stream and flush the stream after each newline. For example, this line of code creates a **PrintWriter** that is connected to console output:

```
PrintWriter pw = new PrintWriter(System.out, true);
```

The following application illustrates using a **PrintWriter** to handle console output:

```
// Demonstrate PrintWriter
import java.io.*;

public class PrintWriterDemo {
  public static void main(String args[]) {
    PrintWriter pw = new PrintWriter(System.out, true);

    pw.println("This is a string");
    int i = -7;
    pw.println(i);
    double d = 4.5e-7;
    pw.println(d);
  }
}
```

The output from this program is shown here:

```
This is a string
-7
4.5E-7
```

Remember, there is nothing wrong with using **System.out** to write simple text output to the console when you are learning Java or debugging your programs. However, using a **PrintWriter** makes your real-world applications easier to internationalize. Because no advantage is gained by using a **PrintWriter** in the sample programs shown in this book, we will continue to use **System.out** to write to the console.

Reading and Writing Files

Java provides a number of classes and methods that allow you to read and write files. Before we begin, it is important to state that the topic of file I/O is quite large and file I/O is examined in detail in Part II. The purpose of this section is to introduce the basic techniques that read from and write to a file. Although bytes streams are used, these techniques can be adapted to the character-based streams.

Two of the most often-used stream classes are **FileInputStream** and **FileOutputStream**, which create byte streams linked to files. To open a file, you simply create an object of one of these classes, specifying the name of the file as an argument to the constructor. Although both classes support additional constructors, the following are the forms that we will be using:

FileInputStream(String *fileName*) throws FileNotFoundException

FileOutputStream(String *fileName*) throws FileNotFoundException

Here, *fileName* specifies the name of the file that you want to open. When you create an input stream, if the file does not exist, then **FileNotFoundException** is thrown. For output streams, if the file cannot be opened or created, then **FileNotFoundException** is thrown. **FileNotFoundException** is a subclass of **IOException**. When an output file is opened, any preexisting file by the same name is destroyed.

NOTE

In situations in which a security manager is present, several of the file classes, including **FileInputStream** and **FileOutputStream**, will throw a **SecurityException** if a security violation occurs when attempting to open a file. By default, applications run via **java** do not use a security manager. For that reason, the I/O examples in this book do not need to watch for a possible **SecurityException**. However, other types of applications (such as applets) will use the security manager, and file I/O performed by such an application could generate a **SecurityException**. In that case, you will need to appropriately handle this exception.

When you are done with a file, you must close it. This is done by calling the **close( )** method, which is implemented by both **FileInputStream** and **FileOutputStream**. It is shown here:

void close( ) throws IOException

Closing a file releases the system resources allocated to the file, allowing them to be used by another file. Failure to close a file can result in "memory leaks" because of unused resources remaining allocated.

NOTE

Beginning with JDK 7, the **close( )** method is specified by the **AutoCloseable** interface in **java.lang**. **AutoCloseable** is inherited by the **Closeable** interface in

java.io. Both interfaces are implemented by the stream classes, including **FileInputStream** and **FileOutputStream**.

Before moving on, it is important to point out that there are two basic approaches that you can use to close a file when you are done with it. The first is the traditional approach, in which **close( )** is called explicitly when the file is no longer needed. This is the approach used by all versions of Java prior to JDK 7 and is, therefore, found in all legacy code. The second is to use the new **try**-with-resources statement added by JDK 7, which automatically closes a file when it is no longer needed. In this approach, no explicit call to **close( )** is executed. Since there are millions of lines of pre-JDK 7 legacy code that are still being used and maintained, it is important that you know and understand the traditional approach. Therefore, we will begin with it. The new automated approach is described in the following section.

To read from a file, you can use a version of **read( )** that is defined within **FileInputStream**. The one that we will use is shown here:

int read( ) throws IOException

Each time that it is called, it reads a single byte from the file and returns the byte as an integer value. **read( )** returns –1 when the end of the file is encountered. It can throw an **IOException**.

The following program uses **read( )** to input and display the contents of a file that contains ASCII text. The name of the file is specified as a command-line argument.

```
/* Display a text file.
   To use this program, specify the name
   of the file that you want to see.
   For example, to see a file called TEST.TXT,
   use the following command line.

   java ShowFile TEST.TXT
*/

import java.io.*;

class ShowFile {
  public static void main(String args[])
  {
    int i;
    FileInputStream fin;

    // First, confirm that a filename has been specified.
    if(args.length != 1) {
      System.out.println("Usage: ShowFile filename");
      return;
    }

    // Attempt to open the file.
    try {
      fin = new FileInputStream(args[0]);
    } catch(FileNotFoundException e) {
      System.out.println("Cannot Open File");
      return;
    }


    // At this point, the file is open and can be read.
    // The following reads characters until EOF is encountered.
    try {
      do {
        i = fin.read();
        if(i != -1) System.out.print((char) i);
      } while(i != -1);
    } catch(IOException e) {
      System.out.println("Error Reading File");
   }

    // Close the file.
    try {
      fin.close();
    } catch(IOException e) {
        System.out.println("Error Closing File");
    }
  }
}
```

In the program, notice the **try/catch** blocks that handle the I/O errors that might occur. Each I/O operation is monitored for exceptions, and if an exception occurs, it is handled. Be aware that in simple programs or example code, it is common to see I/O exceptions simply thrown out of **main( )**, as was done in the earlier console I/O examples. Also, in some real-world code, it can be helpful to let an exception propagate to a calling routine to let the caller know that an I/O operation failed. However, most of the file I/O examples in this book handle all I/O exceptions explicitly, as shown, for the sake of illustration.

Although the preceding example closes the file stream after the file is read, there is a variation that is often useful. The variation is to call **close( )** within a **finally** block. In this approach, all of the methods that access the file are contained within a **try** block, and the **finally** block is used to close the file. This way, no matter how the **try** block terminates, the file is closed. Assuming the preceding example, here is how the **try** block that reads the file can be recoded:

```
try {
  do {
    i = fin.read();
    if(i != -1) System.out.print((char) i);
  } while(i != -1);
} catch(IOException e) {
  System.out.println("Error Reading File");
} finally {
  // Close file on the way out of the try block.
  try {
    fin.close();
  } catch(IOException e) {
    System.out.println("Error Closing File");
  }
}
```

Although not an issue in this case, one advantage to this approach in general is that if the code that accesses a file terminates because of some non-I/O related exception, the file is still closed by the **finally** block.

Sometimes it's easier to wrap the portions of a program that open the file and access the file within a single **try** block (rather than separating the two) and then use a **finally** block to close the file. For example, here is another way to write the **ShowFile** program:

```
/* Display a text file.
   To use this program, specify the name
   of the file that you want to see.
   For example, to see a file called TEST.TXT,
   use the following command line.

   java ShowFile TEST.TXT

   This variation wraps the code that opens and
   accesses the file within a single try block.
   The file is closed by the finally block.
*/

import java.io.*;
class ShowFile {
  public static void main(String args[])
  {
    int i;
    FileInputStream fin = null;

    // First, confirm that a filename has been specified.
    if(args.length != 1) {
      System.out.println("Usage: ShowFile filename");
      return;
    }


    // The following code opens a file, reads characters until EOF
    // is encountered, and then closes the file via a finally block.
    try {
      fin = new FileInputStream(args[0]);

      do {
        i = fin.read();
        if(i != -1) System.out.print((char) i);
      } while(i != -1);

    } catch(FileNotFoundException e) {
      System.out.println("File Not Found.");
    } catch(IOException e) {
      System.out.println("An I/O Error Occurred");
    } finally {
      // Close file in all cases.
      try {
        if(fin != null) fin.close();
      } catch(IOException e) {
        System.out.println("Error Closing File");
      }
    }
  }
}
```

In this approach, notice that **fin** is initialized to **null**. Then, in the **finally** block, the file is closed only if **fin** is not **null**. This works because **fin** will be non-**null** only if the file is successfully opened. Thus, **close( )** is not called if an exception occurs while opening the file.

It is possible to make the **try/catch** sequence in the preceding example a bit more compact. Because **FileNotFoundException** is a subclass of **IOException**, it need not be caught separately. For example, here is the sequence recoded to eliminate catching **FileNotFoundException**. In this case, the standard exception message, which describes the error, is displayed.

```
try {
  fin = new FileInputStream(args[0]);

  do {
    i = fin.read();
    if(i != -1) System.out.print((char) i);
  } while(i != -1);

} catch(IOException e) {
  System.out.println("I/O Error: " + e);
} finally {
  // Close file in all cases.
  try {
    if(fin != null) fin.close();
  } catch(IOException e) {
    System.out.println("Error Closing File");
  }
}
```

In this approach, any error, including an error opening the file, is simply handled by the single **catch** statement. Because of its compactness, this approach is used by many of the I/O examples in this book. Be aware, however, that this approach is not appropriate in cases in which you want to deal separately with a failure to open a file, such as might be caused if a user mistypes a filename. In such a situation, you might want to prompt for the correct name, for example, before entering a **try** block that accesses the file.

To write to a file, you can use the **write( )** method defined by **FileOutputStream**. Its simplest form is shown here:

void write(int *byteval*) throws IOException

This method writes the byte specified by *byteval* to the file. Although *byteval* is declared as an integer, only the low-order eight bits are written to the file. If an error occurs during writing, an **IOException** is thrown. The next example uses **write( )** to copy a file:

```
/* Copy a file.
   To use this program, specify the name
   of the source file and the destination file.
   For example, to copy a file called FIRST.TXT
   to a file called SECOND.TXT, use the following
   command line.

   java CopyFile FIRST.TXT SECOND.TXT
*/

import java.io.*;

class CopyFile {
  public static void main(String args[]) throws IOException
  {
    int i;
    FileInputStream fin = null;
    FileOutputStream fout = null;

    // First, confirm that both files have been specified.
    if(args.length != 2) {
      System.out.println("Usage: CopyFile from to");
      return;
    }


    // Copy a File.
    try {
      // Attempt to open the files.
      fin = new FileInputStream(args[0]);
      fout = new FileOutputStream(args[1]);

      do {
        i = fin.read();
        if(i != -1) fout.write(i);
      } while(i != -1);

    } catch(IOException e) {
      System.out.println("I/O Error: " + e);
    } finally {
      try {
        if(fin != null) fin.close();
      } catch(IOException e2) {
        System.out.println("Error Closing Input File");
      }
      try {
        if(fout != null) fout.close();
      } catch(IOException e2) {
        System.out.println("Error Closing Output File");
      }
    }
  }
}
```

In the program, notice that two separate **try** blocks are used when closing the files. This ensures that both files are closed, even if the call to **fin.close( )** throws an exception.

In general, notice that all potential I/O errors are handled in the preceding two programs by the use of exceptions. This differs from some computer languages that use error codes to report file errors. Not only do exceptions make file handling cleaner, but they also enable Java to easily differentiate the end-of-file condition from file errors when input is being performed. In C/C++, many input functions return the same value when an error occurs and when the end of the file is reached. (That is, in C/C++, an EOF condition often is mapped to the same value as an input error.) This usually means that the programmer must include extra program statements to determine which event actually occurred. In Java, input errors are passed to your program via exceptions, not by values returned by **read( )**. Thus, when **read( )** returns –1, it means only one thing: the end of the file has been encountered.

Automatically Closing a File

In the preceding section, the example programs have made explicit calls to **close( )** to close a file once it is no longer needed. As mentioned, this is the way files were closed when using versions of Java prior to JDK 7. Although this approach is still valid and useful, JDK 7 adds a new feature that offers another way to manage resources, such as file streams, by automating the closing process. This feature, sometimes referred to as *automatic resource management*, or *ARM* for short, is based on an expanded version of the **try** statement. The principal advantage of automatic resource management is that it prevents situations in which a file (or other resource) is inadvertently not released after it is no longer needed. As explained, forgetting to close a file can result in memory leaks, and could lead to other problems.

Automatic resource management is based on an expanded form of the **try** statement. Here is its general form:

```
try (resource-specification) {
  // use the resource
}
```

Here, *resource-specification* is a statement that declares and initializes a resource, such as a file stream. It consists of a variable declaration in which the variable is initialized with a reference to the object being managed. When the **try** block ends, the resource is automatically released. In the case of a file, this means that the file is automatically closed. (Thus, there is no need to call **close( )** explicitly.) Of course, this form of **try** can also include **catch** and **finally** clauses. This new form of **try** is called the ***try**-with-resources* statement.

The **try**-with-resources statement can be used only with those resources that implement the **AutoCloseable** interface defined by **java.lang**. This interface defines the **close( )** method. **AutoCloseable** is inherited by the **Closeable** interface in **java.io**. Both interfaces are implemented by the stream classes. Thus, **try**-with-resources can be used when working with streams, including file streams.

As a first example of automatically closing a file, here is a reworked version of the **ShowFile** program that uses it:

```
/* This version of the ShowFile program uses a try-with-resources
   statement to automatically close a file after it is no longer needed.

   Note: This code requires JDK 7 or later.
*/

import java.io.*;

class ShowFile {
  public static void main(String args[])
  {
    int i;

    // First, confirm that a filename has been specified.
    if(args.length != 1) {
      System.out.println("Usage: ShowFile filename");
      return;
    }

    // The following code uses a try-with-resources statement to open
    // a file and then automatically close it when the try block is left.
    try(FileInputStream fin = new FileInputStream(args[0])) {

      do {
        i = fin.read();
        if(i != -1) System.out.print((char) i);
      } while(i != -1);

    }   catch(FileNotFoundException e) {
        System.out.println("File Not Found.");
    }   catch(IOException e) {
        System.out.println("An I/O Error Occurred");
    }

  }
}
```

In the program, pay special attention to how the file is opened within the **try** statement:

```
try(FileInputStream fin = new FileInputStream(args[0])) {
```

Notice how the resource-specification portion of the **try** declares a **FileInputStream** called **fin**, which is then assigned a reference to the file opened by its constructor. Thus, in this version of the program, the variable **fin** is local to the **try** block, being created when the **try** is entered. When the **try** is left, the stream associated with **fin** is automatically closed by an implicit call to **close( )**. You don't need to call **close( )** explicitly, which means that you can't forget to close the file. This is a key advantage of using **try**-with-resources.

It is important to understand that the resource declared in the **try** statement is implicitly **final**. This means that you can't assign to the resource after it has been created. Also, the scope of the resource is limited to the **try**-with-resources statement.

You can manage more than one resource within a single **try** statement. To do so, simply separate each resource specification with a semicolon. The following program shows an example. It reworks the **CopyFile** program shown earlier so that it uses a single **try**-with-resources statement to manage both **fin** and **fout**.

```
/* A version of CopyFile that uses try-with-resources.
   It demonstrates two resources (in this case files) being
   managed by a single try statement.
*/

import java.io.*;

class CopyFile {
  public static void main(String args[]) throws IOException
  {
    int i;

    // First, confirm that both files have been specified.
    if(args.length != 2) {
      System.out.println("Usage: CopyFile from to");
      return;
    }

    // Open and manage two files via the try statement.
    try (FileInputStream fin = new FileInputStream(args[0]);
         FileOutputStream fout = new FileOutputStream(args[1]))
    {

      do  {
         i = fin.read();
         if(i != -1) fout.write(i);
```

```
      }  while(i != -1);

    } catch(IOException e) {
      System.out.println("I/O Error: " + e);
    }
  }
}
```

In this program, notice how the input and output files are opened within the **try** block:

```
try (FileInputStream fin = new FileInputStream(args[0]);
     FileOutputStream fout = new FileOutputStream(args[1]))
{
  // …
```

After this **try** block ends, both **fin** and **fout** will have been closed. If you compare this version of the program to the previous version, you will see that it is much shorter. The ability to streamline source code is a side-benefit of automatic resource management.

There is one other aspect to **try**-with-resources that needs to be mentioned. In general, when a **try** block executes, it is possible that an exception inside the **try** block will lead to another exception that occurs when the resource is closed in a **finally** clause. In the case of a “normal” **try** statement, the original exception is lost, being preempted by the second exception. However, when using **try**-with-resources, the second exception is *suppressed*. It is not, however, lost. Instead, it is added to the list of suppressed exceptions associated with the first exception. The list of suppressed exceptions can be obtained by using the **getSuppressed( )** method defined by **Throwable**.

Because of the benefits that the **try**-with-resources statement offers, it will be used by many, but not all, of the example programs in this edition of this book. Some of the examples will still use the traditional approach to closing a resource. There are several reasons for this. First, there are millions of lines of legacy code in widespread use that rely on the traditional approach. It is important that all Java programmers be fully versed in, and comfortable with, the traditional approach when maintaining this older code. Second, because not all project development will immediately switch to a new version of the JDK, it is likely that some programmers will continue to work in a pre-JDK 7 environment for a period of time. In such situations, the expanded form of **try** is not available. Finally, there may be cases in which explicitly closing a resource is more appropriate than the automated approach. For these reasons, some of the examples in this book will continue to use the traditional approach, explicitly calling **close( )**. In addition to illustrating the traditional technique, these examples can also be compiled and run by all readers in all environments.

REMEMBER

A few examples in this book use the traditional approach to closing files as a means of illustrating this technique, which is widely used in legacy code. However, for new code, you will usually want to use the new automated approach supported by the **try**-with-resources statement just described.

Applet Fundamentals

All of the preceding examples in this book have been Java console-based applications. However, these types of applications constitute only one class of Java programs. Another type of program is the applet. As mentioned in Chapter 1, *applets* are small applications that are accessed on an Internet server, transported over the Internet, automatically installed, and run as part of a web document. After an applet arrives on the client, it has limited access to resources so that it can produce a graphical user interface and run complex computations without introducing the risk of viruses or breaching data integrity.

Many of the issues connected with the creation and use of applets are found in Part II, when the **applet** package is examined, and also when Swing is described in Part III. However, the fundamentals connected to the creation of an applet are presented here, because applets are not structured in the same way as the programs that have been used thus far. As you will see, applets differ from console-based applications in several key areas.

Let's begin with the simple applet shown here:

```
import java.awt.*;
import java.applet.*;

public class SimpleApplet extends Applet {
  public void paint(Graphics g) {
    g.drawString("A Simple Applet", 20, 20);
  }
}
```

This applet begins with two **import** statements. The first imports the Abstract Window