Module 4

Introducing Classes, Objects, and Methods

CRITICAL SKILLS

4.1 Know the fundamentals of the class

4.2 Understand how objects are created

4.3 Understand how reference variables are assigned

4.4 Create methods, return values, and use parameters

4.5 Use the **return** keyword

4.6 Return a value from a method

4.7 Add parameters to a method

4.8 Utilize constructors

4.9 Create parameterized constructors

4.10 Understand **new**

4.11 Understand garbage collection and finalizers

4.12 Use the **this** keyword

Before you can go much further in your study of Java, you need to learn about the class. The class is the essence of Java. It is the foundation upon which the entire Java language is built because the class defines the nature of an object. As such, the class forms the basis for object-oriented programming in Java. Within a class are defined data and code that acts upon that data. The code is contained in methods. Because classes, objects, and methods are fundamental to Java, they are introduced in this module. Having a basic understanding of these features will allow you to write more sophisticated programs and better understand certain key Java elements described in the following module.

CRITICAL SKILL
4.1

Class Fundamentals

Since all Java program activity occurs within a class, we have been using classes since the start of this book. Of course, only extremely simple classes have been used, and we have not taken advantage of the majority of their features. As you will see, classes are substantially more powerful than the limited ones presented so far.

Let's begin by reviewing the basics. A class is a template that defines the form of an object. It specifies both the data and the code that will operate on that data. Java uses a class specification to construct *objects*. Objects are *instances* of a class. Thus, a class is essentially a set of plans that specify how to build an object. It is important to be clear on one issue: a class is a logical abstraction. It is not until an object of that class has been created that a physical representation of that class exists in memory.

One other point: recall that the methods and variables that constitute a class are called *members* of the class. The data members are also referred to as *instance variables*.

The General Form of a Class

When you define a class, you declare its exact form and nature. You do this by specifying the instance variables that it contains and the methods that operate on them. Although very simple classes might contain only methods or only instance variables, most real-world classes contain both.

A class is created by using the keyword **class**. The general form of a **class** definition is shown here:

```
class classname {
    // declare instance variables
    type var1;
    type var2;
    // ...
    type varN;

    // declare methods
    type method1(parameters) {
```

```
        // body of method
    }
    type method2(parameters) {
        // body of method
    }
        // ...
    type methodN(parameters) {
        // body of method
    }
}
```

Although there is no syntactic rule that enforces it, a well-designed class should define one and only one logical entity. For example, a class that stores names and telephone numbers will not normally also store information about the stock market, average rainfall, sunspot cycles, or other unrelated information. The point here is that a well-designed class groups logically connected information. Putting unrelated information into the same class will quickly destructure your code!

Up to this point, the classes that we have been using have only had one method: **main( )**. Soon you will see how to create others. However, notice that the general form of a class does not specify a **main( )** method. A **main( )** method is required only if that class is the starting point for your program. Also, applets don't require a **main( )**.

Defining a Class

To illustrate classes we will develop a class that encapsulates information about vehicles, such as cars, vans, and trucks. This class is called **Vehicle**, and it will store three items of information about a vehicle: the number of passengers that it can carry, its fuel capacity, and its average fuel consumption (in miles per gallon).

The first version of **Vehicle** is shown next. It defines three instance variables: **passengers**, **fuelcap**, and **mpg**. Notice that **Vehicle** does not contain any methods. Thus, it is currently a data-only class. (Subsequent sections will add methods to it.)

```
class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon
}
```

A **class** definition creates a new data type. In this case, the new data type is called **Vehicle**. You will use this name to declare objects of type **Vehicle**. Remember that a **class** declaration is only a type description; it does not create an actual object. Thus, the preceding code does not cause any objects of type **Vehicle** to come into existence.

To actually create a **Vehicle** object, you will use a statement like the following:

```
Vehicle minivan = new Vehicle(); // create a Vehicle object called minivan
```

After this statement executes, **minivan** will be an instance of **Vehicle**. Thus, it will have "physical" reality. For the moment, don't worry about the details of this statement.

Each time you create an instance of a class, you are creating an object that contains its own copy of each instance variable defined by the class. Thus, every **Vehicle** object will contain its own copies of the instance variables **passengers**, **fuelcap**, and **mpg**. To access these variables, you will use the dot (.) operator. The *dot operator* links the name of an object with the name of a member. The general form of the dot operator is shown here:

object.member

Thus, the object is specified on the left, and the member is put on the right. For example, to assign the **fuelcap** variable of **minivan** the value 16, use the following statement:

```
minivan.fuelcap = 16;
```

In general, you can use the dot operator to access both instance variables and methods.

Here is a complete program that uses the **Vehicle** class:

```
/* A program that uses the Vehicle class.

   Call this file VehicleDemo.java
*/
class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon
}

// This class declares an object of type Vehicle.
class VehicleDemo {
  public static void main(String args[]) {
    Vehicle minivan = new Vehicle();
    int range;

    // assign values to fields in minivan
    minivan.passengers = 7;
    minivan.fuelcap = 16; ←—— Notice the use of the dot
    minivan.mpg = 21;          operator to access a member.

    // compute the range assuming a full tank of gas
    range = minivan.fuelcap * minivan.mpg;
```

```
    System.out.println("Minivan can carry " + minivan.passengers +
                       " with a range of " + range);
  }
}
```

You should call the file that contains this program **VehicleDemo.java** because the **main( )** method is in the class called **VehicleDemo**, not the class called **Vehicle**. When you compile this program, you will find that two **.class** files have been created, one for **Vehicle** and one for **VehicleDemo**. The Java compiler automatically puts each class into its own **.class** file. It is not necessary for both the **Vehicle** and the **VehicleDemo** class to be in the same source file. You could put each class in its own file, called **Vehicle.java** and **VehicleDemo.java**, respectively.

To run this program, you must execute **VehicleDemo.class**. The following output is displayed:

```
Minivan can carry 7 with a range of 336
```

Before moving on, let's review a fundamental principle: each object has its own copies of the instance variables defined by its class. Thus, the contents of the variables in one object can differ from the contents of the variables in another. There is no connection between the two objects except for the fact that they are both objects of the same type. For example, if you have two **Vehicle** objects, each has its own copy of **passengers**, **fuelcap**, and **mpg**, and the contents of these can differ between the two objects. The following program demonstrates this fact. (Notice that the class with **main( )** is now called **TwoVehicles**.)

```
// This program creates two Vehicle objects.

class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon
}

// This class declares an object of type Vehicle.
class TwoVehicles {
  public static void main(String args[]) {
    Vehicle minivan = new Vehicle();
    Vehicle sportscar = new Vehicle();

    int range1, range2;

    // assign values to fields in minivan
    minivan.passengers = 7;
    minivan.fuelcap = 16;
    minivan.mpg = 21;
```

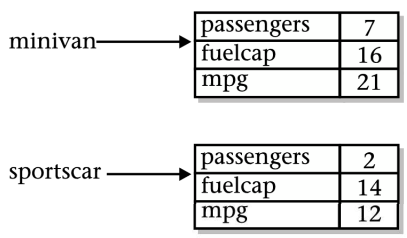
Remember, **minivan** and **sportscar** refer to separate objects.

```
    // assign values to fields in sportscar
    sportscar.passengers = 2;
    sportscar.fuelcap = 14;
    sportscar.mpg = 12;

    // compute the ranges assuming a full tank of gas
    range1 = minivan.fuelcap * minivan.mpg;
    range2 = sportscar.fuelcap * sportscar.mpg;

    System.out.println("Minivan can carry " + minivan.passengers +
                       " with a range of " + range1);

    System.out.println("Sportscar can carry " + sportscar.passengers +
                       " with a range of " + range2);
  }
}
```

The output produced by this program is shown here:

```
Minivan can carry 7 with a range of 336
Sportscar can carry 2 with a range of 168
```

As you can see, **minivan**'s data is completely separate from the data contained in **sportscar**. The following illustration depicts this situation.



Progress Check

1. A class contains what two things?
2. What operator is used to access the members of a class through an object?
3. Each object has its own copies of the class's _____________.

1. Code and data. In Java, this means methods and instance variables.
2. The dot operator.
3. instance variables

CRITICAL SKILL 4.2

How Objects Are Created

In the preceding programs, the following line was used to declare an object of type **Vehicle**:

```
Vehicle minivan = new Vehicle();
```

This declaration performs two functions. First, it declares a variable called **minivan** of the class type **Vehicle**. This variable does not define an object. Instead, it is simply a variable that can *refer to* an object. Second, the declaration creates a physical copy of the object and assigns to **minivan** a reference to that object. This is done by using the **new** operator.

The **new** operator dynamically allocates (that is, allocates at run time) memory for an object and returns a reference to it. This reference is, more or less, the address in memory of the object allocated by **new**. This reference is then stored in a variable. Thus, in Java, all class objects must be dynamically allocated.

The two steps combined in the preceding statement can be rewritten like this to show each step individually:

```
Vehicle minivan; // declare reference to object
minivan = new Vehicle(); // allocate a Vehicle object
```

The first line declares **minivan** as a reference to an object of type **Vehicle**. Thus, **minivan** is a variable that can refer to an object, but it is not an object, itself. At this point, **minivan** contains the value **null**, which means that it does not refer to an object. The next line creates a new **Vehicle** object and assigns a reference to it to **minivan**. Now, **minivan** is linked with an object.

CRITICAL SKILL 4.3

Reference Variables and Assignment

In an assignment operation, object reference variables act differently than do variables of a primitive type, such as **int**. When you assign one primitive-type variable to another, the situation is straightforward. The variable on the left receives a *copy* of the *value* of the variable on the right. When you assign an object reference variable to another, the situation is a bit more complicated because you are changing the object that the reference variable refers to. The effect of this difference can cause some counterintuitive results. For example, consider the following fragment:

```
Vehicle car1 = new Vehicle();
Vehicle car2 = car1;
```

At first glance, it is easy to think that **car1** and **car2** refer to different objects, but this is not the case. Instead, **car1** and **car2** will both refer to the *same* object. The assignment of **car1** to

car2 simply makes **car2** refer to the same object as does **car1**. Thus, the object can be acted upon by either **car1** or **car2**. For example, after the assignment

```
car1.mpg = 26;
```

executes, both of these **println( )** statements

```
System.out.println(car1.mpg);
System.out.println(car2.mpg);
```

display the same value: 26.

Although **car1** and **car2** both refer to the same object, they are not linked in any other way. For example, a subsequent assignment to **car2** simply changes the object to which **car2** refers. For example:

```
Vehicle car1 = new Vehicle();
Vehicle car2 = car1;
Vehicle car3 = new Vehicle();

car2 = car3; // now car2 and car3 refer to the same object.
```

After this sequence executes, **car2** refers to the same object as **car3**. The object referred to by **car1** is unchanged.

Progress Check

1. Explain what occurs when one object reference variable is assigned to another.
2. Assuming a class called **MyClass**, show how an object called **ob** is created.

CRITICAL SKILL 4.4

Methods

As explained, instance variables and methods are the constituents of classes. So far, the **Vehicle** class contains data, but no methods. Although data-only classes are perfectly valid, most classes will have methods. Methods are subroutines that manipulate the data defined by the class and, in many cases, provide access to that data. In most cases, other parts of your program will interact with a class through its methods.

---

1. When one object reference variable is assigned to another object reference variable, both variables will refer to the same object. A copy of the object *is not* made.

2. Myclass ob = new MyClass( );

A method contains one or more statements. In well-written Java code, each method performs only one task. Each method has a name, and it is this name that is used to call the method. In general, you can give a method whatever name you please. However, remember that **main( )** is reserved for the method that begins execution of your program. Also, don't use Java's keywords for method names.

When denoting methods in text, this book has used and will continue to use a convention that has become common when writing about Java. A method will have parentheses after its name. For example, if a method's name is **getval**, it will be written **getval( )** when its name is used in a sentence. This notation will help you distinguish variable names from method names in this book.

The general form of a method is shown here:

ret-type name(*parameter-list*) {
   // body of method
}

Here, *ret-type* specifies the type of data returned by the method. This can be any valid type, including class types that you create. If the method does not return a value, its return type must be **void**. The name of the method is specified by *name.* This can be any legal identifier other than those already used by other items within the current scope. The *parameter-list* is a sequence of type and identifier pairs separated by commas. Parameters are essentially variables that receive the value of the *arguments* passed to the method when it is called. If the method has no parameters, the parameter list will be empty.

Adding a Method to the Vehicle Class

As just explained, the methods of a class typically manipulate and provide access to the data of the class. With this in mind, recall that **main( )** in the preceding examples computed the range of a vehicle by multiplying its fuel consumption rate by its fuel capacity. While technically correct, this is not the best way to handle this computation. The calculation of a vehicle's range is something that is best handled by the **Vehicle** class itself. The reason for this conclusion is easy to understand: the range of a vehicle is dependent upon the capacity of the fuel tank and the rate of fuel consumption, and both of these quantities are encapsulated by **Vehicle**. By adding a method to **Vehicle** that computes the range, you are enhancing its object-oriented structure.

To add a method to **Vehicle**, specify it within **Vehicle**'s declaration. For example, the following version of **Vehicle** contains a method called **range( )** that displays the range of the vehicle.

```
// Add range to Vehicle.

class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
```

```
  int mpg;        // fuel consumption in miles per gallon

  // Display the range.
  void range() {
    System.out.println("Range is " + fuelcap * mpg);
  }
}
```

The **range( )** method is contained within the **Vehicle** class.

Notice that **fuelcap** and **mpg** are used directly, without the dot operator.

```
class AddMeth {
  public static void main(String args[]) {
    Vehicle minivan = new Vehicle();
    Vehicle sportscar = new Vehicle();

    int range1, range2;

    // assign values to fields in minivan
    minivan.passengers = 7;
    minivan.fuelcap = 16;
    minivan.mpg = 21;

    // assign values to fields in sportscar
    sportscar.passengers = 2;
    sportscar.fuelcap = 14;
    sportscar.mpg = 12;


    System.out.print("Minivan can carry " + minivan.passengers +
                     ". ");

    minivan.range(); // display range of minivan

    System.out.print("Sportscar can carry " + sportscar.passengers +
                     ". ");

    sportscar.range(); // display range of sportscar.
  }
}
```

This program generates the following output:

```
Minivan can carry 7. Range is 336
Sportscar can carry 2. Range is 168
```

Let's look at the key elements of this program, beginning with the **range( )** method itself. The first line of **range( )** is

```
void range() {
```

This line declares a method called **range** that has no parameters. Its return type is **void**. Thus, **range( )** does not return a value to the caller. The line ends with the opening curly brace of the method body.

The body of **range( )** consists solely of this line:

```
System.out.println("Range is " + fuelcap * mpg);
```

This statement displays the range of the vehicle by multiplying **fuelcap** by **mpg**. Since each object of type **Vehicle** has its own copy of **fuelcap** and **mpg**, when **range( )** is called, the range computation uses the calling object's copies of those variables.

The **range( )** method ends when its closing curly brace is encountered. This causes program control to transfer back to the caller.

Next, look closely at this line of code from inside **main( )**:

```
minivan.range();
```

This statement invokes the **range( )** method on **minivan**. That is, it calls **range( )** relative to the **minivan** object, using the object's name followed by the dot operator. When a method is called, program control is transferred to the method. When the method terminates, control is transferred back to the caller, and execution resumes with the line of code following the call.

In this case, the call to **minivan.range( )** displays the range of the vehicle defined by **minivan**. In similar fashion, the call to **sportscar.range( )** displays the range of the vehicle defined by **sportscar**. Each time **range( )** is invoked, it displays the range for the specified object.

There is something very important to notice inside the **range( )** method: the instance variables **fuelcap** and **mpg** are referred to directly, without preceding them with an object name or the dot operator. When a method uses an instance variable that is defined by its class, it does so directly, without explicit reference to an object and without use of the dot operator. This is easy to understand if you think about it. A method is always invoked relative to some object of its class. Once this invocation has occurred, the object is known. Thus, within a method, there is no need to specify the object a second time. This means that **fuelcap** and **mpg** inside **range( )** implicitly refer to the copies of those variables found in the object that invokes **range( )**.

CRITICAL SKILL 4.5

Returning from a Method

In general, there are two conditions that cause a method to return—first, as the **range( )** method in the preceding example shows, when the method's closing curly brace is encountered. The second is when a **return** statement is executed. There are two forms of **return**—one for use in **void** methods (those that do not return a value) and one for returning values. The first form is examined here. The next section explains how to return values.

In a **void** method, you can cause the immediate termination of a method by using this form of **return**:

return ;

When this statement executes, program control returns to the caller, skipping any remaining code in the method. For example, consider this method:

```
void myMeth() {
  int i;

  for(i=0; i<10; i++) {
    if(i == 5) return; // stop at 5
    System.out.println();
  }
}
```

Here, the **for** loop will only run from 0 to 5, because once **i** equals 5, the method returns.

It is permissible to have multiple return statements in a method, especially when there are two or more routes out of it. For example:

```
void myMeth() {
  // ...
  if(done) return;
  // ...
  if(error) return;
}
```

Here, the method returns if it is done or if an error occurs. Be careful, however, because having too many exit points in a method can destructure your code; so avoid using them casually. A well-designed method has well-defined exit points.

To review: a **void** method can return in one of two ways—its closing curly brace is reached, or a **return** statement is executed.

CRITICAL SKILL 4.6

Returning a Value

Although methods with a return type of **void** are not rare, most methods will return a value. In fact, the ability to return a value is one of the most useful features of a method. You have already seen one example of a return value: when we used the **sqrt( )** function to obtain a square root.

Return values are used for a variety of purposes in programming. In some cases, such as with **sqrt( )**, the return value contains the outcome of some calculation. In other cases, the return value may simply indicate success or failure. In still others, it may contain a status code. Whatever the purpose, using method return values is an integral part of Java programming.

Methods return a value to the calling routine using this form of **return**:

return *value*;

Here, *value* is the value returned.

You can use a return value to improve the implementation of **range( )**. Instead of displaying the range, a better approach is to have **range( )** compute the range and return this value. Among the advantages to this approach is that you can use the value for other calculations. The following example modifies **range( )** to return the range rather than displaying it.

```
// Use a return value.

class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon

  // Return the range.
  int range() {
    return mpg * fuelcap; ←——— Return the range for a given vehicle.
  }
}

class RetMeth {
  public static void main(String args[]) {
    Vehicle minivan = new Vehicle();
    Vehicle sportscar = new Vehicle();

    int range1, range2;

    // assign values to fields in minivan
    minivan.passengers = 7;
    minivan.fuelcap = 16;
    minivan.mpg = 21;

    // assign values to fields in sportscar
    sportscar.passengers = 2;
    sportscar.fuelcap = 14;
    sportscar.mpg = 12;
```

```
    // get the ranges
    range1 = minivan.range();
    range2 = sportscar.range();      Assign the value
                                     returned to a variable.

    System.out.println("Minivan can carry " + minivan.passengers +
                       " with range of " + range1 + " Miles");

    System.out.println("Sportscar can carry " + sportscar.passengers +
                       " with range of " + range2 + " miles");
  }
}
```

The output is shown here:

```
Minivan can carry 7 with range of 336 Miles
Sportscar can carry 2 with range of 168 miles
```

In the program, notice that when **range( )** is called, it is put on the right side of an assignment statement. On the left is a variable that will receive the value returned by **range( )**. Thus, after

```
range1 = minivan.range();
```

executes, the range of the **minivan** object is stored in **range1**.

Notice that **range( )** now has a return type of **int**. This means that it will return an integer value to the caller. The return type of a method is important because the type of data returned by a method must be compatible with the return type specified by the method. Thus, if you want a method to return data of type **double**, its return type must be type **double**.

Although the preceding program is correct, it is not written as efficiently as it could be. Specifically, there is no need for the **range1** or **range2** variables. A call to **range( )** can be used in the **println( )** statement directly, as shown here:

```
System.out.println("Minivan can carry " + minivan.passengers +
                   " with range of " + minivan.range() + " Miles");
```

In this case, when **println( )** is executed, **minivan.range( )** is called automatically and its value will be passed to **println( )**. Furthermore, you can use a call to **range( )** whenever the range of a **Vehicle** object is needed. For example, this statement compares the ranges of two vehicles:

```
if(v1.range() > v2.range()) System.out.println("v1 has greater range");
```

CRITICAL SKILL 4.7

Using Parameters

It is possible to pass one or more values to a method when the method is called. As explained, a value passed to a method is called an *argument.* Inside the method, the variable that receives the argument is called a *parameter*. Parameters are declared inside the parentheses that follow the method's name. The parameter declaration syntax is the same as that used for variables. A parameter is within the scope of its method, and aside from its special task of receiving an argument, it acts like any other local variable.

Here is a simple example that uses a parameter. Inside the **ChkNum** class, the method **isEven( )** returns **true** if the value that it is passed is even. It returns **false** otherwise. Therefore, **isEven( )** has a return type of **boolean**.

```
// A simple example that uses a parameter.

class ChkNum {
  // return true if x is even
  boolean isEven(int x) {   // Here, x is an integer parameter of isEven( ).
    if((x%2) == 0) return true;
    else return false;
  }
}

class ParmDemo {
  public static void main(String args[]) {
    ChkNum e = new ChkNum();

    if(e.isEven(10)) System.out.println("10 is even.");   // Pass arguments to isEven( ).

    if(e.isEven(9)) System.out.println("9 is even.");

    if(e.isEven(8)) System.out.println("8 is even.");

  }
}
```

Here is the output produced by the program:

```
10 is even.
8 is even.
```

In the program, **isEven( )** is called three times, and each time a different value is passed. Let's look at this process closely. First, notice how **isEven( )** is called. The argument is specified between the parentheses. When **isEven( )** is called the first time, it is passed the value 10. Thus, when **isEven( )** begins executing, the parameter **x** receives the value 10. In the second call, 9 is the argument, and **x**, then, has the value 9. In the third call, the argument is 8, which is the value that **x** receives. The point is that the value passed as an argument when **isEven( )** is called is the value received by its parameter, **x**.

A method can have more than one parameter. Simply declare each parameter, separating one from the next with a comma. For example, the **Factor** class defines a method called **isFactor( )** that determines whether the first parameter is a factor of the second.

```
class Factor {
  boolean isFactor(int a, int b) {   // This method has two parameters.
    if( (b % a) == 0) return true;
    else return false;
  }
}
class IsFact {
  public static void main(String args[]) {
    Factor x = new Factor();
                                      // Pass two arguments to isFactor( ).
    if(x.isFactor(2, 20)) System.out.println("2 is factor");
    if(x.isFactor(3, 20)) System.out.println("this won't be displayed");

  }
}
```

Notice that when **isFactor( )** is called, the arguments are also separated by commas.

When using multiple parameters, each parameter specifies its own type, which can differ from the others. For example, this is perfectly valid:

```
int myMeth(int a, double b, float c) {
 // ...
```

Adding a Parameterized Method to Vehicle

You can use a parameterized method to add a new feature to the **Vehicle** class: the ability to compute the amount of fuel needed for a given distance. This new method is called **fuelneeded( )**. This method takes the number of miles that you want to drive and returns the number of gallons of gas required. The **fuelneeded( )** method is defined like this:

```
double fuelneeded(int miles) {
  return (double) miles / mpg;
}
```

Notice that this method returns a value of type **double**. This is useful since the amount of fuel needed for a given distance might not be an even number.

The entire **Vehicle** class that includes **fuelneeded( )** is shown here:

```
/*
   Add a parameterized method that computes the
   fuel required for a given distance.
*/

class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon

  // Return the range.
  int range() {
    return mpg * fuelcap;
  }

  // Compute fuel needed for a given distance.
  double fuelneeded(int miles) {
    return (double) miles / mpg;
  }
}

class CompFuel {
  public static void main(String args[]) {
    Vehicle minivan = new Vehicle();
    Vehicle sportscar = new Vehicle();
    double gallons;
    int dist = 252;

    // assign values to fields in minivan
    minivan.passengers = 7;
    minivan.fuelcap = 16;
    minivan.mpg = 21;

    // assign values to fields in sportscar
    sportscar.passengers = 2;
    sportscar.fuelcap = 14;
    sportscar.mpg = 12;
```

```
    gallons = minivan.fuelneeded(dist);

    System.out.println("To go " + dist + " miles minivan needs " +
                       gallons + " gallons of fuel.");

    gallons = sportscar.fuelneeded(dist);

    System.out.println("To go " + dist + " miles sportscar needs " +
                       gallons + " gallons of fuel.");

  }
}
```

The output from the program is shown here:

```
To go 252 miles minivan needs 12.0 gallons of fuel.
To go 252 miles sportscar needs 21.0 gallons of fuel.
```

Progress Check

1. When must an instance variable or method be accessed through an object reference using the dot operator? When can a variable or method be used directly?
2. Explain the difference between an argument and a parameter.
3. Explain the two ways that a method can return to its caller.

---

1. When an instance variable is accessed by code that is not part of the class in which that instance variable is defined, it must be done through an object, by use of the dot operator. However, when an instance variable is accessed by code that is part of the same class as the instance variable, that variable can be referred to directly. The same thing applies to methods.

2. An *argument* is a value that is passed to a method when it is invoked. A *parameter* is a variable defined by a method that receives the value of the argument.

3. A method can be made to return through the use of the **return** statement. If the method has a **void** return type, it will also return when its closing curly brace is reached. Non-**void** methods must return a value, so returning by reaching the closing curly brace is not an option.

Project 4-1 Creating a Help Class

`HelpClassDemo.java`

If one were to try to summarize the essence of the class in one sentence, it might be this: a class encapsulates functionality. Of course, sometimes the trick is knowing where one "functionality" ends and another begins. As a general rule, you will want your classes to be the building blocks of your larger application. In order to do this, each class must represent a single functional unit that performs clearly delineated actions. Thus, you will want your classes to be as small as possible—but no smaller! That is, classes that contain extraneous functionality confuse and destructure code, but classes that contain too little functionality are fragmented. What is the balance? It is at this point that the *science* of programming becomes the *art* of programming. Fortunately, most programmers find that this balancing act becomes easier with experience.

To begin to gain that experience you will convert the help system from Project 3-3 in the preceding module into a Help class. Let's examine why this is a good idea. First, the help system defines one logical unit. It simply displays the syntax for Java's control statements. Thus, its functionality is compact and well defined. Second, putting help in a class is an esthetically pleasing approach. Whenever you want to offer the help system to a user, simply instantiate a help-system object. Finally, because help is encapsulated, it can be upgraded or changed without causing unwanted side effects in the programs that use it.

Step by Step

1. Create a new file called **HelpClassDemo.java.** To save you some typing, you might want to copy the file from Project 3-3, **Help3.java**, into **HelpClassDemo.java**.

2. To convert the help system into a class, you must first determine precisely what constitutes the help system. For example, in **Help3.java**, there is code to display a menu, input the user's choice, check for a valid response, and display information about the item selected. The program also loops until the letter q is pressed. If you think about it, it is clear that the menu, the check for a valid response, and the display of the information are integral to the help system. How user input is obtained, and whether repeated requests should be processed, are not. Thus, you will create a class that displays the help information, the help menu, and checks for a valid selection. Its methods will be called **helpon( )**, **showmenu( )**, and **isvalid( )**, respectively.

(continued)

3. Create the **helpon( )** method as shown here:

```
void helpon(int what) {
  switch(what) {
    case '1':
      System.out.println("The if:\n");
      System.out.println("if(condition) statement;");
      System.out.println("else statement;");
      break;
    case '2':
      System.out.println("The switch:\n");
      System.out.println("switch(expression) {");
      System.out.println("  case constant:");
      System.out.println("    statement sequence");
      System.out.println("    break;");
      System.out.println("  // ...");
      System.out.println("}");
      break;
    case '3':
      System.out.println("The for:\n");
      System.out.print("for(init; condition; iteration)");
      System.out.println(" statement;");
      break;
    case '4':
      System.out.println("The while:\n");
      System.out.println("while(condition) statement;");
      break;
    case '5':
      System.out.println("The do-while:\n");
      System.out.println("do {");
      System.out.println("  statement;");
      System.out.println("} while (condition);");
      break;
    case '6':
      System.out.println("The break:\n");
      System.out.println("break; or break label;");
      break;
    case '7':
      System.out.println("The continue:\n");
      System.out.println("continue; or continue label;");
      break;
  }
  System.out.println();
}
```

4. Next, create the **showmenu( )** method:

```
void showmenu() {
  System.out.println("Help on:");
```

```
  System.out.println("  1. if");
  System.out.println("  2. switch");
  System.out.println("  3. for");
  System.out.println("  4. while");
  System.out.println("  5. do-while");
  System.out.println("  6. break");
  System.out.println("  7. continue\n");
  System.out.print("Choose one (q to quit): ");
}
```

5. Create the **isvalid( )** method, shown here:

```
boolean isvalid(int ch) {
  if(ch < '1' | ch > '7' & ch != 'q') return false;
  else return true;
}
```

6. Assemble the foregoing methods into the **Help** class, shown here:

```
class Help {
  void helpon(int what) {
    switch(what) {
      case '1':
        System.out.println("The if:\n");
        System.out.println("if(condition) statement;");
        System.out.println("else statement;");
        break;
      case '2':
        System.out.println("The switch:\n");
        System.out.println("switch(expression) {");
        System.out.println("  case constant:");
        System.out.println("    statement sequence");
        System.out.println("    break;");
        System.out.println("  // ...");
        System.out.println("}");
        break;
      case '3':
        System.out.println("The for:\n");
        System.out.print("for(init; condition; iteration)");
        System.out.println(" statement;");
        break;
      case '4':
        System.out.println("The while:\n");
        System.out.println("while(condition) statement;");
        break;
      case '5':
        System.out.println("The do-while:\n");
```

(continued)

```
          System.out.println("do {");
          System.out.println("  statement;");
          System.out.println("} while (condition);");
          break;
        case '6':
          System.out.println("The break:\n");
          System.out.println("break; or break label;");
          break;
        case '7':
          System.out.println("The continue:\n");
          System.out.println("continue; or continue label;");
          break;
      }
      System.out.println();
    }

    void showmenu() {
      System.out.println("Help on:");
      System.out.println("  1. if");
      System.out.println("  2. switch");
      System.out.println("  3. for");
      System.out.println("  4. while");
      System.out.println("  5. do-while");
      System.out.println("  6. break");
      System.out.println("  7. continue\n");
      System.out.print("Choose one (q to quit): ");
    }

    boolean isvalid(int ch) {
      if(ch < '1' | ch > '7' & ch != 'q') return false;
      else return true;
    }

  }
```

7. Finally, rewrite the **main( )** method from Project 3-3 so that it uses the new **Help** class. Call this class **HelpClassDemo.java**. The entire listing for **HelpClassDemo.java** is shown here:

```
/*
   Project 4-1

   Convert the help system from Project 3-3 into
   a Help class.
*/

class Help {
```

```
void helpon(int what) {
  switch(what) {
    case '1':
      System.out.println("The if:\n");
      System.out.println("if(condition) statement;");
      System.out.println("else statement;");
      break;
    case '2':
      System.out.println("The switch:\n");
      System.out.println("switch(expression) {");
      System.out.println("  case constant:");
      System.out.println("    statement sequence");
      System.out.println("    break;");
      System.out.println("  // ...");
      System.out.println("}");
      break;
    case '3':
      System.out.println("The for:\n");
      System.out.print("for(init; condition; iteration)");
      System.out.println(" statement;");
      break;
    case '4':
      System.out.println("The while:\n");
      System.out.println("while(condition) statement;");
      break;
    case '5':
      System.out.println("The do-while:\n");
      System.out.println("do {");
      System.out.println("  statement;");
      System.out.println("} while (condition);");
      break;
    case '6':
      System.out.println("The break:\n");
      System.out.println("break; or break label;");
      break;
    case '7':
      System.out.println("The continue:\n");
      System.out.println("continue; or continue label;");
      break;
  }
  System.out.println();
}

void showmenu() {
  System.out.println("Help on:");
```

(continued)

```
    System.out.println("  1. if");
    System.out.println("  2. switch");
    System.out.println("  3. for");
    System.out.println("  4. while");
    System.out.println("  5. do-while");
    System.out.println("  6. break");
    System.out.println("  7. continue\n");
    System.out.print("Choose one (q to quit): ");
  }

  boolean isvalid(int ch) {
    if(ch < '1' | ch > '7' & ch != 'q') return false;
    else return true;
  }

}

class HelpClassDemo {
  public static void main(String args[])
    throws java.io.IOException {
    char choice;
    Help hlpobj = new Help();

    for(;;) {
      do {
        hlpobj.showmenu();
        do {
          choice = (char) System.in.read();
        } while(choice == '\n' | choice == '\r');

      } while( !hlpobj.isvalid(choice) );

      if(choice == 'q') break;

      System.out.println("\n");


      hlpobj.helpon(choice);
    }
  }
}
```

When you try the program, you will find that it is functionally the same as before. The advantage to this approach is that you now have a help system component that can be reused whenever it is needed.

CRITICAL SKILL 4.8

Constructors

In the preceding examples, the instance variables of each **Vehicle** object had to be set manually using a sequence of statements, such as:

```
minivan.passengers = 7;
minivan.fuelcap = 16;
minivan.mpg = 21;
```

An approach like this would never be used in professionally written Java code. Aside from being error prone (you might forget to set one of the fields), there is simply a better way to accomplish this task: the constructor.

A *constructor* initializes an object when it is created. It has the same name as its class and is syntactically similar to a method. However, constructors have no explicit return type. Typically, you will use a constructor to give initial values to the instance variables defined by the class, or to perform any other startup procedures required to create a fully formed object.

All classes have constructors, whether you define one or not, because Java automatically provides a default constructor that initializes all member variables to zero. However, once you define your own constructor, the default constructor is no longer used.

Here is a simple example that uses a constructor:

```
// A simple constructor.

class MyClass {
  int x;

  MyClass() {   <-- This constructor for MyClass
    x = 10;
  }
}

class ConsDemo {
  public static void main(String args[]) {
    MyClass t1 = new MyClass();
    MyClass t2 = new MyClass();

    System.out.println(t1.x + " " + t2.x);
  }
}
```

In this example, the constructor for **MyClass** is

```
MyClass() {
  x = 10;
}
```

This constructor assigns the instance variable **x** of **MyClass** the value 10. This constructor is called by **new** when an object is created. For example, in the line

```
MyClass t1 = new MyClass();
```

the constructor **MyClass( )** is called on the **t1** object, giving **t1.x** the value 10. The same is true for **t2**. After construction, **t2.x** has the value 10. Thus, the output from the program is

```
10 10
```

CRITICAL SKILL 4.9

Parameterized Constructors

In the preceding example, a parameter-less constructor was used. Although this is fine for some situations, most often you will need a constructor that accepts one or more parameters. Parameters are added to a constructor in the same way that they are added to a method: just declare them inside the parentheses after the constructor's name. For example, here, **MyClass** is given a parameterized constructor:

```
// A parameterized constructor.

class MyClass {
  int x;

  MyClass(int i) {   <-- This constructor has a parameter.
    x = i;
  }
}

class ParmConsDemo {
  public static void main(String args[]) {
    MyClass t1 = new MyClass(10);
    MyClass t2 = new MyClass(88);

    System.out.println(t1.x + " " + t2.x);
  }
}
```

The output from this program is shown here:

```
10 88
```

In this version of the program, the **MyClass( )** constructor defines one parameter called **i**, which is used to initialize the instance variable, **x**. Thus, when the line

```
MyClass t1 = new MyClass(10);
```

executes, the value 10 is passed to **i**, which is then assigned to **x**.

Adding a Constructor to the Vehicle Class

We can improve the **Vehicle** class by adding a constructor that automatically initializes the **passengers**, **fuelcap**, and **mpg** fields when an object is constructed. Pay special attention to how **Vehicle** objects are created.

```
// Add a constructor.

class Vehicle {
  int passengers; // number of passengers
  int fuelcap;    // fuel capacity in gallons
  int mpg;        // fuel consumption in miles per gallon

  // This is a constructor for Vehicle.
  Vehicle(int p, int f, int m) {     <——— Constructor for Vehicle
    passengers = p;
    fuelcap = f;
    mpg = m;
  }

  // Return the range.
  int range() {
    return mpg * fuelcap;
  }

  // Compute fuel needed for a given distance.
  double fuelneeded(int miles) {
    return (double) miles / mpg;
  }
}

class VehConsDemo {
  public static void main(String args[]) {

    // construct complete vehicles
    Vehicle minivan = new Vehicle(7, 16, 21);
    Vehicle sportscar = new Vehicle(2, 14, 12);
    double gallons;
    int dist = 252;

    gallons = minivan.fuelneeded(dist);

    System.out.println("To go " + dist + " miles minivan needs " +
                       gallons + " gallons of fuel.");
```

```
    gallons = sportscar.fuelneeded(dist);

    System.out.println("To go " + dist + " miles sportscar needs " +
                       gallons + " gallons of fuel.");

  }
}
```

Both **minivan** and **sportscar** are initialized by the **Vehicle( )** constructor when they are created. Each object is initialized as specified in the parameters to its constructor. For example, in the following line,

```
Vehicle minivan = new Vehicle(7, 16, 21);
```

the values 7, 16, and 21 are passed to the **Vehicle( )** constructor when **new** creates the object. Thus, **minivan**'s copy of **passengers**, **fuelcap**, and **mpg** will contain the values 7, 16, and 21, respectively. The output from this program is the same as the previous version.

Progress Check

1. What is a constructor, and when is it executed?
2. Does a constructor have a return type?

CRITICAL SKILL 4.10

The new Operator Revisited

Now that you know more about classes and their constructors, let's take a closer look at the **new** operator. The **new** operator has this general form:

class-var = new *class-name*( );

Here, *class-var* is a variable of the class type being created. The *class-name* is the name of the class that is being instantiated. The class name followed by parentheses specifies the constructor for the class. If a class does not define its own constructor, **new** will use the default constructor supplied by Java. Thus, **new** can be used to create an object of any class type.

---

1. A constructor is a method that is executed when an object of its class is instantiated. A constructor is used to initialize the object being created.
2. No.

Ask the Expert

Q: Why don't I need to use new **for variables of the primitive types, such as** int **or** float**?**

A: Java's primitive types are not implemented as objects. Rather, because of efficiency concerns, they are implemented as "normal" variables. A variable of a primitive type actually contains the value that you have given it. As explained, object variables are references to the object. This layer of indirection (and other object features) adds overhead to an object that is avoided by a primitive type.

Since memory is finite, it is possible that **new** will not be able to allocate memory for an object because insufficient memory exists. If this happens, a run-time exception will occur. (You will learn how to handle this and other exceptions in Module 9.) For the sample programs in this book, you won't need to worry about running out of memory, but you will need to consider this possibility in real-world programs that you write.

CRITICAL SKILL 4.11

Garbage Collection and Finalizers

As you have seen, objects are dynamically allocated from a pool of free memory by using the **new** operator. As explained, memory is not infinite, and the free memory can be exhausted. Thus, it is possible for **new** to fail because there is insufficient free memory to create the desired object. For this reason, a key component of any dynamic allocation scheme is the recovery of free memory from unused objects, making that memory available for subsequent reallocation. In many programming languages, the release of previously allocated memory is handled manually. For example, in C++, you use the **delete** operator to free memory that was allocated. However, Java uses a different, more trouble-free approach: *garbage collection*.

Java's garbage collection system reclaims objects automatically—occurring transparently, behind the scenes, without any programmer intervention. It works like this: when no references to an object exist, that object is assumed to be no longer needed, and the memory occupied by the object is released. This recycled memory can then be used for a subsequent allocation.

Garbage collection occurs only sporadically during the execution of your program. It will not occur simply because one or more objects exist that are no longer used. For efficiency, the garbage collector will usually run only when two conditions are met: there are objects to recycle, and there is a need to recycle them. Remember, garbage collection takes time, so the Java run-time system does it only when necessary. Thus, you can't know precisely when garbage collection will take place.

The finalize( ) Method

It is possible to define a method that will be called just before an object's final destruction by the garbage collector. This method is called **finalize( )**, and it can be used to ensure that an object terminates cleanly. For example, you might use **finalize( )** to make sure that an open file owned by that object is closed.

To add a finalizer to a class, you simply define the **finalize( )** method. The Java runtime calls that method whenever it is about to recycle an object of that class. Inside the **finalize( )** method you will specify those actions that must be performed before an object is destroyed.

The **finalize( )** method has this general form:

```
protected void finalize( )
{
  // finalization code here
}
```

Here, the keyword **protected** is a specifier that prevents access to **finalize( )** by code defined outside its class. This and the other access specifiers are explained in Module 6.

It is important to understand that **finalize( )** is called just before garbage collection. It is not called when an object goes out of scope, for example. This means that you cannot know when—or even if—**finalize( )** will be executed. For example, if your program ends before garbage collection occurs, **finalize( )** will not execute. Therefore, it should be used as a "backup" procedure to ensure the proper handling of some resource, or for special-use applications, not as the means that your program uses in its normal operation.

Ask the Expert

Q: **I know that C++ defines things called *destructors*, which are automatically executed when an object is destroyed. Is** finalize( ) **similar to a destructor?**

A: Java does not have destructors. Although it is true that the **finalize( )** method approximates the function of a destructor, it is not the same. For example, a C++ destructor is always called just before an object goes out of scope, but you can't know when **finalize( )** will be called for any specific object. Frankly, because of Java's use of garbage collection, there is little need for a destructor.

Project 4-2 Demonstrate Finalization

Finalize.java

Because garbage collection runs sporadically, in the background, it is not trivial to demonstrate the **finalize( )** method. Recall that **finalize( )** is called when an object is about to be recycled. As explained, objects are not necessarily recycled as soon as they are no longer needed. Instead, the garbage collector waits until it can perform its collection efficiently, usually when there are many unused objects. Thus, to demonstrate the **finalize( )** method, you often need to create and destroy a large number of objects—and this is precisely what you will do in this project.

Step by Step

1. Create a new file called **Finalize.java.**

2. Create the **FDemo** class shown here:

```
class FDemo {
  int x;

  FDemo(int i) {
    x = i;
  }

  // called when object is recycled
  protected void finalize() {
    System.out.println("Finalizing " + x);
  }

  // generates an object that is immediately destroyed
  void generator(int i) {
    FDemo o = new FDemo(i);
  }

}
```

The constructor sets the instance variable **x** to a known value. In this example, **x** is used as an object ID. The **finalize( )** method displays the value of **x** when an object is recycled. Of special interest is **generator( )**. This method creates and then promptly discards an **FDemo** object. You will see how this is used in the next step.

(continued)

3. Create the **Finalize** class, shown here:

```
class Finalize {
  public static void main(String args[]) {
    int count;

    FDemo ob = new FDemo(0);

    /* Now, generate a large number of objects. At
       some point, garbage collection will occur.
       Note: you might need to increase the number
       of objects generated in order to force
       garbage collection. */

    for(count=1; count < 100000; count++)
      ob.generator(count);
  }
}
```

This class creates an initial **FDemo** object called **ob**. Then, using **ob**, it creates 100,000 objects by calling **generator( )** on **ob**. This has the net effect of creating and discarding 100,000 objects. At various points in the middle of this process, garbage collection will take place. Precisely how often or when depends upon several factors, such as the initial amount of free memory and the operating system. However, at some point, you will start to see the messages generated by **finalize( )**. If you don't see the messages, try increasing the number of objects being generated by raising the count in the **for** loop.

4. Here is the entire **Finalize.java** program:

```
/*
   Project 4-2

   Demonstrate the finalize() method.
*/

class FDemo {
  int x;

  FDemo(int i) {
    x = i;
  }

  // called when object is recycled
  protected void finalize() {
    System.out.println("Finalizing " + x);
  }
```

```
  // generates an object that is immediately destroyed
  void generator(int i) {
    FDemo o = new FDemo(i);
  }

}

class Finalize {
  public static void main(String args[]) {
    int count;

    FDemo ob = new FDemo(0);

    /* Now, generate a large number of objects. At
       some point, garbage collection will occur.
       Note: you might need to increase the number
       of objects generated in order to force
       garbage collection. */

    for(count=1; count < 100000; count++)
      ob.generator(count);
  }
}
```

CRITICAL SKILL 4.12

The this Keyword

Before concluding this module it is necessary to introduce **this**. When a method is called, it is automatically passed an implicit argument that is a reference to the invoking object (that is, the object on which the method is called). This reference is called **this**. To understand **this**, first consider a program that creates a class called **Pwr** that computes the result of a number raised to some integer power:

```
class Pwr {
  double b;
  int e;
  double val;

  Pwr(double base, int exp) {
    b = base;
    e = exp;

    val = 1;
    if(exp==0) return;
    for( ; exp>0; exp--) val = val * base;
```

```
  }

  double get_pwr() {
    return val;
  }
}

class DemoPwr {
  public static void main(String args[]) {
    Pwr x = new Pwr(4.0, 2);
    Pwr y = new Pwr(2.5, 1);
    Pwr z = new Pwr(5.7, 0);

    System.out.println(x.b + " raised to the " + x.e +
                       " power is " + x.get_pwr());
    System.out.println(y.b + " raised to the " + y.e +
                       " power is " + y.get_pwr());
    System.out.println(z.b + " raised to the " + z.e +
                       " power is " + z.get_pwr());
  }
}
```

As you know, within a method, the other members of a class can be accessed directly, without any object or class qualification. Thus, inside **get_pwr( )**, the statement

```
return val;
```

means that the copy of **val** associated with the invoking object will be returned. However, the same statement can also be written like this:

```
return this.val;
```

Here, **this** refers to the object on which **get_pwr( )** was called. Thus, **this.val** refers to that object's copy of **val**. For example, if **get_pwr( )** had been invoked on **x**, then **this** in the preceding statement would have been referring to **x**. Writing the statement without using **this** is really just shorthand.

Here is the entire **Pwr** class written using the **this** reference:

```
class Pwr {
  double b;
  int e;
  double val;

  Pwr(double base, int exp) {
    this.b = base;
```

```
    this.e = exp;

    this.val = 1;
    if(exp==0) return;
    for( ; exp>0; exp--) this.val = this.val * base;
  }

  double get_pwr() {
    return this.val;
  }
}
```

Actually, no Java programmer would write **Pwr** as just shown because nothing is gained, and the standard form is easier. However, **this** has some important uses. For example, the Java syntax permits the name of a parameter or a local variable to be the same as the name of an instance variable. When this happens, the local name *hides* the instance variable. You can gain access to the hidden instance variable by referring to it through **this**. For example, although not recommended style, the following is a syntactically valid way to write the **Pwr( )** constructor.

```
Pwr(double b, int e) {
  this.b = b;
  this.e = e;

  val = 1;
  if(e==0) return;
  for( ; e>0; e--) val = val * b;
}
```

This refers to the **b** instance variable, not the parameter.

In this version, the names of the parameters are the same as the names of the instance variables, thus hiding them. However, **this** is used to "uncover" the instance variables.

✓ Module 4 Mastery Check

1. What is the difference between a class and an object?
2. How is a class defined?
3. What does each object have its own copy of?
4. Using two separate statements, show how to declare an object called **counter** of a class called **MyCounter**.