code>	Multiplication assignment	<code>i *= 8</code>	<code>i = i * 8</code>
<code>/=</code>	Division assignment	<code>i /= 8</code>	<code>i = i / 8</code>
<code>%=</code>	Remainder assignment	<code>i %= 8</code>	<code>i = i % 8</code>

The augmented assignment operator is performed last after all the other operators in the expression are evaluated. For example,

```
x /= 4 + 5.5 * 1.5;
```

is same as

```
x = x / (4 + 5.5 * 1.5);
```



Caution

There are no spaces in the augmented assignment operators. For example, `+ =` should be `+=`.



Note

Like the assignment operator (`=`), the operators (`+=`, `-=`, `*=`, `/=`, and `%=`) can be used to form an assignment statement as well as an expression. For example, in the following code, `x += 2` is a statement in the first line, and an expression in the second line:

```
x += 2; // Statement
System.out.println(x += 2); // Expression
```

2.14.1 Show the output of the following code:

```
double a = 6.5;
a += a + 1;
System.out.println(a);
a = 6;
a /= 2;
System.out.println(a);
```



2.15 Increment and Decrement Operators

The increment operator (++) and decrement operator (--) are for incrementing and decrementing a variable by 1.

The **++** and **--** are two shorthand operators for incrementing and decrementing a variable by 1. These are handy because that's often how much the value needs to be changed in many programming tasks. For example, the following code increments **i** by 1 and decrements **j** by 1.

```
int i = 3, j = 3;
i++; // i becomes 4
j--; // j becomes 2
```

i++ is pronounced as "i plus plus" and **i--** as "i minus minus." These operators are known as *postfix increment* (or *postincrement*) and *postfix decrement* (or *postdecrement*), because the operators **++** and **--** are placed after the variable. These operators can also be placed before the variable. For example,

```
int i = 3, j = 3;
++i; // i becomes 4
--j; // j becomes 2
```

++i increments **i** by 1 and **--j** decrements **j** by 1. These operators are known as *prefix increment* (or *preincrement*) and *prefix decrement* (or *predecrement*).

As you see, the effect of **i++** and **++i** or **i--** and **--i** are the same in the preceding examples. However, their effects are different when they are used in statements that do more than just increment and decrement. Table 2.5 describes their differences and gives examples.

TABLE 2.5 Increment and Decrement Operators

Operator	Name	Description	Example (assume i = 1)
++var	preincrement	Increment var by 1, and use the new var value in the statement	int j = ++i; // j is 2, i is 2
var++	postincrement	Increment var by 1, but use the original var value in the statement	int j = i++; // j is 1, i is 2
--var	predecrement	Decrement var by 1, and use the new var value in the statement	int j = --i; // j is 0, i is 0
var--	postdecrement	Decrement var by 1, and use the original var value in the statement	int j = i--; // j is 1, i is 0

Here are additional examples to illustrate the differences between the prefix form of **++** (or **--**) and the postfix form of **++** (or **--**). Consider the following code:

```
int i = 10;
int newNum = 10 * i++;
System.out.print("i is " + i
+ ", newNum is " + newNum);
Output is
i is 11, newNum is 100
```

Same effect as

```
int newNum = 10 * i;
i = i + 1;
```



increment operator (+ +)
decrement operator (− −)

postincrement
postdecrement

preincrement
predecrement



In this case, `i` is incremented by 1, then the *old* value of `i` is used in the multiplication. Thus, `newNum` becomes 100. If `i++` is replaced by `++i`, then it becomes as follows:



```

int i = 10;
int newNum = 10 * (++i);           Same effect as
                                    ↓
System.out.print("i is " + i
+ ", newNum is " + newNum);
                                    ↓ Output is
                                    ↓
i is 11, newNum is 110

```

`i` is incremented by 1, and the new value of `i` is used in the multiplication. Thus, `newNum` becomes 110.

Here is another example:

```

double x = 1.0;
double y = 5.0;
double z = x-- + (++y);

```

After all three lines are executed, `y` becomes 6.0, `z` becomes 7.0, and `x` becomes 0.0.

Operands are evaluated from left to right in Java. The left-hand operand of a binary operator is evaluated before any part of the right-hand operand is evaluated. This rule takes precedence over any other rules that govern expressions. Here is an example:

```

int i = 1;
int k = ++i + i * 3;

```

`++i` is evaluated and returns 2. When evaluating `i * 3`, `i` is now 2. Therefore, `k` becomes 8.



Tip

Using increment and decrement operators makes expressions short, but it also makes them complex and difficult to read. Avoid using these operators in expressions that modify multiple variables or the same variable multiple times, such as this one: `int k = ++i + i * 3;`



2.15.1 Which of these statements are true?

- Any expression can be used as a statement.
- The expression `x++` can be used as a statement.
- The statement `x = x + 5` is also an expression.
- The statement `x = y = x = 0` is illegal.

2.15.2 Show the output of the following code:

```

int a = 6;
int b = a++;
System.out.println(a);
System.out.println(b);
a = 6;
b = ++a;
System.out.println(a);
System.out.println(b);

```

2.16 Numeric Type Conversions



Floating-point numbers can be converted into integers using explicit casting.

Can you perform binary operations with two operands of different types? Yes. If an integer and a floating-point number are involved in a binary operation, Java automatically converts the integer to a floating-point value. Therefore, `3 * 4.5` is the same as `3.0 * 4.5`.

You can always assign a value to a numeric variable whose type supports a larger range of values; thus, for instance, you can assign a `long` value to a `float` variable. You cannot, however, assign a value to a variable of a type with a smaller range unless you use *type casting*. *Casting* is an operation that converts a value of one data type into a value of another data type. Casting a type with a small range to a type with a larger range is known as *widening a type*. Casting a type with a large range to a type with a smaller range is known as *narrowing a type*. Java will automatically widen a type, but you must narrow a type explicitly.

casting
widening a type
narrowing a type

The syntax for casting a type is to specify the target type in parentheses, followed by the variable's name or the value to be cast. For example, the following statement

```
System.out.println((int)1.7);
```

displays 1. When a `double` value is cast into an `int` value, the fractional part is truncated.

The following statement

```
System.out.println((double)1 / 2);
```

displays 0.5, because 1 is cast to 1.0 first, then 1.0 is divided by 2. However, the statement

```
System.out.println(1 / 2);
```

displays 0, because 1 and 2 are both integers and the resulting value should also be an integer.



Caution

Casting is necessary if you are assigning a value to a variable of a smaller type range, such as assigning a `double` value to an `int` variable. A compile error will occur if casting is not used in situations of this kind. However, be careful when using casting, as loss of information might lead to inaccurate results.

possible loss of precision



Note

Casting does not change the variable being cast. For example, `d` is not changed after casting in the following code:

```
double d = 4.5;
int i = (int)d; // i becomes 4, but d is still 4.5
```



Note

In Java, an augmented expression of the form `x1 op= x2` is implemented as `x1 = (T)(x1 op x2)`, where T is the type for `x1`. Therefore, the following code is correct:

```
int sum = 0;
sum += 4.5; // sum becomes 4 after this statement
sum += 4.5 is equivalent to sum = (int)(sum + 4.5).
```

casting in an augmented expression



Note

To assign a variable of the `int` type to a variable of the `short` or `byte` type, explicit casting must be used. For example, the following statements have a compile error:

```
int i = 1;
byte b = i; // Error because explicit casting is required
```

However, so long as the integer literal is within the permissible range of the target variable, explicit casting is not needed to assign an integer literal to a variable of the `short` or `byte` type (see Section 2.10, Numeric Literals).

The program in Listing 2.8 displays the sales tax with two digits after the decimal point.

LISTING 2.8 SalesTax.java

```

1 import java.util.Scanner;
2
3 public class SalesTax {
4     public static void main(String[] args) {
5         Scanner input = new Scanner(System.in);
6
7         System.out.print("Enter purchase amount: ");
8         double purchaseAmount = input.nextDouble();
9
10        double tax = purchaseAmount * 0.06;
11        System.out.println("Sales tax is $" + (int)(tax * 100) / 100.0);
12    }
13 }
```



Enter purchase amount: 197.55 ↵ Enter
Sales tax is \$11.85



line#	purchaseAmount	tax	Output
8	197.55		
10		11.853	
11			11.85

casting

Using the input in the sample run, the variable **purchaseAmount** is **197.55** (line 8). The sales tax is **6%** of the purchase, so the **tax** is evaluated as **11.853** (line 10). Note

tax * 100 is 1185.3
(int)(tax * 100) is 1185
(int)(tax * 100) / 100.0 is 11.85

formatting numbers

Thus, the statement in line 11 displays the tax **11.85** with two digits after the decimal point. Note the expression **(int)(tax * 100) / 100.0** rounds down **tax** to two decimal places. If **tax** is **3.456**, **(int)(tax * 100) / 100.0** would be **3.45**. Can it be rounded up to two decimal places? Note any double value **x** can be rounded up to an integer using **(int)(x + 0.5)**. Thus, **tax** can be rounded up to two decimal places using **(int)(tax * 100 + 0.5) / 100.0**.



- 2.16.1** Can different types of numeric values be used together in a computation?
2.16.2 What does an explicit casting from a **double** to an **int** do with the fractional part of the **double** value? Does casting change the variable being cast?
2.16.3 Show the following output:

```

float f = 12.5F;
int i = (int)f;
System.out.println("f is " + f);
System.out.println("i is " + i);
```

- 2.16.4** If you change **(int)(tax * 100) / 100.0** to **(int)(tax * 100) / 100** in line 11 in Listing 2.8, what will be the output for the input purchase amount of **197.556**?
2.16.5 Show the output of the following code:
- ```

double amount = 5;
System.out.println(amount / 2);
System.out.println(5 / 2);
```
- 2.16.6** Write an expression that rounds up a **double** value in variable **d** to an integer.

## 2.17 Software Development Process

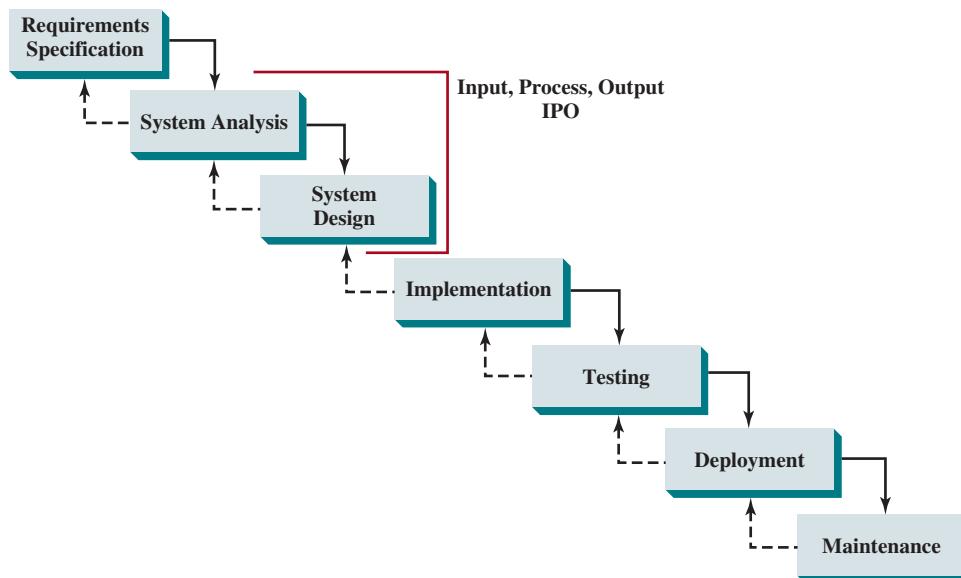
The software development life cycle is a multistage process that includes requirements specification, analysis, design, implementation, testing, deployment, and maintenance.

Developing a software product is an engineering process. Software products, no matter how large or how small, have the same life cycle: requirements specification, analysis, design, implementation, testing, deployment, and maintenance, as shown in Figure 2.9.



### VideoNote

Software development process



**FIGURE 2.9** At any stage of the software development life cycle, it may be necessary to go back to a previous stage to correct errors or deal with other issues that might prevent the software from functioning as expected.

*Requirements specification* is a formal process that seeks to understand the problem the software will address, and to document in detail what the software system needs to do. This phase involves close interaction between users and developers. Most of the examples in this book are simple, and their requirements are clearly stated. In the real world, however, problems are not always well defined. Developers need to work closely with their customers (the individuals or organizations that will use the software) and study the problem carefully to identify what the software needs to do.

requirements specification

*System analysis* seeks to analyze the data flow and to identify the system's input and output. When you perform analysis, it helps to identify what the output is first, then figure out what input data you need in order to produce the output.

system analysis

*System design* is to design a process for obtaining the output from the input. This phase involves the use of many levels of abstraction to break down the problem into manageable components and design strategies for implementing each component. You can view each component as a subsystem that performs a specific function of the system. The essence of system analysis and design is input, process, and output (IPO).

system design

*Implementation* involves translating the system design into programs. Separate programs are written for each component then integrated to work together. This phase requires the use of a programming language such as Java. The implementation involves coding, self-testing, and debugging (that is, finding errors, called *bugs*, in the code).

IOP  
implementation

*Testing* ensures the code meets the requirements specification and weeds out bugs. An independent team of software engineers not involved in the design and implementation of the product usually conducts such testing.

testing

deployment

*Deployment* makes the software available for use. Depending on the type of software, it may be installed on each user's machine, or installed on a server accessible on the Internet.

maintenance

*Maintenance* is concerned with updating and improving the product. A software product must continue to perform and improve in an ever-evolving environment. This requires periodic upgrades of the product to fix newly discovered bugs and incorporate changes.



VideoNote

Compute loan payments

To see the software development process in action, we will now create a program that computes loan payments. The loan can be a car loan, a student loan, or a home mortgage loan. For an introductory programming course, we focus on requirements specification, analysis, design, implementation, and testing.

### Stage 1: Requirements Specification

The program must satisfy the following requirements:

- It must let the user enter the interest rate, the loan amount, and the number of years for which payments will be made.
- It must compute and display the monthly payment and total payment amounts.

### Stage 2: System Analysis

The output is the monthly payment and total payment, which can be obtained using the following formulas:

$$\text{monthlyPayment} = \frac{\text{loanAmount} \times \text{monthlyInterestRate}}{1 - \frac{1}{(1 + \text{monthlyInterestRate})^{\text{numberOfYears} \times 12}}}$$

$$\text{totalPayment} = \text{monthlyPayment} \times \text{numberOfYears} \times 12$$

Therefore, the input needed for the program is the monthly interest rate, the length of the loan in years, and the loan amount.



#### Note

The requirements specification says the user must enter the annual interest rate, the loan amount, and the number of years for which payments will be made. During analysis, however, it is possible you may discover that input is not sufficient or some values are unnecessary for the output. If this happens, you can go back and modify the requirements specification.



#### Note

In the real world, you will work with customers from all walks of life. You may develop software for chemists, physicists, engineers, economists, and psychologists, and of course you will not have (or need) complete knowledge of all these fields. Therefore, you don't have to know how formulas are derived, but given the monthly interest rate, the number of years, and the loan amount, you can compute the monthly payment in this program. You will, however, need to communicate with customers and understand how a mathematical model works for the system.

### Stage 3: System Design

During system design, you identify the steps in the program.

Step 3.1. Prompt the user to enter the annual interest rate, the number of years, and the loan amount.

(The interest rate is commonly expressed as a percentage of the principal for a period of one year. This is known as the *annual interest rate*.)

Step 3.2. The input for the annual interest rate is a number in percent format, such as 4.5%. The program needs to convert it into a decimal by dividing it by **100**. To obtain the monthly interest rate from the annual interest rate, divide it by **12**, since a year has 12 months. Thus, to obtain the monthly interest rate in decimal format, you need to divide the annual interest rate in percentage by **1200**. For example, if the annual interest rate is 4.5%, then the monthly interest rate is  $4.5/1200 = 0.00375$ .

Step 3.3. Compute the monthly payment using the preceding formula.

Step 3.4. Compute the total payment, which is the monthly payment multiplied by **12** and multiplied by the number of years.

Step 3.5. Display the monthly payment and total payment.

#### Stage 4: Implementation

Implementation is also known as *coding* (writing the code). In the formula, you have to compute  $(1 + \text{monthlyInterestRate})^{\text{numberOfYears} \times 12}$ , which can be obtained using **Math.pow(1 + monthlyInterestRate, numberOfYears \* 12)**.

**Math.pow(a, b)** method

Listing 2.9 gives the complete program.

#### LISTING 2.9 ComputeLoan.java

```

1 import java.util.Scanner; import class
2
3 public class ComputeLoan { create a Scanner
4 public static void main(String[] args) {
5 // Create a Scanner
6 Scanner input = new Scanner(System.in);
7
8 // Enter annual interest rate in percentage, e.g., 7.25
9 System.out.print("Enter annual interest rate, e.g., 7.25: ");
10 double annualInterestRate = input.nextDouble(); enter interest rate
11
12 // Obtain monthly interest rate
13 double monthlyInterestRate = annualInterestRate / 1200;
14
15 // Enter number of years
16 System.out.print(
17 "Enter number of years as an integer, e.g., 5: ");
18 int numberOfYears = input.nextInt(); enter years
19
20 // Enter loan amount
21 System.out.print("Enter loan amount, e.g., 120000.95: ");
22 double loanAmount = input.nextDouble(); enter loan amount
23
24 // Calculate payment
25 double monthlyPayment = loanAmount * monthlyInterestRate / (1
26 - 1 / Math.pow(1 + monthlyInterestRate, numberOfYears * 12)); monthlyPayment
27 double totalPayment = monthlyPayment * numberOfYears * 12; totalPayment
28
29 // Display results
30 System.out.println("The monthly payment is $" +
31 (int)(monthlyPayment * 100) / 100.0); casting
32 System.out.println("The total payment is $" +
33 (int)(totalPayment * 100) / 100.0); casting
34 }
35 }
```



```
Enter annual interest rate, for example, 7.25: 5.75 ↵ Enter
Enter number of years as an integer, for example, 5: 15 ↵ Enter
Enter loan amount, for example, 120000.95: 250000 ↵ Enter
The monthly payment is $2076.02
The total payment is $373684.53
```



| variables           | Line# | 10 | 13   | 18              | 22 | 25     | 27           |
|---------------------|-------|----|------|-----------------|----|--------|--------------|
| annualInterestRate  |       |    | 5.75 |                 |    |        |              |
| monthlyInterestRate |       |    |      | 0.0047916666666 |    |        |              |
| numberOfYears       |       |    |      |                 | 15 |        |              |
| loanAmount          |       |    |      |                 |    | 250000 |              |
| monthlyPayment      |       |    |      |                 |    |        | 2076.0252175 |
| totalPayment        |       |    |      |                 |    |        | 373684.539   |

Line 10 reads the annual interest rate, which is converted into the monthly interest rate in line 13.

Choose the most appropriate data type for the variable. For example, `numberOfYears` is best declared as an `int` (line 18), although it could be declared as a `long`, `float`, or `double`. Note `byte` might be the most appropriate for `numberOfYears`. For simplicity, however, the examples in this booktext will use `int` for integer and `double` for floating-point values.

The formula for computing the monthly payment is translated into Java code in lines 25–27.

Casting is used in lines 31 and 33 to obtain a new `monthlyPayment` and `totalPayment` with two digits after the decimal points.

The program uses the `Scanner` class, imported in line 1. The program also uses the `Math` class, and you might be wondering why that class isn't imported into the program. The `Math` class is in the `java.lang` package, and all classes in the `java.lang` package are implicitly imported. Therefore, you don't need to explicitly import the `Math` class.

java.lang package

### Stage 5: Testing

After the program is implemented, test it with some sample input data and verify whether the output is correct. Some of the problems may involve many cases, as you will see in later chapters. For these types of problems, you need to design test data that cover all cases.



#### Tip

The system design phase in this example identified several steps. It is a good approach to code and test these steps incrementally by adding them one at a time. This approach, called incremental coding and testing, makes it much easier to pinpoint problems and debug the program.



#### 2.17.1 How would you write the following arithmetic expression?

$$\frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

## 2.18 Case Study: Counting Monetary Units

*This section presents a program that breaks a large amount of money into smaller units.*



Suppose you want to develop a program that changes a given amount of money into smaller monetary units. The program lets the user enter an amount as a `double` value representing a

total in dollars and cents, and outputs a report listing the monetary equivalent in the maximum number of dollars, quarters, dimes, nickels, and pennies, in this order, to result in the minimum number of coins.

Here are the steps in developing the program:

1. Prompt the user to enter the amount as a decimal number, such as **11.56**.
2. Convert the amount (e.g., **11.56**) into cents (**1156**).
3. Divide the cents by **100** to find the number of dollars. Obtain the remaining cents using the cents remainder **100**.
4. Divide the remaining cents by **25** to find the number of quarters. Obtain the remaining cents using the remaining cents remainder **25**.
5. Divide the remaining cents by **10** to find the number of dimes. Obtain the remaining cents using the remaining cents remainder **10**.
6. Divide the remaining cents by **5** to find the number of nickels. Obtain the remaining cents using the remaining cents remainder **5**.
7. The remaining cents are the pennies.
8. Display the result.

The complete program is given in Listing 2.10.

### **LISTING 2.10 ComputeChange.java**

```

1 import java.util.Scanner; import class
2
3 public class ComputeChange {
4 public static void main(String[] args) {
5 // Create a Scanner
6 Scanner input = new Scanner(System.in);
7
8 // Receive the amount
9 System.out.print(
10 "Enter an amount in double, for example 11.56: ");
11 double amount = input.nextDouble(); enter input
12
13 int remainingAmount = (int)(amount * 100); dollars
14
15 // Find the number of one dollars
16 int numberOfOneDollars = remainingAmount / 100;
17 remainingAmount = remainingAmount % 100; quarters
18
19 // Find the number of quarters in the remaining amount
20 int numberOfQuarters = remainingAmount / 25; quarters
21 remainingAmount = remainingAmount % 25;
22
23 // Find the number of dimes in the remaining amount
24 int numberOfDimes = remainingAmount / 10; dimes
25 remainingAmount = remainingAmount % 10;
26
27 // Find the number of nickels in the remaining amount
28 int numberOfNickels = remainingAmount / 5; nickels
29 remainingAmount = remainingAmount % 5;
30
31 // Find the number of pennies in the remaining amount
32 int numberOfPennies = remainingAmount; pennies
33

```

output

```

34 // Display results
35 System.out.println("Your amount " + amount + " consists of");
36 System.out.println(" " + numberOfOneDollars + " dollars");
37 System.out.println(" " + numberOfQuarters + " quarters ");
38 System.out.println(" " + numberOfDimes + " dimes");
39 System.out.println(" " + numberOfNickels + " nickels");
40 System.out.println(" " + numberOfPennies + " pennies");
41 }
42 }
```



Enter an amount in double, for example, 11.56: 11.56

Your amount 11.56 consists of

- 11 dollars
- 2 quarters
- 0 dimes
- 1 nickels
- 1 pennies



| variables          | line# | 11 | 13 | 16    | 17   | 20 | 21 | 24 | 25 | 28 | 29 | 32 |
|--------------------|-------|----|----|-------|------|----|----|----|----|----|----|----|
| amount             |       |    |    | 11.56 |      |    |    |    |    |    |    |    |
| remainingAmount    |       |    |    |       | 1156 | 56 | 6  | 6  | 1  |    |    |    |
| numberOfOneDollars |       |    |    |       |      | 11 |    |    |    |    |    |    |
| numberOfQuarters   |       |    |    |       |      |    | 2  |    |    |    |    |    |
| numberOfDimes      |       |    |    |       |      |    |    | 0  |    |    |    |    |
| numberOfNickels    |       |    |    |       |      |    |    |    | 1  |    |    |    |
| numberOfPennies    |       |    |    |       |      |    |    |    |    |    | 1  |    |

The variable `amount` stores the amount entered from the console (line 11). This variable is not changed, because the amount has to be used at the end of the program to display the results. The program introduces the variable `remainingAmount` (line 13) to store the changing remaining amount.

The variable `amount` is a `double` decimal representing dollars and cents. It is converted to an `int` variable `remainingAmount`, which represents all the cents. For instance, if `amount` is `11.56`, then the initial `remainingAmount` is `1156`. The division operator yields the integer part of the division, so `1156 / 100` is `11`. The remainder operator obtains the remainder of the division, so `1156 % 100` is `56`.

The program extracts the maximum number of singles from the remaining amount and obtains a new remaining amount in the variable `remainingAmount` (lines 16–17). It then extracts the maximum number of quarters from `remainingAmount` and obtains a new `remainingAmount` (lines 20–21). Continuing the same process, the program finds the maximum number of dimes, nickels, and pennies in the remaining amount.

loss of precision

One serious problem with this example is the possible loss of precision when casting a `double` amount to an `int` `remainingAmount`. This could lead to an inaccurate result. If you try to enter the amount `10.03`, `10.03 * 100` becomes `1002.999999999999`. You will find that the program displays `10` dollars and `2` pennies. To fix the problem, enter the amount as an integer value representing cents (see Programming Exercise 2.22).



**2.18.1** Show the output of Listing 2.10 with the input value `1.99`. Why does the program produce an incorrect result for the input `10.03`?

## 2.19 Common Errors and Pitfalls

*Common elementary programming errors often involve undeclared variables, uninitialized variables, integer overflow, unintended integer division, and round-off errors.*



### Common Error 1: Undeclared/Uninitialized Variables and Unused Variables

A variable must be declared with a type and assigned a value before using it. A common error is not declaring a variable or initializing a variable. Consider the following code:

```
double interestRate = 0.05;
double interest = interestrate * 45;
```

This code is wrong, because `interestRate` is assigned a value `0.05`; but `interestrate` has not been declared and initialized. Java is case sensitive, so it considers `interestRate` and `interestrate` to be two different variables.

If a variable is declared, but not used in the program, it might be a potential programming error. Therefore, you should remove the unused variable from your program. For example, in the following code, `taxRate` is never used. It should be removed from the code.

```
double interestRate = 0.05;
double taxRate = 0.05;
double interest = interestRate * 45;
System.out.println("Interest is " + interest);
```

If you use an IDE such as Eclipse and NetBeans, you will receive a warning on unused variables.

### Common Error 2: Integer Overflow

Numbers are stored with a limited numbers of digits. When a variable is assigned a value that is too large (*in size*) to be stored, it causes *overflow*. For example, executing the following statement causes overflow, because the largest value that can be stored in a variable of the `int` type is **2147483647**. **2147483648** will be too large for an `int` value:

```
int value = 2147483647 + 1;
// value will actually be -2147483648
```

what is overflow?

Likewise, executing the following statement also causes overflow, because the smallest value that can be stored in a variable of the `int` type is **-2147483648**. **-2147483649** is too large in size to be stored in an `int` variable.

```
int value = -2147483648 - 1;
// value will actually be 2147483647
```

what is underflow?

Java does not report warnings or errors on overflow, so be careful when working with integers close to the maximum or minimum range of a given type.

When a floating-point number is too small (i.e., too close to zero) to be stored, it causes *underflow*. Java approximates it to zero, so normally you don't need to be concerned about underflow.

### Common Error 3: Round-off Errors

A *round-off error*, also called a *rounding error*, is the difference between the calculated approximation of a number and its exact mathematical value. For example,  $1/3$  is approximately 0.333 if you keep three decimal places, and is 0.3333333 if you keep seven decimal places. Since the number of digits that can be stored in a variable is limited, round-off errors are inevitable. Calculations involving floating-point numbers are approximated because these numbers are not stored with complete accuracy. For example,

floating-point approximation

```
System.out.println(1.0 - 0.1 - 0.1 - 0.1 - 0.1 - 0.1);
```

displays **0.5000000000000001**, not **0.5**, and

```
System.out.println(1.0 - 0.9);
```

displays **0.0999999999999998**, not **0.1**. Integers are stored precisely. Therefore, calculations with integers yield a precise integer result.

#### Common Error 4: Unintended Integer Division

Java uses the same divide operator, namely `/`, to perform both integer and floating-point division. When two operands are integers, the `/` operator performs an integer division. The result of the operation is an integer. The fractional part is truncated. To force two integers to perform a floating-point division, make one of the integers into a floating-point number. For example, the code in (a) displays that average as **1** and the code in (b) displays that average as **1.5**.

```
int number1 = 1;
int number2 = 2;
double average = (number1 + number2) / 2;
System.out.println(average);
```

(a)

```
int number1 = 1;
int number2 = 2;
double average = (number1 + number2) / 2.0;
System.out.println(average);
```

(b)

#### Common Pitfall 1: Redundant Input Objects

New programmers often write the code to create multiple input objects for each input. For example, the following code in (a) reads an integer and a double value:

```
Scanner input = new Scanner(System.in);
System.out.print("Enter an integer: ");
int v1 = input.nextInt();

Scanner input1 = new Scanner(System.in); BAD CODE
System.out.print("Enter a double value: ");
double v2 = input1.nextDouble();
```

The code is not good. It creates two input objects unnecessarily and may lead to some subtle errors. You should rewrite the code in (b):

```
Scanner input = new Scanner(System.in); GOOD CODE
System.out.print("Enter an integer: ");
int v1 = input.nextInt();
System.out.print("Enter a double value: ");
double v2 = input.nextDouble();
```



**2.19.1** Can you declare a variable as `int` and later redeclare it as `double`?

**2.19.2** What is an integer overflow? Can floating-point operations cause overflow?

**2.19.3** Will overflow cause a runtime error?

**2.19.4** What is a round-off error? Can integer operations cause round-off errors? Can floating-point operations cause round-off errors?

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## CHAPTER SUMMARY

---

1. *Identifiers* are names for naming elements such as variables, constants, methods, classes, and packages in a program.
2. An identifier is a sequence of characters that consists of letters, digits, underscores (\_), and dollar signs (\$). An identifier must start with a letter or an underscore. It cannot start with a digit. An identifier cannot be a reserved word. An identifier can be of any length.
3. *Variables* are used to store data in a program. To declare a variable is to tell the compiler what type of data a variable can hold.
4. There are two types of **import** statements: *specific import* and *wildcard import*. The specific import specifies a single class in the import statement. The wildcard import imports all the classes in a package.
5. In Java, the equal sign (=) is used as the *assignment operator*.
6. A variable declared in a method must be assigned a value before it can be used.
7. A *named constant* (or simply a *constant*) represents permanent data that never changes.
8. A named constant is declared by using the keyword **final**.
9. Java provides four integer types (**byte**, **short**, **int**, and **long**) that represent integers of four different sizes.
10. Java provides two *floating-point types* (**float** and **double**) that represent floating-point numbers of two different precisions.
11. Java provides *operators* that perform numeric operations: + (addition), – (subtraction), \* (multiplication), / (division), and % (remainder).
12. Integer arithmetic (/) yields an integer result.
13. The numeric operators in a Java expression are applied the same way as in an arithmetic expression.

14. Java provides the augmented assignment operators `+=` (addition assignment), `-=` (subtraction assignment), `*=` (multiplication assignment), `/=` (division assignment), and `%=` (remainder assignment).
15. The *increment operator* (`++`) and the *decrement operator* (`--`) increment or decrement a variable by 1.
16. When evaluating an expression with values of mixed types, Java automatically converts the operands to appropriate types.
17. You can explicitly convert a value from one type to another using the `(type)value` notation.
18. Casting a variable of a type with a small range to a type with a larger range is known as *widening a type*.
19. Casting a variable of a type with a large range to a type with a smaller range is known as *narrowing a type*.
20. Widening a type can be performed automatically without explicit casting. Narrowing a type must be performed explicitly.
21. In computer science, midnight of January 1, 1970, is known as the *UNIX epoch*.



## QUIZ

---

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

MyProgrammingLab™

learn from examples

document analysis and design

even-numbered programming exercises



### Debugging Tip

The compiler usually gives a reason for a syntax error. If you don't know how to correct it, compare your program closely, character by character, with similar examples in the text.



### Pedagogical Note

Instructors may ask you to document your analysis and design for selected exercises. Use your own words to analyze the problem, including the input, output, and what needs to be computed, and describe how to solve the problem in pseudocode.



### Pedagogical Note

The solution to most even-numbered programming exercises are provided to students. These exercises serve as additional examples for a variety of programs. To maximize the benefits of these solutions, students should first attempt to complete the even-numbered exercises and then compare their solutions with the solutions provided in the book. Since the book provides a large number of programming exercises, it is sufficient if you can complete all even-numbered programming exercises.

## Sections 2.2–2.13

- 2.1** (*Convert mile to kilometer*) Write a program that reads a mile in a `double` value from the console, converts it to kilometers, and displays the result. The formula for the conversion is as follows:

$$1 \text{ mile} = 1.6 \text{ kilometers}$$

Here is a sample run:

Enter miles: 96   
96 miles is 153.6 kilometers



- 2.2** (*Compute the volume of a triangle*) Write a program that reads in the length of sides of an equilateral triangle and computes the area and volume using the following formulas:

$$\text{area} = \frac{\sqrt{3}}{4} (\text{length of sides})^2$$

$$\text{volume} = \text{area} \times \text{length}$$

Here is a sample run:

Enter length of the sides and height of the equilateral triangle: 3.5   
The area is 3.89  
The volume of the Triangular prism is 19.48



- 2.3** (*Convert meters into feet*) Write a program that reads a number in meters, converts it to feet, and displays the result. One meter is **3.2786** feet. Here is a sample run:

Enter a value for meter: 10   
10.0 meters is 32.786 feet



- 2.4** (*Convert square meter into ping*) Write a program that converts square meter into ping. The program prompts the user to enter a number in square meter, converts it to ping, and displays the result. One square meter is **0.3025** ping

Here is a sample run:

Enter a number in square meters: 50   
50.0 square meters is 15.125 pings



- \*2.5** (*Financial application: calculate tips*) Write a program that reads the subtotal and the gratuity rate and then computes the gratuity and total. For example, if the user enters **10** for subtotal and **12%** for gratuity rate, the program displays **\$1.2** as gratuity and **\$11.2** as total. Here is a sample run:

Enter the subtotal and a gratuity rate: 10 12   
The gratuity is \$1.2 and total is \$11.2



- \*\*2.6** (*Sum the digits in an integer*) Write a program that reads an integer between **0** and **1000** and adds all the digits in the integer. For example, if an integer is **932**, the sum of all its digits is **14**.

*Hint:* Use the **%** operator to extract digits, and use the **/** operator to remove the extracted digit. For instance, **932 % 10 = 2** and **932 / 10 = 93**.

Here is a sample run:

Enter a number between 0 and 1000: 999   
The sum of the digits is 27



- \*2.7** (*Find the number of years*) Write a program that prompts the user to enter the minutes (e.g., 1 billion), and displays the maximum number of years and remaining days for the minutes. For simplicity, assume that a year has 365 days. Here is a sample run:



```
Enter the number of minutes: 1000000000 ↵ Enter
1000000000 minutes is approximately 1902 years and 214 days
```

- \*2.8** (*Current time*) Listing 2.7, ShowCurrentTime.java, gives a program that displays the current time in GMT. Revise the program so it prompts the user to enter the time zone offset to GMT and displays the time in the specified time zone. Here is a sample run:



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

- 2.9** (*Physics: Motion*) Newton's equation of motion for distance covered given initial velocity, constant acceleration, and total time is described by the expression

$$s = ut + \frac{1}{2}at^2$$

Write a program that prompts the user to enter the initial velocity  $u$  in meters/second, time span  $t$  in seconds and acceleration  $a$  in meters/second<sup>2</sup>, and returns the distance covered. Here is a sample run



```
Enter u, t, and a: 3.5 4 6.5
The distance covered is 14.0
```

- 2.10** (*Science: calculating energy*) Write a program that calculates the energy needed to heat water from an initial temperature to a final temperature. Your program should prompt the user to enter the amount of water in kilograms and the initial and final temperatures of the water. The formula to compute the energy is

$$Q = M * (\text{finalTemperature} - \text{initialTemperature}) * 4184$$

where  $M$  is the weight of water in kilograms, initial and final temperatures are in degrees Celsius, and energy  $Q$  is measured in joules. Here is a sample run:



```
Enter the amount of water in kilograms: 55.5 ↵ Enter
Enter the initial temperature: 3.5 ↵ Enter
Enter the final temperature: 10.5 ↵ Enter
The energy needed is 1625484.0
```

- 2.11** (*Population projection*) Rewrite Programming Exercise 1.11 to prompt the user to enter the number of years and display the population after the number of years. Use the hint in Programming Exercise 1.11 for this program. Here is a sample run of the program:



```
Enter the number of years: 5 ↵ Enter
The population in 5 years is 325932969
```

- 2.12** (*Physics: finding runway length*) Given an airplane's acceleration  $a$  and take-off speed  $v$ , you can compute the minimum runway length needed for an airplane to take off using the following formula:

$$\text{length} = \frac{v^2}{2a}$$

Write a program that prompts the user to enter  $v$  in meters/second (m/s) and the acceleration  $a$  in meters/second squared (m/s<sup>2</sup>), then, displays the minimum runway length.

```
Enter speed and acceleration: 60 3.5 [Enter]
The minimum runway length for this airplane is 514.286
```



- \*\*2.13** (*Financial application: compound value*) Suppose you save \$100 each month in a savings account with annual interest rate 3.75%. Thus, the monthly interest rate is  $0.0375/12 = 0.003125$ . After the first month, the value in the account becomes

$$100 * (1 + 0.003125) = 100.3125$$

After the second month, the value in the account becomes

$$(100 + 100.3125) * (1 + 0.003125) = 200.938$$

After the third month, the value in the account becomes

$$(100 + 200.938) * (1 + 0.003125) = 301.878$$

and so on.

Write a program that prompts the user to enter a monthly saving amount and displays the account value after the sixth month. (In Exercise 5.30, you will use a loop to simplify the code and display the account value for any month.)

```
Enter the monthly saving amount: 100 [Enter]
After the first month, the account value is 100.3125
After the second month, the account value is 200.9384765625
After the third month, the account value is 301.8789093017578
After the sixth month, the account value is 606.5967866995037
```



- \*2.14** (*Health application: computing BMI*) Body Mass Index (BMI) is a measure of health on weight. It can be calculated by taking your weight in kilograms and dividing, by the square of your height in meters. Write a program that prompts the user to enter a weight in pounds and height in inches and displays the BMI. Note one pound is 0.45359237 kilograms and one inch is 0.0254 meters. Here is a sample run:

```
Enter weight in pounds: 95.5 [Enter]
Enter height in inches: 50 [Enter]
BMI is 26.8573
```



**VideoNote**  
Compute BMI



- 2.15** (*Geometry: distance of two points*) Write a program that prompts the user to enter two points  $(x_1, y_1)$  and  $(x_2, y_2)$  and displays their distance. The formula for computing the distance is  $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ . Note you can use `Math.pow(a, 0.5)` to compute  $\sqrt{a}$ . Here is a sample run:

```
Enter x1 and y1: 1.5 -3.4 [Enter]
Enter x2 and y2: 4 5 [Enter]
The distance between the two points is 8.764131445842194
```



- 2.16** (*Geometry: area of a hexagon*) Write a program that prompts the user to enter the side of a hexagon and displays its area. The formula for computing the area of a hexagon is

$$\text{Area} = \frac{3\sqrt{3}}{2}s^2,$$

where  $s$  is the length of a side. Here is a sample run:



Enter the length of the side: 5.5

The area of the hexagon is 78.5918

- \*2.17** (*Science: wind-chill temperature*) How cold is it outside? The temperature alone is not enough to provide the answer. Other factors including wind speed, relative humidity, and sunshine play important roles in determining coldness outside. In 2001, the National Weather Service (NWS) implemented the new wind-chill temperature to measure the coldness using temperature and wind speed. The formula is

$$t_{wc} = 35.74 + 0.6215t_a - 35.75v^{0.16} + 0.4275t_a v^{0.16}$$

where  $t_a$  is the outside temperature measured in degrees Fahrenheit,  $v$  is the speed measured in miles per hour, and  $t_{wc}$  is the wind-chill temperature. The formula cannot be used for wind speeds below 2 mph or temperatures below  $-58^{\circ}\text{F}$  or above  $41^{\circ}\text{F}$ .

Write a program that prompts the user to enter a temperature between  $-58^{\circ}\text{F}$  and  $41^{\circ}\text{F}$  and a wind speed greater than or equal to 2 then displays the wind-chill temperature. Use `Math.pow(a, b)` to compute  $v^{0.16}$ . Here is a sample run:



Enter the temperature in Fahrenheit between  $-58^{\circ}\text{F}$  and  $41^{\circ}\text{F}$ :  
5.3

Enter the wind speed ( $\geq 2$ ) in miles per hour: 6   
The wind chill index is -5.56707

- 2.18** (*Print a table*) Write a program that displays the following table. Calculate the middle point of two points.

| a       | b       | Middle Point |
|---------|---------|--------------|
| (0, 0)  | (2, 1)  | (1.0, 0.5)   |
| (1, 4)  | (4, 2)  | (2.5, 3.0)   |
| (2, 7)  | (6, 3)  | (4.0, 5.0)   |
| (3, 9)  | (10, 5) | (6.5, 7.0)   |
| (4, 11) | (12, 7) | (8.0, 9.0)   |

- \*2.19** (*Geometry: area of a triangle*) Write a program that prompts the user to enter three points,  $(x_1, y_1)$ ,  $(x_2, y_2)$ , and  $(x_3, y_3)$ , of a triangle then displays its area. The formula for computing the area of a triangle is

$$s = (\text{side1} + \text{side2} + \text{side3})/2;$$

$$\text{area} = \sqrt{s(s - \text{side1})(s - \text{side2})(s - \text{side3})}$$

Here is a sample run:



Enter the coordinates of three points separated by spaces

like  $x_1 \ y_1 \ x_2 \ y_2 \ x_3 \ y_3$ : 1.5 -3.4 4.6 5 9.5 -3.4

The area of the triangle is 33.6

**Sections 2.13–2.18**

- \*2.20** (*Financial application: calculate interest*) If you know the balance and the annual percentage interest rate, you can compute the interest on the next monthly payment using the following formula:

$$\text{interest} = \text{balance} \times (\text{annualInterestRate}/1200)$$

Write a program that reads the balance and the annual percentage interest rate and displays the interest for the next month. Here is a sample run:

```
Enter balance and interest rate (e.g., 3 for 3%): 1000 3.5 ↴Enter
The interest is 2.91667
```



- \*2.21** (*Financial application: calculate future investment value*) Write a program that reads in investment amount, annual interest rate, and number of years and displays the future investment value using the following formula:

$$\text{futureInvestmentValue} = \\ \text{investmentAmount} \times (1 + \text{monthlyInterestRate})^{\text{numberOfYears} * 12}$$

For example, if you enter amount **1000**, annual interest rate **3.25%**, and number of years **1**, the future investment value is **1032.98**.

Here is a sample run:

```
Enter investment amount: 1000.56 ↴Enter
Enter annual interest rate in percentage: 4.25 ↴Enter
Enter number of years: 1 ↴Enter
Future value is $1043.92
```



- \*2.22** (*Financial application: monetary units*) Rewrite Listing 2.10, ComputeChange.java, to fix the possible loss of accuracy when converting a **double** value to an **int** value. Enter the input as an integer whose last two digits represent the cents. For example, the input **1156** represents **11** dollars and **56** cents.

- \*2.23** (*Cost of driving*) Write a program that prompts the user to enter the distance to drive, the fuel efficiency of the car in miles per gallon, and the price per gallon then displays the cost of the trip. Here is a sample run:

```
Enter the driving distance: 900.5 ↴Enter
Enter miles per gallon: 25.5 ↴Enter
Enter price per gallon: 3.55 ↴Enter
The cost of driving is $125.36
```

**Note**

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