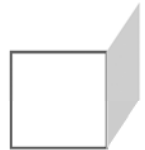
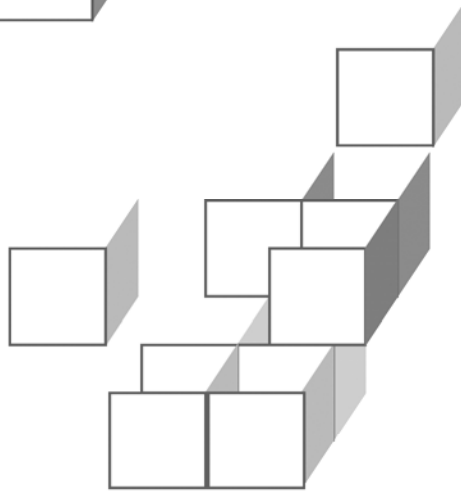
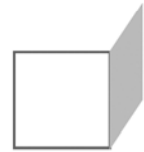




**CHAPTER 7**  
**OBJECTS AND CLASSES**



## OBJECTIVES

*After completing “Objects and Classes,” you will be able to:*

- Explain the use of classes in Java for representing structured data.
- Distinguish between objects and classes.
- Describe how Java classes support encapsulation through member data and methods.
- Use the public and private access specifiers in Java programs.
- Explain the use of the new operator to instantiate objects from classes.
- Describe the use of references in Java and explain the role of garbage collection.
- Use constructors to initialize your objects.

## Structured Data

---

- Java defines primitive data types that are built into the language.
  - Data types such as **int**, **double**, and **boolean** can be used to represent simple data.
- Java provides the **class** mechanism to represent more complex forms of data.
- Through a class you can build up structured data out of simpler elements.

```
public class Product
{
    String description;
    double price;
}
```

- **Product** is now a new data type.
- A product has a description (e.g. “Airplane toy”) and a price (e.g. 2.55).
- The Java libraries predefine many classes that you can use in your programs.
  - **String**, although not a primitive data type, is predefined for you in the standard Java library.

## Classes and Objects

---

- A **class** represents a “kind of” or type of data.
  - It is analogous to the built-in types like **int** and **double**.
- A class can be thought of as a template from which individual instances can be created.
  - When you create a **class**, you are only creating a **definition** .
- An **instance** of a class is called an **object**.
  - Just as you can have several individual integers that are instances of **int**, you can have several products that are instances of **Product**.

## References

---

- There is a fundamental distinction between the primitive data types and the extended data types that can be created using classes.
- When you declare a variable of a primitive data you are allocating memory and creating the instance.

```
int x;    // 4 bytes of memory have been allocated
```

- When you declare a variable of a class type (an “object variable”), you are only obtaining memory for a **reference** to an object of the class type.
  - No memory is allocated for the object itself, which may be quite large.

```
Product p;  
// p is a reference to a Product object  
// The object itself does not yet exist
```

## Instantiating and Using an Object

---

- You instantiate an object with the **new** operator.

```
p = new Product (); // a Product object now exists
                    // and p is a reference to it
```

- Once an object exists you work with it, including accessing its data members (or “fields”) and methods.
  - Our simple **Product** example at this point has no methods, only two data members.
  - You access data members and methods using a dot (normally you will not access data members directly – they are usually “private”).

```
p.description = "Airplane toy";
p.price = 2.55; // values have now been assigned
```



- Before the object exists, its object reference is **null**.
  - You can test for an object reference being **null**.

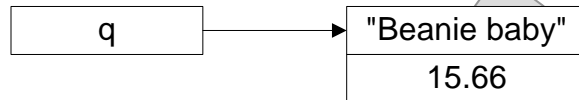
```
if (p != null)
{
    // OK to assign values
    p.description = "Airplane toy";
    p.price = 2.55;
}
```

## Assigning Object Variables

---

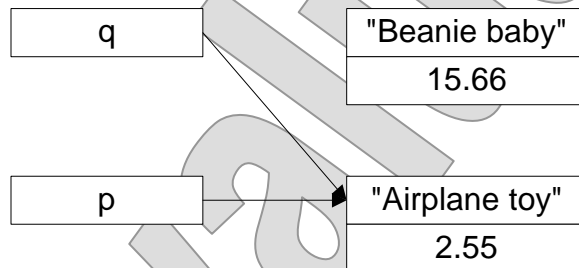
- Consider a second object variable referencing a second object.

```
Product q = new Product();  
q.description = "Beanie baby";  
q.price = 15.66
```



- When you assign an object variable you are only assigning the reference, there is no copying of data.

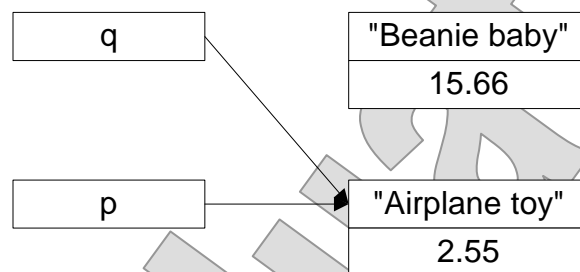
```
q = p; // q now refers to same object p does
```



## Garbage Collection

---

- Through the assignment of a reference, an object may become orphaned.
  - Such an orphan object (or “garbage”) takes up memory in the computer which can now never be referenced.
  - “Beanie baby” is now garbage.



- The Java Virtual Machine automatically reclaims the memory of unreferenced objects.
  - This process is known as **garbage collection**.
  - Garbage collection takes up some execution time, but it is a great convenience for programmers, helping to avoid a common program error known as a “memory leak”.

## Programming a Class

**EXAMPLE**

- To program a class in Java do the following:
  - Enter the class definition in a file.
  - The file should have the same name as the class with the extension **.java**.
  - Make the class **public** in order to be able to use it in other classes.
  - Declare **fields**, which are like variables but they exist for the life of each object of the class, rather than just for the duration of a method invocation.
- Example program shows definition and use of a simple **Product** class.
  - See **Examples/Product/Step0**.

```
public class Product
{
    String description;
    double price;
}
```

## Default Values

---

- Notice that you do not need to initialize fields, though you can if you so choose.
- If you don't, the compiler will assign a default value, which is essentially the “zero representation” appropriate to the data type of the field.
- The following table shows the default value for the primitive data types:

Type	Default
<code>boolean</code>	<code>false</code>
<code>char</code>	<code>\u0000</code>
<code>byte</code>	<code>0</code>
<code>short</code>	<code>0</code>
<code>int</code>	<code>0</code>
<code>long</code>	<code>0L</code>
<code>float</code>	<code>0.0f</code>
<code>double</code>	<code>0.0</code>

- Object references default to **null**.

## Using a Class

**EXAMPLE**

- To use a class:
  - Declare a reference to the class and instantiate an object instance by **new** (can be done on the same line).
  - Access members (and methods) by using the dot notation.
  - See **Examples/Product/Step0**.

```
public class TestProduct
{
    public static void main(String[] args)
    {
        Product p1 = new Product();
        Product p2 = new Product();
        Product q;
        p1.description = "Airplane toy";
        p1.price = 2.50;
        p2.description = "Beanie baby";
        p2.price = 15.66;
        q = p1;
        System.out.println(q.description + " " +
                           q.price);
        q = p2;
        System.out.println(q.description + " " +
                           q.price);
    }
}
```

## Methods

---

- Typically a class will specify **behavior** as well as **data**.
  - A class **encapsulates** data and behavior in a single entity.
- A **method** consists of:
  - An access specifier, typically **public** or **private**.
  - A return type (can be **void** if the method does not return data).
  - A method name, which can be any legal Java identifier.
  - A parameter list, enclosed by parentheses, which specifies data that is passed to the method (can be empty, if no data is passed).
  - A method body, enclosed by curly braces, which contains the Java code that the method will execute.

## Methods

---

- **Example:**

- The return type is **void** (no data is passed back).
- The method name is **adjustPrice**.
- The parameter list consists of a single parameter of type **double**.
- The body contains one line of code that increments the member variable **price** by the value that is passed in.

```
public void adjustPrice(double p)
{
    price += p;
}
```

- **Example:**

- The return type is **double** (data of type **double** will be passed back).
- The method name is **getPrice**.
- There are no parameters.
- The body contains one line of code that returns the current value of member variable **price**.

```
public double getPrice()
{
    return price;
}
```

## Public and Private

---

- Data members and methods of a Java class can be specified as **public** or **private**.
- Normally you declare data members as **private**.
  - A **private** member can only be accessed from within the class, not from outside.
- Methods may be declared as either **public** or **private**.
  - Public methods are called from outside the class and are used to perform calculations and to manipulate the private data.
  - You may also have private methods, which can be thought of as “helper functions” for use within the class (rather than duplicating code several places, you may create a private method, which will be called wherever it is needed).

## Abstraction

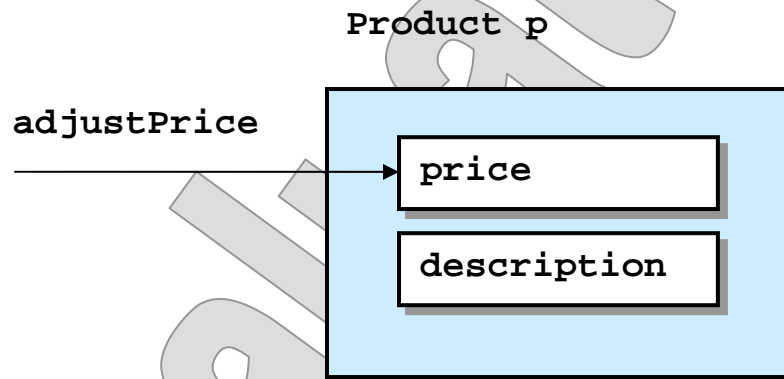
---

- Our **Product** class captures the essential features of a product, suppressing unnecessary details.
  - There are many possible features of a *product*, but for our purposes the only essential things are its **description** and its **price**.
- All instances of the **Product** class share these common features.
- This helps us deal with complexity.

## Encapsulation

---

- Encapsulation is an important feature of Object Orientation.
- The implementation of a class should be hidden from the rest of the system, or **encapsulated**.
- Objects have a public and a private side.
- Public side is what the rest of the system knows, while private side implements the public side.



- Data itself should be private and only accessible through methods with a public interface.
- There are two kinds of protection:
  - Internal data is protected from corruption.
  - Users of the object are protected from changes in the representation.

## Constructors

---

- Another important issue for classes is **initialization**.
  - When an object is created, what initial values are assigned to the instance data?
- Through a **constructor** you can initialize an object in any way you wish.
  - Besides initializing instance data you can perform other appropriate initializations (e.g. open a file).
- A constructor is like a special method which is automatically called when an object is created.
  - A constructor has no return type.
  - A constructor has the same name as the class.
  - A constructor may take parameters, which are passed when invoking **new**.

```
public Product(String d, double p)
{
    description = d;
    price = p;
}
```

## A Product Class

**EXAMPLE**

- Another version of the **Product** class illustrates the features we have been discussing.
  - See **Examples/Product/Step1**.

```
public class Product
{
    // constructor
    public Product(String d, double p)
    {
        description = d;
        price = p;
    }
    public void adjustPrice(double p)
    {
        // method increments the price by p
        price += p;
    }
    public double getPrice()
    {
        // method retrieves the price
        return price;
    }
    public String getDescription()
    {
        // method retrieves the description
        return description;
    }
    public String toString()
    {
        // method converts to string
        return String.format("%s $%,1.2f",
                               description, price);
    }
    private String description;
    private double price;
}
```

## A Product Class

**EXAMPLE**

```
public class TestProduct
{
    public static void main(String[] args)
    {
        Product p1, p2, p3;
        p1 = new Product("Airplane toy", 2.50);
            // uses constructor
        p1.adjustPrice(.50); // uses method
        p2 = new Product("Beanie baby", 15.66);
        p3 = new Product("Cat carrier", 5.50);
            // uses constructor

        System.out.println(p1.toString());
        System.out.println(p2.toString());
        System.out.println(p3.toString());
            // conversion to string

        System.out.println(p3);
            // implicit conversion
    }
}
```

– Try it out:

```
build
run TestProduct
Airplane toy $3.00
Beanie baby $15.66
Cat carrier $5.50
Cat carrier $5.50
```

## The toString Method

---

- It is often useful to define a **toString** method in your class.
  - This method should return a **String** value that represents the current object instance.
- **toString** is known to Java.
  - If an object reference is used when a **String** reference is expected, your object will be converted to a **String** using the **toString** method.
  - For example, the **println** method expects a **String** parameter, and a **Product** variable will be converted to a **String** variable using the **toString** method.

## Formatted Output

---

- Java 5 introduces a simple means of formatting output to a stream.
  - This is a feature long known in the C language, and to some it has been conspicuous by its absence in Java.
- The **System.out** object offers a method **format**.
  - The **format** method takes a formatting string as its first parameter, and then any number of objects after that.

```
System.out.format ("%8d %s%n", 77, "Hello");
```

- The call shown above produces the following – note the leading spaces to observe an eight-character “width” for the numeric argument:

```
 77 Hello
```

- The **String** class offers a **format** method as well.
  - It takes the same parameters, but instead of producing the results to the console it returns a formatted string object.

```
String representation =  
String.format ("%8d %s%n", 77, "Hello");
```

- This provides a means of capturing formatted presentations and passing them around between objects.

```
public String toString ()  
{  
    return String.format ("(%d, %d)", x, y);  
}
```

## Formatting Strings

---

- The formatting string passed to **format** consists of literal text and **fields**.
- Each field in the string must correspond to an argument passed to the method – with a few exceptional field types that produce special characters and don't need a value to be provided.
- Common field types are
  - **%d**, which formats an integer
  - **%s**, which formats a string
  - **%f**, which formats a floating-point number
  - **%n**, which produces an end-of-line sequence appropriate for the runtime operating system
- Most fields can be modified in a few simple ways:
  - A number preceding the one-letter field code defines the field width, which is a minimum number of characters to be produced by the field.
  - A hyphen preceding the number indicates the field will be **left-justified**, where **right-justified** is the default, if a width has been specified – even for strings.

## Formatting Examples

---

- The following pairs of lines show the Java code to format certain values and the resulting output:

```
System.out.format ("%d %s %s%n",  
    77, "Hi", "there");  
77 Hi there
```

```
System.out.format ("%4d %8s %8s%n",  
    77, "Hi", "there");  
77      Hi      there
```

```
System.out.format ("%4d %-8s %-8s%n",  
    77, "Hi", "there");  
77 Hi          there
```

```
System.out.format ("% -16s $%,8.2f",  
    "Dog bone", 70);  
Dog bone          $      70.00(and no line break!)
```

```
System.out.format ("The value is $%,-1.2f.", 70);  
The value is $70.00.
```

- Formatted output is simple to use, but for many purposes it is still simpler and easier to simply **print** or **println**.
- Formatted output is especially helpful in establishing regular widths for fields, and in justifying the output text, so that columns of values are neatly aligned for the reader of the output.
- We will use a combination of the two practices in the rest of our code examples and exercises.

## Using a Money Class

**LAB 7**

In this lab you will create a **Money** class that can be used to hold and display currency values. The **Money** class will encapsulate formatting logic, hiding this detail from the rest of the program.

Detailed instructions are contained in the Lab 7 write-up at the end of the chapter.

Suggested time: 60 minutes

Evaluation Only

## SUMMARY

- **Classes are used in Java for representing structured data.**
- **An object is an instance of a class.**
- **Java classes support encapsulation through private member data and public methods.**
- **The new operator is used to instantiate objects from classes.**
- **Java uses references to refer to objects.**
- **An object without a reference represents unused memory, which will be cleaned up by garbage collection.**
- **Constructors are used to initialize objects.**

## Using a Money Class

### LAB 7

### Introduction

In this lab you will create a **Money** class that can be used to hold and display currency values. The **Money** class will encapsulate formatting logic, hiding this detail from the rest of the program.

<b>Directories:</b>	<b>Labs/Lab07/Money</b>	(Exercise 1 work)
	<b>Examples/Money/Step0</b>	(Backup of starter code)
	<b>Examples/Money/Step1</b>	(Intermediate answer)
	<b>Examples/Money/Step2</b>	(Exercise 1 answer)
	<b>Labs/Lab07/Product</b>	(Exercise 2 work)
	<b>Examples/Product/Step1</b>	(Backup of starter code)
	<b>Examples/Product/Step2</b>	(Exercise 2 answer)

### Instructions

#### Exercise 1. Creating a Money Class

Create a file **src/Money.java** that defines a class to encapsulate storing and displaying a currency value. You are supplied a test program **src/TestMoney.java** that can be used to exercise your class. Your class should have the following features:

A private data member **price** of type **double** that is used as the internal representation.

A constructor that initializes **price** from a **double** parameter that is passed in.

An implementation of the standard **toString** method that returns a string representation of a double used for currency value. Use **String.format** to get a currency representation that includes two digits to the right of the decimal point, and includes comma separators every three digits to the left of the decimal point. (See the final example of formatted output for the exact formatting field to use.) (This is the **Step1** intermediate answer, and the one that's used in the next exercise.)

```
run TestMoney
$2.55
$15.50
$5,000.00
```

Optionally, try to make **TestMoney** produce clean columns of numbers, with the decimal points lined up. How about “%,6.2f” as a field, to accommodate up to 6-figure values? It doesn't quite work! If this is confusing, note that the digit to the left of the decimal point in a formatting field specifies the minimum width of the total field output – that is, including commas, decimal point, and digits to the right. So six as a width only allows for six character columns – not enough to accommodate the string “\$5,000.00”

without breaking alignment. Try “%,10.2f” and see that you do get clean output, like this (and this is the **Step2** final answer):

```
run TestMoney
$      2.55
$     15.50
$   5,000.00
```

## Exercise 2. Using the Money Class in the Product Class

In this exercise you will replace the internal representation of **price** in the **Product** class. You will use **Money** as the type of **price** in place of **double**. The external interface remains the same, so all calling programs should run unchanged. The **Step1** version of **Money.java** has been placed in the **src** directory for this exercise. Try to make all the remaining changes on your own. If you get stuck you can refer to the following detailed list of the changes that you should make to **src/Product.java**:

1. In the definition of the private data member **price** replace the type **double** by **Money**.
2. Modify the constructor to initialize **price** by instantiating a new **Money** object.
3. Modify the **getPrice** method to return a **Money**.
4. Simplify the implementation of **toString** to use the **toString** method of **Money**. Note that you can get particularly elegant code by relying on Java to automatically convert a **Money** object to a **String** object, implicitly using the **toString** method of **Money**.
5. Try to compile the program. You will find an error in **adjustPrice**, because the operator **+=** cannot be applied to the **Money** type. Go back to the **Money** class and implement a new method **adjust** which adds a **double** value to the internal **price**. Use this **adjust** method in **adjustPrice**.
6. You should now be able to run the test program **src/TestProduct.java** without making any changes.

As a final enhancement you can simplify the test program by printing out all the string representations of products using the implicit invocation of **toString** of **Product** class – i.e. just call **System.out.println(p1)**, etc.