Inheritance

9

Outcomes:

By the end of this chapter you should be able to:

- *explain the term* ***inheritance***;
- *design inheritance structures using UML notation*;
- *implement inheritance relationships in Java*;
- *distinguish between* ***method overriding*** *and* ***method overloading***;
- *explain the term* ***type cast*** *and implement this in Java*;
- *explain the use of the* **`abstract`** *modifier when applied to classes and methods*;
- *explain the use of the* **`final`** *modifier, when applied to classes and methods*;
- *describe the way in which all Java classes are derived from the* `Object` *class.*

9.1 Introduction

One of the greatest benefits of the object-oriented approach to software development is that it offers the opportunity for us to *reuse* classes that have already been written—either by ourselves or by someone else. Let's look at a possible scenario. Say you wanted to develop a software system and you have, during your analysis, identified the need for a class called `Employee`. You might be aware that a colleague in your organization has already written an `Employee` class; rather than having to write your own class, it would be easier to approach your colleague and ask her to let you use her `Employee` class.

So far so good, but what if the `Employee` class that you are given doesn't quite do everything that you had hoped? Perhaps your employees are part-time employees, and you want your class to have an attribute like `hourlyPay`, or

Q. Charatan and A. Kans, *Java in Two Semesters*, Texts in Computer Science,
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methods like `calculateWeeklyPay` and `setHourlyPay`, and these attributes and methods do not exist in the `Employee` class you have been given.

You may think it would be necessary to go into the old class and start messing about with the code. But there is no need, because object-oriented programming languages provide the ability to extend existing classes by adding attributes and methods to them. This is called **inheritance**.

9.2 Defining Inheritance

Inheritance is the sharing of attributes and methods among classes. We take a class, and then define other classes based on the first one. The new classes *inherit* all the attributes and methods of the first one, but also have attributes and methods of their own. Let's try to understand this by thinking about the `Employee` class.

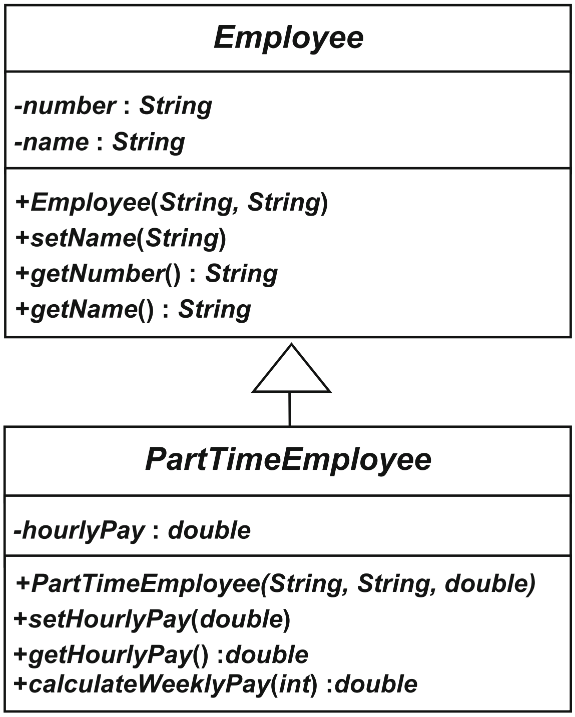


Fig. 9.1 An inheritance relationship

Say our `Employee` class has two attributes, `number` and `name`, a user-defined constructor, and some basic `get`- and `set`-methods for the attributes. We now define our `PartTimeEmployee` class; this class will *inherit* these attributes and methods, but can also have attributes and methods of its own. We will give it one additional attribute, `hourlyPay`, some methods to access this attribute and one additional method, `calculateWeeklyPay`.

This is illustrated in Fig. 9.1 which uses the UML notation for inheritance, namely a triangle.

You can see from this diagram that an inheritance relationship is a *hierarchical* relationship. The class at the top of the hierarchy—in this case the `Employee` class—is referred to as the **superclass** (or **base class**) and the `PartTimeEmployee` as the **subclass** (or **derived class**).

The inheritance relationship is also often referred to as an *is-a-kind-of* relationship; in this case a `PartTimeEmployee` *is a kind of* `Employee`.

9.3 Implementing Inheritance in Java

The code for the `Employee` class is shown below:

Employee

```
public class Employee
{
   private String number;
   private String name;
   public Employee(String numberIn, String nameIn)
   {
      number = numberIn;
      name = nameIn;
   }

   public void setName(String nameIn)
   {
      name = nameIn;
   }

   public String getNumber()
   {
      return number;
   }

   public String getName()
   {
      return name;
   }
}
```

There is nothing new here, so let's get on with our `PartTimeEmployee` class. We will present the code first and analyse it afterwards.

PartTimeEmployee

```
public class PartTimeEmployee extends Employee // this class is a subclass of Employee
{
   private double hourlyPay; // this attribute is unique to the subclass

   // the constructor
   public PartTimeEmployee(String numberIn, String nameIn, double hourlyPayIn)
   {
      super(numberIn, nameIn); // call the constructor of the superclass
      hourlyPay = hourlyPayIn;
   }

   // these methods are also unique to the subclass
   public double getHourlyPay()
   {
      return hourlyPay;
   }

   public void setHourlyPay(double hourlyPayIn)
   {
      hourlyPay = hourlyPayIn;
   }

   public double calculateWeeklyPay(int noOfHoursIn)
   {
      return noOfHoursIn * hourlyPay;
   }
}
```

The first line of interest is the class header itself:

```
public class PartTimeEmployee extends Employee // this class is a subclass of Employee
```

Here we see the use of the keyword **`extends`**. Using this word in this way means that the `PartTimeEmployee` class (the *subclass*) inherits all the attributes and methods of the `Employee` class (the *superclass*). So although we haven't coded them, any object of the `PartTimeEmployee` class will have, for example, an attribute called `name` and a method called `getNumber`. A `PartTimeEmployee` is now a *kind of* `Employee`.

But can you see a problem here? The attributes have been declared as **`private`** in the superclass so although they are now part of our `PartTimeEmployee` class, none of the `PartTimeEmployee` class methods can directly access them—the subclass has only the same access rights as any other class!

There are a number of possible ways around this:

1. We could declare the original attributes as **`public`**—but this would take away the whole point of encapsulation.
2. We could use the special keyword **`protected`** instead of **`private`**. The effect of this is that anything declared as **`protected`** is accessible to the methods of any subclasses. There are, however, two issues to think about here. The first is that you have to anticipate in advance when you want your class to be able to be inherited. The second problem is that it weakens your efforts to encapsulate information within the class, since, in Java, **`protected`** attributes are also accessible to any other class in the same package (you will find out much more about the meaning of the word **package** in Chap. 19).

The above remarks notwithstanding, this is a perfectly acceptable approach to use, particularly in situations where you are writing a class as part of a discrete application, and you will be aware in advance that certain classes will need to be subclassed. You will see an example of this in Sect. 9.5.
Incidentally, in a UML diagram a **protected** attribute is indicated by a hash symbol, #.

3. The other solution, and the one we will use now, is to leave the attributes as **private**, but to plan carefully in advance which get- and set-methods we are going to provide.

After the class header we have the following declaration:

```
private double hourlyPay;
```

This declares an attribute, hourlyPay, which is unique to our subclass—but remember that the attributes of the superclass, Employee, will be inherited, so in fact any PartTimeEmployee object will have *three* attributes.

Next comes the constructor. We want to be able to assign values to the number and name at the time that the object is created, just as we do with an Employee object; so our constructor will need to receive parameters that will be assigned to the number and name attributes.

But wait a minute! How are we going to do this? The number and name attributes have been declared as **private** in the superclass—so they aren't accessible to objects of the subclass. Luckily there is a way around this problem. We can call the constructor of the superclass by using the keyword **super**. Look how this is done:

```
public PartTimeEmployee(String numberIn, String nameIn, double hourlyPayIn)
{
   super(numberIn, nameIn); // call the constructor of the superclass
   hourlyPay = hourlyPayIn;
}
```

After calling the constructor of the superclass, we need to perform one more task —namely to assign the third parameter, hourlyPayIn, to the hourlyPay attribute. Notice, however, that the line that calls **super** has to be the first one—if we had written our constructor like this it would not compile:

```
/* This version of the constructor would not compile - the call to super has to be the
   first instruction */

public PartTimeEmployee(String numberIn, String nameIn, double hourlyPayIn)
{
        hourlyPay = hourlyPayIn;
        super(numberIn, nameIn); // this call should have been the first instruction!
}
```

The remaining methods of `PartTimeEmployee` are new methods specific to the subclass:

```
public double getHourlyPay()
{
   return hourlyPay;
}
public void setHourlyPay(double hourlyPayIn)
{
   hourlyPay = hourlyPayIn;
}
public double calculateWeeklyPay(int noOfHoursIn)
{
   return noOfHoursIn * hourlyPay;
}
```

The first two provide read and write access respectively to the `hourlyPay` attribute. The third one receives the number of hours worked and calculates the pay by multiplying this by the hourly rate. Th program below demonstrates the use of the `PartTimeEmployee` class.

PartTimeEmployeeTester

```
import java.util.Scanner;
public class PartTimeEmployeeTester
{
    public static void main(String[] args)
    {
        Scanner keyboard = new Scanner(System.in);
        Scanner keyboardString = new Scanner(System.in);
        String number, name;
        double pay;
        int hours;
        PartTimeEmployee emp;

        // get the details from the user
        System.out.print("Employee Number? ");
        number = keyboardString.nextLine();
        System.out.print("Employee's Name? ");
        name = keyboardString.nextLine();
        System.out.print("Hourly Pay? ");
        pay = keyboard.nextDouble();
        System.out.print("Hours worked this week? ");
        hours = keyboard.nextInt();

        // create a new part-time employee
        emp = new PartTimeEmployee(number, name, pay);

        // display part-time employee's details, including the weekly pay
        System.out.println();

        // the next two methods have been inhreted from the Employee class
        System.out.println(emp.getName());
        System.out.println(emp.getNumber());

        System.out.println(emp.calculateWeeklyPay(hours));
    }
}
```

Here is a sample test run:

```
Employee Number? A103456
Employee's Name? Mandy Lifeboats
Hourly Pay? 15.50
Hours worked this week? 20
```

```
Mandy Lifeboats
A103456
310.0
```

We can now move on to look at another inheritance example; let's choose the `Oblong` class that we developed in the last chapter.

9.4 Extending the *Oblong* Class

We are going to define a new class called `ExtendedOblong`, which extends the `Oblong` class. First, let's remind ourselves of the `Oblong` class itself.

The *Oblong* class – a reminder

```
public class Oblong
{
   // the attributes
   private double length;
   private double height;

   // the methods

   // the constructor
   public Oblong(double lengthIn, double heightIn)
   {
      length = lengthIn;
      height = heightIn;
   }

   // this method allows us to read the length attribute
   public double getLength()
   {
      return length;
   }

   // this method allows us to read the height attribute
   public double getHeight()
   {
      return height;
   }

   // this method allows us to write to the length attribute
   public void setLength(double lengthIn)
   {
      length = lengthIn;
   }

   // this method allows us to write to the height attribute
   public void setHeight(double heightIn)
   {
      height = heightIn;
   }

   // this method returns the area of the Oblong
   public double calculateArea()
   {
      return length * height;
   }

   // this method returns the perimeter of the Oblong
   public double calculatePerimeter()
   {
      return 2 * (length + height);
   }
}
```

The original `Oblong` class had the capability of reporting on the perimeter and area of the oblong. Our extended class will have the capability of sending back a string representation of itself composed of a number of symbols such as asterisks—for example:

```
*****
*****
*****
```

Now at first glance you might think that this isn't a string at all, because it consists of several lines. But if we think of the instruction to start a new line as just another character—which for convenience we could call <NEWLINE>—then our string could be written like this.

```
*****<NEWLINE>*****<NEWLINE>*****
```

In Java we are able to represent this <NEWLINE> character with a special character that looks like this:

```
'\n'
```

This is one of a number of special characters called **escape characters**, which are always introduced by a backslash (\). Another useful escape character is '`\t`' which inserts a tab.[1]

Our `ExtendedOblong` class will need an additional attribute, which we will call `symbol`, to hold the character that is to be used to draw the oblong. We will also provide a `setSymbol` method, and of course we will need a method that sends back the string representation. We will call this method `draw`. The new constructor will accept values for the length and height as before, but will also receive the character to be used for drawing the oblong.

The design is shown in Fig. 9.2.

Now for the implementation. As well as those aspects of the code that relate to inheritance, there is an additional new technique used in this class—this is the technique known as **type casting**. Take a look at the complete code first—then we can discuss this new concept along with some other important features of the class.

[1]You would also have to place a backslash in front of a double quote (\"), a single quote (\') or another backslash (\\) if you wanted any of these to be output as part of a string. This is because the compiler would interpret these as having a special meaning such as terminating the string.

ExtendedOblong

```
public class ExtendedOblong extends Oblong
{
    private char symbol;

    // the constructor
    public ExtendedOblong(double lengthIn, double heightIn, char symbolIn)
    {
        super(lengthIn, heightIn);
        symbol = symbolIn;
    }

    public void setSymbol(char symbolIn)
    {
        symbol = symbolIn;
    }

    public String draw()
    {
        String s = new String(); // start off with an empty string
        int l, h;

        /* in the next two lines we type cast from double to integer so that we are able to count how
        many times we print the symbol */
        l = (int) getLength();
        h = (int) getHeight();
        for (int i = 1; i <= h; i++)
        {
            for (int j = 1; j <= l; j++)
            {
                s = s + symbol; // add the symbol to the string
            }
            s = s + '\n'; // add the <NEWLINE> character
        }
        return s; // return the string representation
    }
}
```

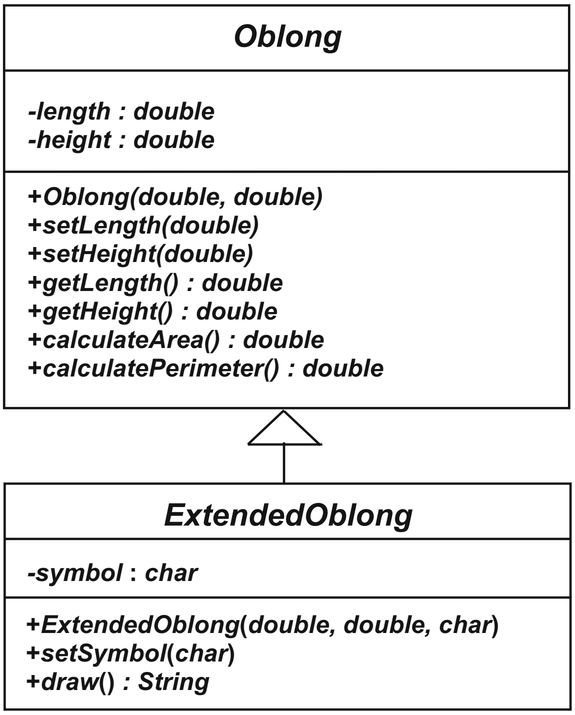


Fig. 9.2 The *Oblong* hierarchy

So let's take a closer look at all this. After the class header—which **extend**s the `Oblong` class—we declare the additional attribute, `symbol`, and then define our constructor:

```
public ExtendedOblong(double lengthIn, doubleheightIn, char symbolIn)
{
   super(lengthIn, heightIn);
   symbol = symbolIn;
}
```

Once again we call the constructor of the superclass with the keyword **super**. After the constructor comes the `setSymbol` method—which allows the symbol to be changed during the oblong's lifetime—and then we have the `draw` method, which introduces the new concept of **type casting**:

```
public String draw()
{
   String s = new String(); // start off with an empty string
   int l, h;
   l = (int) getLength();
   h = (int) getHeight();
   for (int i = 1; i <= h; i++)
   {
      for (int j = 1; j <= l; j++)
      {
         s = s + symbol; // add a symbol to end of the string
      }
      s = s + '\n'; // add a new line to the string
   }
   return s;
}
```

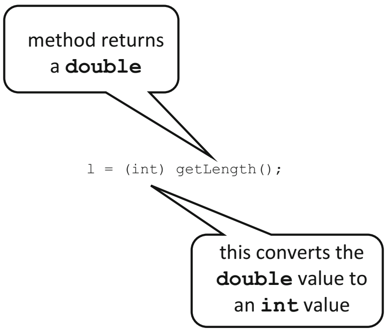
Inspect the code carefully—notice that we have declared two local variables of type **int**. In order to understand the purpose of these two variables, `l` and `h`, we need to explore this business of type casting, which means forcing an item to change from one type to another.

The `draw` method is going to create a string of one or more rows of stars or crosses or whatever symbol is chosen. Now the dimensions of the oblong are defined as **double**s. Clearly our `draw` method needs to be dealing with whole numbers of rows and columns—so we must convert the length and height of the oblong from **double**s to **int**s. There will obviously be some loss of precision here, but that won't matter in this particular case.

As you can see from the above code, type casting is achieved by placing the new type name in brackets before the item you wish to change. This is illustrated in Fig. 9.3.

The following program uses the `ExtendedOblong` class. It creates an oblong of length 10 and height 5, with an asterisk as the symbol; it then draws the oblong, changes the symbol to a cross, and draws it again.

Fig. 9.3 Type casting


method returns a **double**
l = (int) getLength();
this converts the **double** value to an **int** value

ExtendedOblongTester

```
public class ExtendedOblongTester
{
   public static void main(String[] args)
   {
      ExtendedOblong extOblong = new ExtendedOblong(10.2,5.3,'*');
      System.out.println(extOblong.draw());
      extOblong.setSymbol('+');
      System.out.println(extOblong.draw());
   }
}
```

The output from this program is shown below:

```
**********
**********
**********
**********
**********

++++++++++
++++++++++
++++++++++
++++++++++
++++++++++
```

9.5 Method Overriding

In Chap. 5 you were introduced to the concept of polymorphism—the idea that we can have different methods and operators with the same name, but whose behaviour is different. You saw in that chapter that one way of achieving polymorphism was by method *overloading*, which involves methods of the same class having the same name, but being distinguished by their parameter lists.

Now we are going to explore another way of achieving polymorphism, namely by **method overriding**. In order to do this we are going to extend the `BankAccount` class that we developed in the previous chapter. You will recall that the class we developed there did not provide any overdraft facility—the `withdraw` method was designed so that the withdrawal would take place only if the amount to be withdrawn did not exceed the balance.

Now let's consider a special account which is the same as the original account, but allows holders of the account to be given an overdraft limit and to withdraw funds up to this limit. We will call this account `GoldAccount`. Since a `GoldAccount` *is a kind of* `BankAccount`, we can use inheritance here to design the `GoldAccount` class. In addition to the attributes of a `BankAccount`, a `GoldAccount` will need to have an attribute to represent the overdraft limit, and should have `get-` and `set-`methods for this attribute. As far as the methods are concerned, we need to reconsider the `withdraw` method. This will differ from the original method, because, instead of checking that the amount to be withdrawn does not exceed the balance, it will now check that the amount does not exceed the total of the balance plus the overdraft limit. So what we are going to do is to re-write—or *override*—the `withdraw` method in the subclass.

The UML diagram for the `BankAccount` class and the `GoldAccount` class appear in Fig. 9.4. You will notice that we have made a small change to the original `BankAccount` class. The balance attribute has a hash sign (#) in front of it instead of a minus sign. You will remember from our previous discussion that this means access to the attribute is **`protected`**, rather than **`private`**. The reason why we have decided to make this change is explained below.

You will also notice that the `withdraw` method appears in both classes—this, of course, is because we are going to override it in the subclass.

You might already be thinking about how to code the `withdraw` method in the `GoldAccount` class. If you are doing this, you will probably have worked out that this method is going to need access to the `balance` attribute, which of course was declared as **`private`** in the `BankAccount` class, and (for good reason) was not provided with a `set-`method.

When we developed the `BankAccount` class in Chap. 8, we developed it as a stand-alone class, and we didn't think about how it might be used in a larger application where it could be refined. Had we known about inheritance at that point we might have given the matter a little more thought, and realised that it would be useful if any sub-classes of `BankAccount` that were developed in the future had access to the `balance` attribute. As we explained in Sect. 9.3, we can achieve that by declaring that attribute as **`protected`** instead of **`private`**. That is what we have done here. The version of `BankAccount` that we are going to use in this

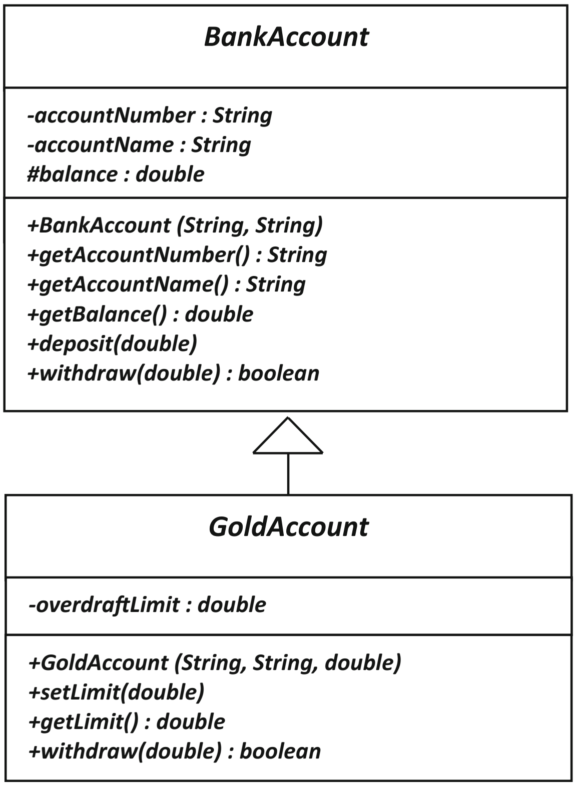


Fig. 9.4 The UML diagram for the *BankAccount* hierarchy

chapter is therefore exactly the same as the previous one, with the single difference that the declaration of the `balance` attribute now looks like this, with the keyword **`protected`** replacing **`private`**:

```
protected double balance;
```

This new version of the `BankAccount` class is available on the website.

Here is the code for the `GoldAccount` class you will notice that there is something new here, namely the line that reads `@Override`—have a look at the code, then we will explain this.

GoldAccount

```
public class GoldAccount extends BankAccount
{
   private double overdraftLimit;

   public GoldAccount(String numberIn, String nameIn, double limitIn)
   {
      super(numberIn, nameIn);
      overdraftLimit = limitIn;
   }

   public void setLimit(double limitIn)
   {
      overdraftLimit = limitIn;
   }


   public double getLimit()
   {
      return overdraftLimit;
   }

   @Override
   public boolean withdraw(double amountIn)
   {
      if(amountIn > balance + overdraftLimit) // the customer can withdraw up to the overdraft limit
      {
         return false; // no withdrawal was made
      }
      else
      {
         balance = balance - amountIn; // balance is protected so we have direct access to it
         return true; // money was withdrawn successfully
      }
   }
}
```

The thing that we are interested in here is the `withdraw` method. As we have pointed out this is introduced with **`@Override`**. This is an example of a Java **annotation**. Annotations begin with the @ symbol, and always start with an upper case letter. Although it is not mandatory that we include this annotation, it is very good practice to do so. Its purpose is to inform the compiler that we are overriding a method from the superclass. This helps us to avoid making the common error of not giving the overridden method exactly the same name and parameter list as the method it is supposed to be overriding. Without the annotation, this would escape the notice of the compiler, and you would have simply written a new method. But with the annotation included you would get a compile error if the method headings did not match.

As far as the method itself is concerned, the test in the **`if`** statement differs from the original method in the `BankAccount` class (as shown below), in order to take account of the fact that customers with a gold account are allowed an overdraft:

`withdraw` method in `BankAccount` class

```
public boolean withdraw(double amountIn)
{
   if(amountIn > balance)
   {
      return false;
   }
   else
   {
      balance = balance - amountIn;
      return true;
   }
}
```

`withdraw` method in `GoldAccount` class

```
public boolean withdraw(double amountIn)
{
   if(amountIn > balance + overdraftLimit)
   {
      return false;
   }
   else
   {
      balance = balance - amountIn;
      return true;
   }
}
```

When we dealt with method *overloading* in Chap. 5 we told you that the methods with the same name *within* a class are distinguished by their parameter lists. In the case of method *overriding*, the methods have the same parameter list but belong to different classes—the superclass and the subclass. In this case they are distinguished by the *object with which they are associated*. We illustrate this in the program below.

OverridingDemo

```
public class OverridingDemo
{
   public static void main(String[] args)
   {
      boolean ok;
      //declare a BankAccount object
      BankAccount bankAcc = new BankAccount("123", "Ordinary Account Holder");
      //declare a GoldAccount object
      GoldAccount goldAcc = new GoldAccount("124", "Gold Account Holder", 500);

      bankAcc.deposit(1000);
      goldAcc.deposit(1000);

      ok = bankAcc.withdraw(1250); // the withdraw method of BankAccount is called
      if(ok)
      {
         System.out.print("Money withdrawn. ");
      }
      else
      {
         System.out.print("Insufficient funds. ");
      }
      System.out.println("Balance of " + bankAcc.getAccountName() + " is " + bankAcc.getBalance());
      System.out.println();

      ok = goldAcc.withdraw(1250); // the withdraw method of GoldAccount is called
      if(ok)
      {
         System.out.print("Money withdrawn. ");
      }
      else
      {
         System.out.print("Insufficient funds. ");
      }
      System.out.println("Balance of " + goldAcc.getAccountName() + " is " + goldAcc.getBalance());
      System.out.println();
   }
}
```

In this program we create an object of the `BankAccount` class and an object of the `GoldAccount` class (with an overdraft limit of 500), and deposit an amount of 1000 in each:

```
BankAccount bankAcc = new BankAccount("123", "Ordinary Account Holder");
GoldAccount goldAcc = new GoldAccount("124", "Gold Account Holder", 500);
bankAcc.deposit(1000);
goldAcc.deposit(1000);
```

Next we attempt to withdraw the sum of 1250 from the `BankAccount` object and assign the return value to a **`boolean`** variable, `ok`:

```
ok = bankAcc.withdraw(1250);
```

The `withdraw` method that is called here will be that of `BankAccount`, because it is called via the `BankAccount` object, `bankAcc`.

Once this is done we display a message showing whether or not the withdrawal was successful, followed by the balance of that account:

```
if(ok)
{
   System.out.print("Money withdrawn. ");
}
else
{
   System.out.print("Insufficient funds. ");
}
System.out.println("Balance of " + bankAcc.getAccountName() + " is " + bankAcc.getBalance());
```

Now the `withdraw` method is called again, but in this case via the `GoldAccount` object, `goldAcc`:

```
ok = goldAcc.withdraw(1250);
```

This time it is the `withdraw` method of `GoldAccount` that will be called, because `goldAcc` is an object of this class. The appropriate message and the balance are again displayed.

The output from this program is shown below:

```
Insufficient funds. Balance of Ordinary Account Holder
  is1000.0

Money withdrawn. Balance of Gold Account Holder is -250.0
```

As we would expect, the withdrawal from `BankAccount` does not take place —the balance is 1000, and since there is no overdraft facility a request to withdraw 1250 is denied.

In the case of the `GoldAccount`, however, a withdrawal of 1250 would result in a negative balance of 250, which is allowed, because it is within the overdraft limit of 500.

9.6 Abstract Classes

Let's think again about our `Employee` class. Imagine that our business expands, and we now employ full-time employees as well as part-time employees. A full-time employee object, rather than having an hourly rate of pay, will have an

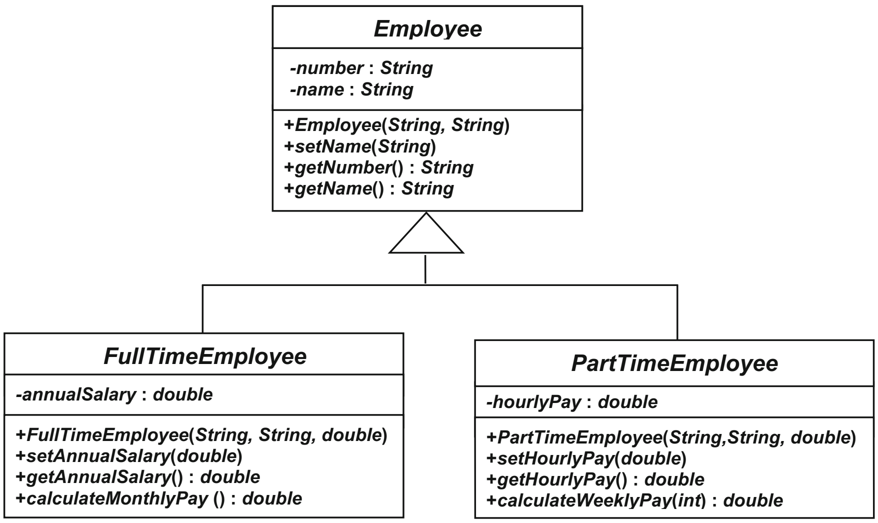


Fig. 9.5 An inheritance relationship showing the superclass *Employee* and the subclasses *FullTimeEmployee* and *PartTimeEmployee*

annual salary. It might also need a method that calculates the monthly pay (by dividing the annual salary by 12).

Figure 9.5 shows the structure of an employee hierarchy with the two types of employee, the full-time and the part-time employee.

Notice how the two subclasses contain the attributes and methods appropriate to the class. If you think about this a bit more, it will occur to you that *any* employee will always be either a full-time employee or a part-time employee. There is never going to be a situation in which an individual is just a plain old employee! So users of a program that included all these classes would never find themselves creating objects of the `Employee` class. In fact, it would be a good idea to prevent people from doing this—and, as you might have guessed, there is a way to do so, which is to declare the class as **`abstract`**. Once a class has been declared in this way it means that you are not allowed to create objects of that class. In order to make our employee class abstract all we have to do is to place the keyword **`abstract`** in the header:

```
public abstract class Employee
```

The `Employee` class simply acts a basis on which to build other classes. Now, if you tried to create an object of the `Employee` class you would get a compiler error.

We have already seen the code for `Employee` and `PartTimeEmployee`; Here is the code for the `FullTimeEmployee` class:

FullTimeEmployee

```
public class FullTimeEmployee extends Employee
{
    private double annualSalary;

    public FullTimeEmployee(String numberIn, String nameIn, double salaryIn)
    {
        super(numberIn,nameIn);
        annualSalary = salaryIn;
    }

    public void setAnnualSalary(double salaryIn)
    {
        annualSalary = salaryIn;
    }

    public double getAnnualSalary()
    {
        return annualSalary;
    }

    public double calculateMonthlyPay()
    {
        return annualSalary/12;
    }
}
```

As we said before, an inheritance relationship is often referred to as an "*is-a-kind-of*" relationship. A full-time employee is a *kind of* employee, as is a part-time employee. Therefore an object that is of type `PartTimeEmployee` is also of type `Employee`—an object is the type of its class, and also of any of the superclasses in the hierarchy.

Let's see how this relationship works in a Java program. Imagine a method which is set up to receive an `Employee` object. If we call that method and send in a `FullTimeEmployee` object or a `PartTimeEmployee` object, either is absolutely fine—because both are *kinds of* `Employee`. We demonstrate this in the program that follows:

EmployeeTester

```
public class EmployeeTester
{
   public static void main(String[] args)
   {
      FullTimeEmployee fte = new FullTimeEmployee("A123", "Ms Full-Time", 25000);
      PartTimeEmployee pte = new PartTimeEmployee("B456", "Mr Part-Time",30);
      testMethod(fte); // call testMethod with a full-time employee object
      testMethod(pte); // call testMethod with a part-time employee object
   }

   static void testMethod(Employee employeeIn) // the method expects to receive an Employee object
   {
      System.out.println(employeeIn.getName());
   }
}
```

In this program `testMethod` expects to receive an `Employee` object. It calls the `getName` method of `Employee` in order to display the employee's name.

In the main method, we create two objects, one FullTimeEmployee and one PartTimeEmployee:

```
FullTimeEmployee fte = new FullTimeEmployee("A123", "Ms Full-Time", 25000);
PartTimeEmployee pte = new PartTimeEmployee("B456", "Mr Part-Time",30);
```

We then call testMethod twice—first with FullTimeEmployee object and then with the PartTimeEmployee object:

```
testMethod(fte); // call testMethod with a full-time employee object
testMethod(pte); // call testMethod with a part-time employee object
```

The method accepts either object, and calls the getName method. The output is, as expected:

```
Ms Full-Time
Mr Part-Time
```

9.7 Abstract Methods

In the last program we conveniently gave our objects the names "Ms Full-Time" and "Mr Part-Time" so that we could easily identify them in our output. In fact, it wouldn't be a bad idea—particularly for testing purposes—if every Employee type actually had a method that returned a string telling us the kind of object we were dealing with. Adding such a method—we could call it getStatus—would be simple. For the FullTimeEmployee the method would look like this:

```
@Override
public String getStatus()
{
   return "Full-Time";
}
```

Notice that we have included the **@Override** annotation, even though it is not compulsory to do so.

For the `PartTimeEmployee`, `getStatus` would look like this:

```
@Override
public String getStatus()
{
   return "Part-Time";
}
```

It would be very useful if we could say to anyone using any of the `Employee` types, that we *guarantee* that this class will have a `getStatus` method. That way, a developer could, for example, write a method that accepts an `Employee` object, and call that object's `getStatus` method, even without knowing anything else about the class.

As you have probably guessed, we *can* guarantee it! What we have to do is to write an **`abstract`** method in the superclass—in this case `Employee`. Declaring a method as **`abstract`** means that any subclass is *forced* to override it—otherwise there would be a compiler error. So in this case we just have to add the following line into the `Employee` class:

```
public abstract String getStatus();
```

You can see that to declare an **`abstract`** method, we use the Java keyword **`abstract`**, and we define the header, but no body—the actual implementation is left to the individual subclasses. Of course, **`abstract`** methods can only be declared in **`abstract`** classes—it wouldn't make much sense to try to declare an object if one or more of its methods were undefined.

Now, having defined the **`abstract`** `getStatus` method in the `Employee` class, if we tried to compile the `FullTimeEmployee` or the `PartTimeEmployee` class (or any other class that extends `Employee`) without including a `getStatus` method we would be unsuccessful.

Once we have added the different `getStatus` methods into the `Employee` classes, we could re-write our `EmployeeTester` program from the previous sections using the `getStatus` method in `testMethod`. We have done this with `EmployerTester2` below:

EmployeeTester2

```
public class EmployeeTester2
{
   public static void main(String[] args)
   {
      FullTimeEmployee fte = new FullTimeEmployee("A123", "Ms Full-Time", 25000);
      PartTimeEmployee pte = new PartTimeEmployee("B456", "Mr Part-Time",30);
      testMethod(fte); // call testMethod with a full-time employee object
      testMethod(pte); // call testMethod with a part-time employee object
   }

   static void testMethod(Employee employeeIn) // the method expects to receive an Employee object
   {
      System.out.println(employeeIn.getStatus());
   }
}
```

In the above program it was clear at the time the program was compiled which version of `getStatus` was being referred to. The first time that the `tester` method is called, a `FullTimeEmployee` object is sent in, so the `getStatus` method of `FullTimeEmployee` is called; the second time that the `tester` method is called, a `PartTimeEmployee` object is sent in, so the `getStatus` method of `PartTimeEmployee` is called. But now have a look at the next program (where, incidentally, we have made use of our `EasyScanner` class for input).

EmployeeTester3

```
public class EmployeeTester3
{
    public static void main(String[] args)
    {
        Employee emp; // a reference to an Employee
        char choice;
        String numberEntered, nameEntered;
        double salaryEntered, payEntered;
        System.out.print("Choose (F)ull-Time or (P)art-Time Employee: ");
        choice = EasyScanner.nextChar();

        System.out.print("Enter employee number: ");
        numberEntered = EasyScanner.nextString();

        System.out.print("Enter employee name: ");
        nameEntered = EasyScanner.nextString();

        if(choice == 'F' || choice == 'f')
        {
            System.out.print("Enter annual salary: ");
            salaryEntered = EasyScanner.nextDouble();

            // create a FullTimeEmployee object
            emp = new FullTimeEmployee (numberEntered, nameEntered, salaryEntered);
        }
        else
        {
            System.out.print("Enter hourly pay: ");
            payEntered = EasyScanner.nextDouble();

            // create a PartTimeEmployee object
            emp = new PartTimeEmployee (numberEntered, nameEntered, payEntered);
        }
        testMethod(emp); // call tester with the object created
    }


    static void testMethod(Employee employeeIn)
    {
        System.out.println(employeeIn.getStatus());
    }
}
```

In this program, we call `testMethod` only once, and allow the user of the program to decide whether a `FullTimeEmployee` object is sent in as a parameter, or a `PartTimeEmployee` object. You can see that at the beginning of the program we have declared a reference to an `Employee`:

```
Employee emp;
```

Although `Employee` is an **`abstract`** class, it is perfectly possible to declare a reference to this class—what we would not be allowed to do, of course, is to create an `Employee` *object*. However, as you will see in a moment, we can point this reference to an object of any subclass of `Employee`, since such objects, like `FullTimeEmployee` and `PartTimeEmployee`, are kinds of `Employee`.

You can see that we request the employee number and name from the user, and then ask if the employee is full-time or part-time. In the former case we get the annual salary and then create a `FullTimeEmployee` object which we assign to the `Employee` reference, `emp`.

```
if(choice == 'F' || choice == 'f')
{
       System.out.print("Enter annual salary: ");
       salaryEntered = input.nextDouble();

       // create a FullTimeEmployee object
       emp = new FullTimeEmployee (numberEntered, nameEntered, salaryEntered);
}
```

In the latter case we request the hourly pay and then assign `emp` to a new `PartTimeEmployee` object:

```
else
{
       System.out.print("Enter hourly pay: ");
       payEntered = input.nextDouble();

       // create a PartTimeEmployee object
       emp = new PartTimeEmployee (numberEntered, nameEntered, payEntered);
}
```

Finally we call the `testMethod` with `emp`:

```
testMethod(emp);
```

The `getStatus` method of the appropriate `Employee` object will then be called.

Here are two sample runs from this program:

```
Choose (F)ull-Time or (P)art-Time Employee: F
Enter employee number: 123
Enter employee name: Robertson
Enter annual salary: 23000
Full-Time

Choose (F)ull-Time or (P)art-Time Employee: P
Enter employee number: 876
Enter employee name: Adebayo
Enter hourly pay: 25
Part-Time
```

As you can see, we do not know *until the program is run* whether the getStatus method is going to be called with a FullTimeEmployee object or a PartTimeEmployee object—and yet when the getStatus method is called, the correct version is executed.

The technique which makes it possible for this decision to be made at run-time is quite a complex one, and differs slightly from one programming language to another.

9.8 The **final** Modifier

You have already seen the use of the keyword **final** in Chap. 2, where it was used to modify a variable and turn it into a constant. It can also be used to modify a class and a method. In the case of a class it is placed before the class declaration, like this:

```
public final class SomeClass
{
   // code goes here
}
```

This means that the class cannot be subclassed. In the case of a method it is used like this:

```
public final void someMethod()
{
   // code goes here
}
```

This means that the method cannot be overridden.

9.9 The *Object* Class

One of the very useful things about inheritance is the *is-a-kind-of* relationship that we mentioned earlier. For example, when the ExtendedOblong class extended the Oblong class it became a kind of Oblong—so, we can use Extended-Oblong objects with any code written for Oblong objects. When the Part-TimeEmployee class extended the Employee class it became a kind of Employee. We have seen in Sect. 9.6 that, in Java, if a method of some class expects to receive as a parameter an object of another class (say, for example, Vehicle), then it is quite happy to receive instead an object of a *subclass* of Vehicle—this is because that object will be *a kind of* Vehicle.

In Java, every single class that is created is in fact derived from what we might call a special “super superclass”. This super superclass is called Object. So every object in Java is in fact *a kind of* Object. Any code written to accept objects of type Object can be used with objects of any type.

9.10 The toString Method

In the previous chapter you saw a menu-driven program, BankApplication, which provided an option to display the details of a particular bank account—and this option of course made use of the get-methods of the Bank class.

If this were to be a real-world application, then—as you will see from our case study—there would be an extensive period of testing. In order to test an application, it would be very useful if we had a way of simply displaying all the information about an object without having to invoke a lot of individual methods each time.

We are able to do this by making use of a method called toString which belongs to the Object class, and is therefore inherited by all classes, and can be overridden for each individual class.

The System.out.print and println methods are overloaded, and have a version which simply accepts a whole object as a parameter, and then displays whatever has been defined in the object's toString method.

For example, we could add the following method to our BankAccount class:

```
@Override
 public String toString()
 {
     return "Name: " + accountName + '\n' + "Account number: " + accountNumber + '\n'
                                                              + "Balance: " + balance;
 }
```

We can test this out with a little program—notice how the println method is called simply with the name of the object:

ToStringDemo

```
public class ToStringDemo
{
    public static void main(String[] args)
    {
        BankAccount acc = new BankAccount("12345678", "Patel");
        System.out.println(acc);
    }
}
```

The output from this program would be:

```
Name: Patel
Account number: 12345678
Balance: 0.0
```

And if you are wondering what happens if we haven't overridden the toString method, the answer is that the output is simply the name of the class and its location in memory. So the above program would have given us something like:

```
BankAccount@15db9742
```

9.11 Wrapper Classes and Autoboxing

We mentioned previously that collection classes such as `ArrayList` cannot be used to hold simple types such as **`int`** or **`char`**. However it is not uncommon that you would want to be able to do exactly that. Well, there is no need to worry—Java provides a very simple means of doing this.

To understand how it works you need to know about **wrapper** classes. For every primitive type, Java provides a corresponding class—the name of the class is similar to the basic type, but begins with a capital letter—for example `Integer`, `Character`, `Float`, `Double`. They are called *wrappers* because they "wrap" a *class* around the basic *type*. So an object of the `Integer` class, for example, holds an integer value. In future chapters you will find that these classes also contain some other very useful methods.

We could declare a list of integers by using the `Integer` class with the following statement:

```
ArrayList<Integer> myList = new ArrayList<>();
```

One way of storing an integer value such as 37 in this array would be as follows:

```
myList.add(new Integer(37));
```

The constructor of the Integer class accepts a primitive value and creates the corresponding `Integer` object—here we have created an `Integer` object from the primitive value 37, and this is now stored in the array.

Java, however, allows us to make use of a technique known as **autoboxing**. This involves the automatic conversion of a primitive type such as an **`int`** to an object of the appropriate wrapper class. This allows us to do the following, which as you can see is much simpler:

```
myList.add(37);
```

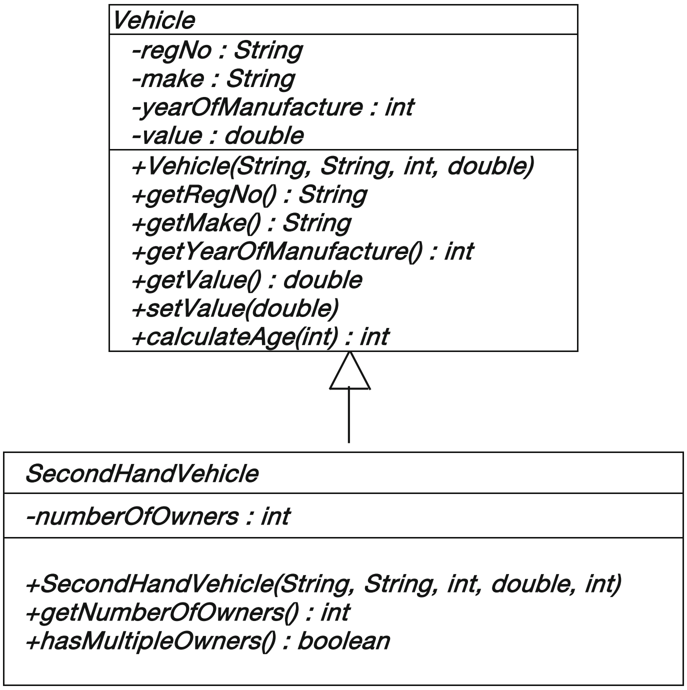
Java also allows us to make use of a technique called **unboxing**, which converts from the wrapper class back to the primitive type—so to assign the first item in the list to an integer `x`, we would simply write:

```
int x = myList.get(0);
```

Exactly the same technique would be used to store other primitive types such as **`char`** and **`double`**.

9.12 Self-test Questions

1. Below is a UML diagram for an inheritance relationship between two classes—`Vehicle` and `SecondHandVehicle`.



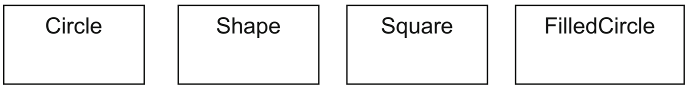
   (a) By referring to the diagram, explain the meaning of the term *inheritance*.

   (b) What do you think might be the function of each of the constructors?

   (c) What do you think might be the reason for the fact that in the `Vehicle` class there is a `set`-method for the `value` attribute, but not for the other three?

   (d) Write the header for the `SecondHandVehicle` class.

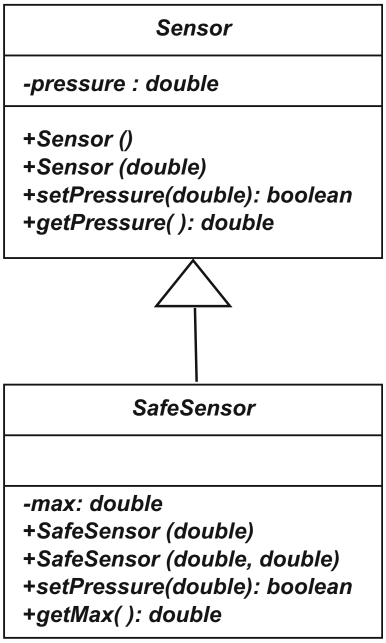
2. (a) Consider the following classes and arrange them into an inheritance hierarchy using UML notation:



(b) Write the top line of the class declaration for each of these classes when implementing them in Java.

(c) Explain what effect the **abstract** modifier has on a class and identify which, if any, of the classes above could be considered as abstract classes?

3. Consider once again an application to record the reading of a pressure sensor as discussed in programming exercise 4 of the previous chapter. Now assume a `SafeSensor` class is developed that ensures that the pressure is never set above some maximum value. A `SafeSensor` *is a kind of* `Sensor`. The UML design is given below:



The `SafeSensor` class has two constructors. The first sets the maximum safe value to the given parameter and the actual value of the sensor reading to 10. The second constructor accepts two parameters, the first is used to set the maximum safe value and the second is used to set the initial value for the reading of the sensor.
The `setPressure` method is redefined so that only safe values (values no greater than the safe maximum value and no less than zero) are set.

(a) In the example above, distinguish between *method overriding* and *method overloading*.

(b) Below is one attempt at the Java code for the first `SafeSensor` constructor. Identify why it will not compile.

```
// THIS WILL NOT COMPILE!!
public SafeSensor(double maxIn)
{
       max = maxIn;
       pressure = 10;
}
```

(c) Here is another attempt at the Java code for the first `SafeSensor` constructor. Identify why it will not compile.

```
// THIS WILL NOT COMPILE!!
public SafeSensor(double maxIn)
{
       max = maxIn;
       super();
}
```

(d) Write the correct code for the first `SafeSensor` constructor.

4. By referring to the `BankAccount` class of Sect. 9.5, distinguish between **`private`**, **`public`** and **`protected`** access.
5. How are all classes in Java related to the `Object` class?
6. Explain, with an example, the term *type cast*.
7. (a) Consider the following definition of a class called `Robot`:

```
public abstract class Robot
{
    private String id;
    private int securityLevel;
    private int warningLevel = 0;

   public Robot(String IdIn, int levelIn)
   {
        id = IdIn;
        securityLevel = levelIn;
   }

   public String getId()
   {
        return id;
   }


   public int getSecurityLevel()
   {
        return securityLevel;
   }

   public abstract void calculateWarningLevel();
}
```

(i) The following line of code is used in a program that has access to the `Robot` class:

```
Robot aRobot = new Robot("R2D2", 1000);
```

Explain why this line of code would cause a compiler error.

(ii) Consider the following class:

```
public class CleaningRobot extends Robot
{
   public String typeOfCleaningFluid;

   public CleaningRobot(String IdIn, int levelIn, String fluidIn)
   {
        super(IdIn, levelIn);
        typeOfCleaningFluid = fluidIn;
   }

   public String getTypeOfCleaningFluid()
   {
        return typeOfCleaningFluid;
   }
}
```

Explain why any attempt to compile this class would result in a compiler error.

8. What is the effect of the **`final`** modifier, when applied to both classes and methods?

9. Look back at the `EmployeeTester` class from Sect. 9.6. What do you think would happen if you replaced this line of `testMethod`:

```
System.out.println(employeeIn.getName());
```

with the following line?

```
System.out.println(employeeIn.getAnnualSalary());
```

Give a reason for your answer.

9.13 Programming Exercises

1. (a) Copy the `ExtendedOblong` class from the website, then implement the `ExtendedOblongTester` from Sect. 9.4. You will, of course, need to ensure that the `Oblong` class itself is accessible to the compiler.

   (b) Modify the `ExtendedOblongTester` program so that the user is able to choose the symbol used to display the oblong.

2. (a) Implement the `SafeSensor` class of self-test question 3. You will need to ensure that the `Sensor` class itself is accessible to the compiler.

   (b) Write a tester class to test the methods of the `SafeSensor` class.

3. (a) Implement the `Vehicle` and the `SecondHandVehicle` classes of self-test question 1.
   You should note that:

   - the `calculateAge` method of `Vehicle` accepts an integer representing the current year, and returns the age of the vehicle as calculated by subtracting the year of manufacture from the current year;
   - the `hasMultipleOwners` method of `SecondHandVehicle` should return **`true`** if the `numberOfOwners` attribute has a value greater than 1, or **`false`** otherwise.

   (b) Write a tester class that tests all the methods of the `SecondHandVehicle` class.

4. Write a menu-driven program that uses an `ArrayList` to hold `Vehicles`. The menu should offer the following options:

```
1. Add a vehicle
2. Display a list of vehicle details
3. Delete a vehicle
4. Quit
```