Java Just in Time: task questions

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1 Chapter 1 Introduction

1.6 Section / task 1.6 Our first Java program

- Aim of example: To show the mechanics of processing a finished Java source program so that it can be **run**, through to actually running it.
- Coursework title: **Compile and run HelloWorld**
- Coursework summary: To **compile** and **run** the HelloWorld program.
- Question: Carefully type in the **source code** for the HelloWorld program, and save it in the appropriately named **file**. Check it to make sure you have not made any typing errors—otherwise you may get error messages that will alarm you! (Try to get the **indentation** right—e.g. line 3 has two spaces at the front, and line 5 has four.) Now **compile** and **run** it. Record your progress and any observations you make, in your logbook.

1.7 Section / task 1.7 Our second Java program

- Aim of example: To reinforce the process of the **compile** and **run** cycle of a Java program.
- Coursework title: **Compile and run HelloSolarSystem**
- Coursework summary: To **compile** and **run** the HelloSolarSystem program.
- Question: Carefully type in the **source code** for the HelloSolarSystem program, and save it in the appropriately named **file**. Check it to make sure you have not made any typing errors—otherwise you may get error messages that will alarm you! (Try to get the **indentation** right—e.g. line 3 has two spaces at the front, and line 5 has four.) Now **compile** and **run** it. Record your progress and any observations in your logbook.

2 Chapter 2 Sequential execution and program errors

2.2 Section / task 2.2 Hello world

- Aim of example: To introduce some very basic Java concepts, including the **main method** and **System.out.println()**.
- Coursework title: **HelloWorld in French**
- Coursework summary: Write a program to greet the whole world, in French!
- Question: Write a new version of HelloWorld which gives its greeting in French (or any other language of your choice, apart from English). You will learn most if you try to do this without looking at the original version. Your program should still be called HelloWorld, as only the message **data** is in French. Type the program in and save it in the appropriately named **file**. Check it against the original to see you have not made any
mistakes – otherwise you may get error messages that will alarm you. Then compile and run it.

2.3  Section / task 2.3 Hello world with a syntactic error

- Aim of example: To introduce the principle of program errors, in particular syntactic errors. We also see that a string literal must be ended on the same line it starts on.
- Coursework title: Fortune syntactic errors
- Coursework summary: Take a given program that has syntactic errors in it, and get it working.
- Question: Carefully type in the following program exactly. It contains some deliberate mistakes – type them in anyway even if you spot them as you read the code.

```
001: public class Fortune
002: {
003:    public static void main(String [] args)
004:    {
005:        System.out.println("Sometimes having a fortune is too expensive!");
006:    }
007: }
```

Now compile the program and examine the error messages. Record these in your log-book, each along with your best attempt to explain the meaning and the cause of it. Can you see any errors which appear not to have caused a message? If so, record these too.

Now fix the errors one at a time, and compile the program in between. Record any new error messages that appear, along with your explanation for them.

Optional extra: Make the smallest number of edits to your HelloWorld program so as to have javac produce the largest number of syntactic errors! For example, what happens if you simply delete a space between two words of the program?

2.4  Section / task 2.4 Hello world with a semantic error

- Aim of example: To introduce semantic errors and note that these and syntactic errors are compile time errors.
- Coursework title: ManchesterWeather semantic errors
- Coursework summary: Take a given program that has semantic errors in it, and get it working.
- Question: Carefully type in the following program exactly. It contains some deliberate mistakes – type them in anyway even if you spot them as you read the code.

```
001: public class ManchesterWeather
002: {
003:    public static void main(spring[] args)
```
Now compile the program and examine the error messages. Record these in your logbook, each along with your best attempt to explain the meaning and the cause of it. Can you see any errors which appear not to have caused a message? If so, record these too.

Now fix the errors one at a time, and compile the program in between. Record any new error messages that appear, along with your explanation for them.

2.5 Section / task 2.5 Hello solar system

- Aim of example: To introduce the principle of sequential execution.
- Coursework title: HelloFamily
- Coursework summary: Write a program to greet some of your family.
- Question: Preferably without looking at HelloSolarSystem, write a program called HelloFamily which greets your maternal grandparents and all their descendants. Don’t forget to include yourself. If you have a lot of relatives, then you may limit your program to around 12 of them if you wish. The greeting must be done in alphabetical order by name – so you had better plan the output before you start typing.

(Hint: one approach would be to type the names into a text file, one name per line, and then use some program which sorts lines of text – for example the sort program. After this the resulting text could be edited to become the final program.)

2.6 Section / task 2.6 Hello solar system with a run time error

- Aim of example: To introduce the principle of run time errors.
- Coursework title: Quote run time errors
- Coursework summary: Take a given program that has run time errors in it, and get it working.
- Question: Carefully type in the following program exactly. It contains some deliberate mistakes – type them in anyway even if you spot them as you read the code.
2.7 Section / task 2.7 Hello anyone

Now compile the program, and if you have typed it correctly it should compile without errors. However, when you run the program you will get an error message. Record this in your logbook, along with your best attempt to explain the meaning and the cause of it.

Now fix the error and run the program again. Record any new error messages that appear, along with your explanation for them.

2.7 Section / task 2.7 Hello anyone

- Aim of example: To introduce the principle of making Java programs perform a variation of their task based on command line arguments, which can be accessed via an index. We also meet string concatenation.

- Coursework title: FlatterMe

- Coursework summary: Write a program to say how wonderful the user is.

- Question: Without looking at HelloAnyone, write a program called FlatterMe which flatters the person named as the first command line argument, three times. The first comment should start with the person’s name, the second should end with it, and the third should have some text either side of the name. (Hint: you will need to use two concatenation operators for that.)

2.8 Section / task 2.8 Hello anyone with a logical error

- Aim of example: To introduce the principle of logical errors.

- Coursework title: Birthday logical errors

- Coursework summary: Take a given program that has logical errors in it, and get it working.

- Question: Carefully type in the following program exactly. It contains some deliberate mistakes – type them in anyway even if you spot them as you read the code.

```java
001: public class Birthday
002: {
003:   public static void main(String[] args)
004:   {
006:     System.out.println("Born: " + args[0]);
007:   }
008: }
```

Now compile the program, and if you have typed it correctly it should compile without errors. Next you should run the program with three command line arguments – the first should be your personal name, the second should be your surname or family name,
and the third should be your date of birth, e.g. 24/04/1959. It is intended to print a result like the following.

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ java Birthday John Latham 24/04/1959</td>
</tr>
<tr>
<td>Name: Latham, John; Born: 24/04/1959</td>
</tr>
</tbody>
</table>

Note the position of spaces and punctuation in the desired output. However you will see that the output you actually get is wrong! Record the errors in your logbook, along with your best attempt to explain the cause of them.

Now fix the errors and run the program again. Record any new errors that appear, along with your explanation for them.

During this process you should have learnt about a method which is similar to `System.out.println()`. Record what this method is called and what it does.

### 2.9 Section / task 2.9 Hello solar system, looking at the layout

- **Aim of example:** To begin to explore the decisions behind the way we lay out the source code for a program.
- **Coursework title:** Limerick layout
- **Coursework summary:** Take a given program and lay it out properly.
- **Question:** Carefully type in the following program exactly. It contains very poor layout – type it in anyway even if you can see how it should be laid out as you read the code.

```java
001: public class Limerick{
002:  public static void main(String[] args){
003:    System.out.println("There was a young user of Java");
004:    System.out.println("Whose coding was such a palava!");
005:    System.out.println("His layout was pooh!");
006:    System.out.println("So what did we do?");
007:    System.out.println("We told him to stick to making coffee!");
}
```

You should compile the program, and if you have typed it correctly it should compile and run without errors. Record all the instances of poor layout you can see, in your logbook.

Now fix the layout!

### 3 Chapter 3 Types, variables and expressions

#### 3.2 Section / task 3.2 Age next year

- **Aim of example:** To introduce the concepts of **type**, **int**, **variable**, **expression** and **assignment statement**. We also find out how to convert a number to a string, and discover what it means for **data** to be **hard coded**.
3.4 Section / task 3.4 Age next year with a command line argument

- Coursework title: **Hard coded YearsBeforeRetirement**
- Coursework summary: Write a program to determine how many years *you* have before you retire!
- Question: Preferably without looking at AgeNextYear, write a program called YearsBeforeRetirement which has your age hard coded into it, along with the age you expect to retire at (probably 68 – although that may well change before you get there!). Your program will need two variables for these values. It should then compute the difference between them and store it in a third variable, for which you should choose an appropriate name. Finally, it should produce three lines of output, similar to the following.

```
Console Input / Output
$ java YearsBeforeRetirement
My age now is 51
I will retire at the age of 68
Years left working is 17
$ _
```

3.4 Section / task 3.4 Age next year with a command line argument

- Aim of example: To introduce the idea of converting a command line argument into an int and using the value in a program.
- Coursework title: **Command line YearsBeforeRetirement**
- Coursework summary: Write a program to determine how many years the user has before he or she retires.
- Question: Here you will write another version of YearsBeforeRetirement, which is similar to the fully hard coded version of the program, but takes the user’s age as its first command line argument. The retirement age is still to be hard coded as 68.

*Before* implementing the program, you should design test data for various tests which do the following.

- Make the program behave sensibly.
- Make the program behave inappropriately (i.e. a silly input resulting in a silly output).
- Make the program crash.

You should record this data in your logbook along with what you expect from each test. Then copy your previous version of the program and alter it to suit the new requirement. You will learn most if you try not to look at the latest version of AgeNextYear while you do this. Finally, run it with your pre-planned tests and record whether the outcome was as you expected.
3.5 Section / task 3.5 Finding the volume of a fish tank

- Aim of example: To reinforce the use of command line arguments and expressions, and introduce the idea of splitting up lines of code which are too long, whilst maintaining their readability. We also see that a variable can be given a value when it is declared.

- Coursework title: FieldPerimeter

- Coursework summary: Write a program to determine how much fence is needed to surround a rectangular field.

- Question: Here you will write a program called FieldPerimeter which takes the length and width of a field as its two command line arguments, and computes the length of fence needed to enclose the field. (The simplest way to compute this is length + length + width + width).

Before implementing the program, you should design test data for various tests which do the following.

- Make the program behave sensibly.
- Make the program behave inappropriately (i.e. a silly input resulting in a silly output).
- Make the program crash.

You should record this data in your logbook along with what you expect from each test. You will learn most if you try not to look at FishTankVolume while writing your program. Afterwards, run it with your pre-planned tests and record whether the outcome was as you expected.

3.6 Section / task 3.6 Sum the first N numbers – incorrectly

- Aim of example: To introduce the principle of operator precedence, and have a program containing a bug.

- Coursework title: FishTankMaterials

- Coursework summary: Take a program with bugs in it, and fix them.

- Question: Suppose you want to build fish tanks. Each tank has five pieces of glass – two sides, a front, a back and a bottom. It also has twelve pieces of metal angle-strip to form the edges. Below is a program which computes the surface area and the length of the edges for a tank with dimensions given by three command line arguments.

Design some test data for the program, predicting what the surface area and edge length should be if the program worked correctly. For simplicity, you do not need to worry about missing or meaningless arguments for this program. Record your planned test data in your logbook.

Then carefully type in the program, as is, and run it with your tests. Record the actual results, and attempt to explain the bugs, in your logbook.
```java
public class FishTankMaterials {
    public static void main(String[] args) {
        int width = Integer.parseInt(args[0]);
        int depth = Integer.parseInt(args[1]);
        int height = Integer.parseInt(args[2]);

        int surfaceArea = width + height * depth + height + 2 * width + depth;
        int edgesLength = height * width * depth + 4;

        System.out.println("The surface area of a tank with dimensions " + ", " + width + ", " + depth + ", " + height + ") " + surfaceArea);
        System.out.println("The length of the edges of a tank with dimensions " + ", " + width + ", " + depth + ", " + height + ") " + edgesLength);
    }
}
```

Now fix the program and test it again, making a record of your bug corrections. Does the program now produce the results you originally predicted, or is it still wrong, or were your original predictions wrong?

### 3.7 Section / task 3.7 Disposable income

- **Aim of example:** To introduce **operator associativity**. We also take a look at the **string literal escape sequences**.

- **Coursework title:** ThreeWeights

- **Coursework summary:** Write a program to show what weights can be weighed using a balance scale and three given weights.

- **Question:** In the days before accurate mechanical spring weighing scales (let alone digital ones), gold merchants were quite clever in their use of a small number of brass or lead weights, and a balance scale. (Indeed, many still use these in preference to inferior modern technology!) They would place the gold to be weighed in the left pan of the balance scale, and then place known weights in the right pan, and maybe also in the left pan, until the scales balanced. For example, suppose an unknown amount of gold was placed in the left pan. The merchant might experiment with a number of weights until he or she managed to make it balance with a known weight of $R$ ounces in the right pan, and $L$ ounces in the left pan along with the gold. This would show that the gold weighed $R - L$ ounces. In order to be able to weigh different amounts of gold, each merchant would carry a small number of known weights. When making a particular weighing, each weight could be placed in one of three positions: in the left pan with the gold, in the right one or not used.[?]
Suppose that a merchant carries just three known brass or lead weights. Each of
the three weights has three positions, thus giving rise to $3^3$ combinations. These 27
combinations are listed below.

<table>
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<tr>
<th>Position of</th>
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</thead>
<tbody>
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<td>Wt 2</td>
<td>Wt 3</td>
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</table>

Not all of these are useful. For example, at least one of them results in a weighing of zero
– the one in which none of the weights are used. In fact, any combination in which the
total of the known weights in the two pans is equal, results in a weighing of zero amount
of gold. Then also, any combination for which the total known weight in the left pan is
greater than that of the right pan is not useful – this would need a negative weight of
gold in the left pan in order to balance!

Smart gold merchants chose the weights they would carry in such a way as to maximize
their usefulness – that is, to enable the greatest range of weighings for a given number
of carried weights. Suppose the number of weights carried is to be three. To maximize
their effectiveness, there must be only one way of weighing zero, that is, the sum of any
two weights must not equal the third. Also, of the 26 non-zero weighing combinations,
for each that totals a positive weight, i.e., where the sum of the weights in the right pan
exceeds that in the left, there is a corresponding negative weighing – formed by simply
swapping the weights in the left and right pans over. This means there will be 13 com-
binations giving positive weighings, and 13 which give the opposite negative weighings.
These negative weighings are of no use, and some of the positive weighings could add
up to the same amount, which would not be efficient. The maximum effectiveness is
achieved when the 13 positive weighings are the numbers 1 to 13.

You are going to write a program to help you experiment with this scenario, and by a
mixture of trial and error with your grasp of number theory, discover which three weight values gives the ability to weigh whole amounts from 1 to 13 inclusive.

Your program should be called ThreeWeights, and will take the three weights as **command line arguments.** It should then print out all 27 possible weighing values. Each value will appear on one line of the output. You will use 27 calls to `System.out.println()`.

Attempt to derive which three weights are the best to use, that is, the three values which produce weighing values from -13 through to 13 inclusive. If you are running in a Unix environment, and the first, or only, item on each output line is the weighing value, then the following command may help you assess your output.

```
Console Input / Output

$ java ThreeWeights 1 2 3 | sort -n
(Output shown using multiple columns to save space.)

<table>
<thead>
<tr>
<th>-6</th>
<th>-4</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>-4</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

$ _
```

This runs your program and pipes the output of it into the input of `sort`, for which the `-n` option means ‘**sort** numerically’.

On Microsoft Windows, the nearest equivalent is `java ThreeWeights 1 2 3 | sort` which sorts the lines lexicographically (alphabetically), rather than numerically – e.g. 10 comes before 2. Nevertheless, even this is helpful.

As you can see from the above output, there are duplicate values in the 27 listed, so 1 2 3 is not the right answer. (They don’t even add up to 13…) You will substitute the arguments you think the weights should be instead. If you are successful, attempt to explain why your values are the best three weights, in your logbook.

**Coffee time:** When weighing food, one would not wish to place weights in the pan containing the food, and so grocers did not use a three state, negative weighing scheme. What **four** weights did they use to weigh units of 1 to 15 inclusive? What is the connection between this and your answer for the gold merchants?

### 3.8 Section / task 3.8 Sum the first N numbers – correctly

- **Aim of example:** To introduce the fact that **integer division** produces a truncated result. We then look at the interaction between that and **operator associativity**.

- **Coursework title:** **RoundPennies**

- **Coursework summary:** Write a program to help a child determine whether she has enough pennies to go shopping!
3.9 Question: Imagine there is a child who collects pennies in a piggy bank. Her mother tells her she is allowed to spend some of it when she has saved "about X pounds", where X varies depending on what her mother thinks the girl is likely to want to buy. Your job is to write a program that helps the girl convert a number of pennies, which she is able to count up, into "about pounds" – i.e. round the number of pennies to the nearest pound. The program will take the number of pennies as its command line argument, and report how many pounds it rounds to. So, any non-negative number less than 50 will round to zero, but 50 through to 149 will round to 1. The value 749 rounds to 7, but 750 and 751 round to 8. And so on.

Start by designing test data and expected results in your logbook. You do not need to worry about arguments which are missing or are not integer numbers, but you should consider what the program will do for negative numbers, even though they are not really valid inputs.

Now write the program, calling it RoundPennies. You will learn most if you try to avoid looking at any other program while you do this. To get you thinking, the calculation will exploit the fact that integer division truncates its result. However that is not enough. For example, 750 / 100 will yield 7, not 8 as we want here. There is some value you must add to the numerator before the division by 100.

Then, after implementing the program, you should run it with your pre-planned tests and record whether the outcome was as you expected. Record comments about the negative cases – is this the behaviour of a more general round-to-the-nearest-whole-number function? If not, what could we do to make it so?

3.9 Aim of example: To introduce the double type and some associated concepts, including converting to and from strings, and double division.

Coursework title: FahrenheitToCelsius

Coursework summary: Write a program to convert a temperature from Fahrenheit to Celsius.

Question: In this task you will write a program called FahrenheitToCelsius which converts a given Fahrenheit temperature into its Celsius equivalent.

Start by designing test data and expected results in your logbook. You do not need to worry about arguments which are missing or not real numbers.

Now design your program. You can derive the formula by manipulating the one given for converting the other way. Show your working in your logbook. There is a temperature at which the Fahrenheit and Celsius measurements are the same. Figure out what this is, showing your working in your logbook, and add it to your tests.

As always, you will learn most if you try to avoid looking at any other program while writing this one. Afterwards, run it with your pre-planned tests and record whether the outcome was as you expected.
4 Chapter 4 Conditional execution

4.2 Section / task 4.2 Oldest spouse 1

- Aim of example: To introduce the idea of **conditional execution**, implemented by the **if else statement**, and controlled by **boolean expressions** based on the use of **relational operators**.

- Coursework title: **MaxTwoDoubles**

- Coursework summary: Write a program to find the maximum of two given numbers, using an **if else statement**.

- Question: In this task you will write a program called **MaxTwoDoubles** which takes two **command line arguments**, interprets them as **double** values, and reports both numbers along with which one of the two is the greatest, on the **standard output**. You will use an **if else statement**.

Start by designing **test data** and expected results in your logbook. You do not need to worry about arguments which are missing or are not **real** numbers.

Now **design** your program, preferably without looking at **OldestSpouse**. After implementing the program, you should **run** it with your pre-planned tests and record whether the outcome was as you expected.

4.3 Section / task 4.3 Oldest spouse 2

- Aim of example: To introduce the idea of nesting **if else statements**.

- Coursework title: **DegreeCategory**

- Coursework summary: Write a program to report the degree category of a given mark.

- Question: In this task you will write a program called **DegreeCategory** which takes a student mark (e.g. final year, total assessment mark) and reports what degree category it is worth. The input is a single number, which might have decimal places in it, entered as a **command line argument**.

<table>
<thead>
<tr>
<th>Input</th>
<th>Required output</th>
</tr>
</thead>
<tbody>
<tr>
<td>input ≥ 70</td>
<td>Honours, first class</td>
</tr>
<tr>
<td>70 &gt; input ≥ 60</td>
<td>Honours, second class, division one</td>
</tr>
<tr>
<td>60 &gt; input ≥ 50</td>
<td>Honours, second class, division two</td>
</tr>
<tr>
<td>50 &gt; input ≥ 40</td>
<td>Honours, third class</td>
</tr>
<tr>
<td>40 &gt; input ≥ 32</td>
<td>Pass / ordinary degree</td>
</tr>
<tr>
<td>input &lt; 32</td>
<td>Fail</td>
</tr>
</tbody>
</table>

Start by designing your **test data** and expected output in your logbook. You do not need to worry about input which is invalid. Then **design** and implement your program, preferably without looking at **OldestSpouse**. Finally, **run** it with your pre-planned tests and record whether your outcome was as you expected.
4.4 Section / task 4.4 Film certificate age checking

- Aim of example: To introduce the if statement without a false part.
- Coursework title: PassFailDistinction
- Coursework summary: Write a program to report the pass or fail status of an exam candidate, giving a message of distinction if appropriate using an if statement. Here is the specification of the required output for a given input.

The input is a single number, which might have decimal places in it, entered as a command line argument.

<table>
<thead>
<tr>
<th>Input</th>
<th>First line of output</th>
</tr>
</thead>
<tbody>
<tr>
<td>input ≥ 50</td>
<td>Pass</td>
</tr>
<tr>
<td>input &lt; 50</td>
<td>Fail</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input</th>
<th>Second line of output</th>
</tr>
</thead>
<tbody>
<tr>
<td>input ≥ 70</td>
<td>Distinction</td>
</tr>
<tr>
<td>input &lt; 70</td>
<td>(no second line)</td>
</tr>
</tbody>
</table>

Start by designing your test data and expected output in your logbook. You do not need to worry about input which is invalid. Then design and implement your program, preferably without looking at any others. Finally, run it with your pre-planned tests and record whether your outcome was as you expected.

5 Chapter 5 Repeated execution

5.2 Section / task 5.2 Minimum tank size

- Aim of example: To introduce the idea of repeated execution, implemented by the while loop. We also meet the notion of a variable update.
- Coursework title: MinimumTankSize in half measures
- Coursework summary: Write a program which calculates the minimum size of cubic tanks to hold given required volumes, where the possible sizes are in steps of 0.5 metre.
- Question: In this task you will write a program called MinimumTankSize which is the same as the one we have just covered, except that the tanks can be made with side lengths which are any positive whole multiple of 0.5 metre, instead of whole metres. (Hint: use double for the side length.)

Use the same test data as was used for the whole metres version of the program. Start by planning the expected output, in your logbook.
Then design and implement your program, preferably without looking at the previous version while you do this. When completed, run it with your pre-planned tests and record whether your outcome was as you expected.

Now change your program so that it has increments of 0.1 metres and test it again with the same data. Are there some surprises due to the accuracy of real numbers? Would you go so far as to say that some of them are wrong, rather than just inaccurate?

5.3 Section / task 5.3 Minimum bit width

- Aim of example: To introduce the idea of using pseudo code to help us design programs. We also meet Math.pow().
- Coursework title: LargestSquare
- Coursework summary: Write a program to find the largest square number which is less than or equal to a given number.
- Question: A square number is a whole number which is the square of another (or the same) whole number. Examples are 0, 1, 4, 9, 25, 36, 49, 64, 81, 100, 121, 144, 169, etc.. In this task you will write a program called LargestSquare which takes a given positive integer as its command line argument and finds the largest square number which is less than or equal to that given number.

Start by planning your test data and expected results in your logbook. You do not need to worry about invalid inputs.

Now think about the design of your program. Perhaps the simplest approach to use is to focus on the square roots, rather than their squares. Start with a value which is equal to the given number, and keep decrementing it until its square is not greater than the number. So, for example, if the given number was 99, then we would start at 99 and count down until we finally get to 9 – this being the first number we find whose square is less than or equal to 99.

Express this algorithm in pseudo code in your logbook.

Finally, implement the program and test it with your test data, recording the results in your logbook.

Optional extra: Would it be quicker for the program to loop upwards from 0, rather than downwards from the given command line argument?

Optional extra: Look in the on-line Java documentation for the Java Math class, and find out how to obtain the square root of a number. Use this to speed up your program by making it start at a number which is much closer to the answer than the given command line argument is.

5.5 Section / task 5.5 Compound interest one

- Aim of example: To reinforce the while loop and the compound statement.
5.6 Section / task 5.6 Compound interest two

- Coursework title: **MinimumBitWidth by doubling**

- Coursework summary: Write a program to find the minimum **bit** width needed to support a given number of values, by doubling.

- Question: In this task you will write a variation of the **MinimumBitWidth** program which works a little more efficiently. Instead of computing a power of 2 in the **loop condition** on each **iteration**, your version will accumulate 2 to the power of **noOfBits** in a separate **variable**. This can be done by initializing your new variable to 1, and simply doubling its value each time you increment **noOfBits**.

You will use the same **test data** as used for the previous version of the program – except, do not try higher than 1073741824, otherwise your program will not end!

First think about the **design** of your program and plan in your logbook the changes you need to make to the original version.

Finally, implement the program and test it with your test data, recording the results in your logbook.

**Optional extra:** Explain why an input of, say, 1073741825 will cause a never ending **infinite loop**. Is there a solution?

---

5.6 Section / task 5.6 Compound interest two

- Aim of example: To introduce the **for loop**.

- Coursework title: **Power**

- Coursework summary: Write a program to raise a given number to the power of a second given number, without using **Math.pow()**.

- Question: What would you do if you needed to compute powers, and somebody had not already written the **method** **Math.pow()**? You would write the code yourself, and perhaps make it available for others to use.

In this task you will write a program, called **Power**, that takes two **integer** values as **command line arguments** and prints out the result of the first number raised to the power of the second. You may not use the **Math.pow()** method – somebody had to write that code, and let us pretend it is you! However, for simplicity, you may assume that both arguments exist and represent integers, and that the second number is non-negative.

Start by planning your **test data** and expected results in in your logbook.

Now think about the **design** of your program. One approach is to have a **variable** to accumulate the result, which starts off with the value 1. Then, using a **loop**, this result is multiplied by the first number as many times as the value of the second number. A **for loop** is appropriate for this task. Write **pseudo code** in your logbook.

Finally implement the program, (ideally without looking at **CompoundInterestKnownYears**)! test it with your preplanned tests and record the results in your logbook.
Aim of example: To show how to get the length of a list, note that an index can be a variable, and introduce type casting.

Coursework title: Variance

Coursework summary: Write a program to produce the variance of some given numbers.

Question: In statistics, the variance of a set of numbers is one way of measuring the spread of them. It is the sum of the squares of the deviations (differences) between each number and the mean average of the numbers, all divided by the number of numbers.

For example, a set of student marks \{2, 4, 6, 8, 10\} (out of 10) has a mean of 6 (which also happens to be one of the marks). The deviations from the mean are \{-4, -2, 0, 2, 4\} and the squares of such are \{16, 4, 0, 4, 16\}. The variance is thus \((16 + 4 + 0 + 4 + 16)/5\), which is 8. Whereas, the results \{4, 5, 6, 7, 8\} share the same mean but have a variance of only 2.

One approach to computing the variance is as follows. First compute the mean average of the numbers. Then, go through each number and compute the deviation between it and the mean, squaring this difference and accumulating the sum of all these squared deviations. Finally, divide that sum by the number of numbers.

In this task you will write a program, called Variance that takes a list of integer values as command line arguments and prints out the mean average and the variance of them. You may assume that there is at least one number, and that all the arguments represent integers.

Here is an example run of the program.

```
$ java Variance 2 4 6 8 10
The mean average is 6.0
The variance is 8.0
$ 
```

Start by planning your test data and expected results in in your logbook.

Now think about the design of your program. You can copy the code for computing the mean of the numbers from the example in this section. This will then be followed by a second for loop to compute the sum of the squares of the deviations between each number and the mean. You will need more variables, including one to hold the mean of the numbers, and another for the sum of the squares of the deviation between each number and the mean. Then the variance can be computed and output.

Write pseudo code in your logbook.

Finally, implement the program, test it with your preplanned tests and record the results in your logbook.
5.8 Section / task 5.8 Single times table

- Aim of example: To reinforce the for loop.
- Coursework title: SinTable
- Coursework summary: Write a program to produce a sin table.

Question: In the days before scientific calculators, students of trigonometry used to use mathematical tables to look up values of functions, such as sin, cosin and tan.

In this task you will write a program, called SinTable to produce a sin table. It will take three integer command line arguments: the starting point of the table, the increment and the ending point. You can assume these arguments represent whole numbers of degrees. Here is an example run.

```
java SinTable 0 10 90
------------------------------------------
<table>
<thead>
<tr>
<th>Sin table from 0 to 90 in steps of 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>sin(0) = 0.0</td>
</tr>
<tr>
<td>sin(10) = 0.17364817766693033</td>
</tr>
<tr>
<td>sin(20) = 0.3420201433256687</td>
</tr>
<tr>
<td>sin(30) = 0.49999999999999994</td>
</tr>
<tr>
<td>sin(40) = 0.6427876096865393</td>
</tr>
<tr>
<td>sin(50) = 0.766044443118978</td>
</tr>
<tr>
<td>sin(60) = 0.8660254037844386</td>
</tr>
<tr>
<td>sin(70) = 0.9396926207859083</td>
</tr>
<tr>
<td>sin(80) = 0.984807753012208</td>
</tr>
<tr>
<td>sin(90) = 1.0</td>
</tr>
</tbody>
</table>
```

In Java, in order to compute the sin of a value, d, which is expressed in degrees, we can use the following expression.

```
Math.sin(Math.toRadians(d))
```

The method sin() is available in the standard class Math. It takes a value, expressed in radians, and returns the sin of that value. The method toRadians(), in the same class, converts a given value in degrees to the corresponding value in radians.

Start by planning your test data and expected results in in your logbook.

Now think about the design of your program. It should use a for loop. Write pseudo code in your logbook. You will learn most if you try not to look at TimesTable while designing – perhaps you should compare the two programs after you have completed the task?

Finally, implement the program, test it with your preplanned tests and record the results in your logbook.
5.9 Section / task 5.9 Age history

- Aim of example: To introduce the idea of documenting programs using comments.
- Coursework title: WorkFuture
- Coursework summary: Write a program to print out all the years from the present day until the user retires.
- Question: In this task you will write a program, called WorkFuture, which shows the future working time of a user, assuming he or she retires at 68. The program will take two command line arguments, which you may assume are valid. The first is the present year, the second is the birth year of the user.

An example use of the program might be as follows.

```
$ java WorkFuture 2010 1959
You have 17 years left to work
In 2011 you will have 16 years left to work
In 2012 you will have 15 years left to work
In 2013 you will have 14 years left to work
In 2014 you will have 13 years left to work
In 2015 you will have 12 years left to work
In 2016 you will have 11 years left to work
In 2017 you will have 10 years left to work
In 2018 you will have 9 years left to work
In 2019 you will have 8 years left to work
In 2020 you will have 7 years left to work
In 2021 you will have 6 years left to work
In 2022 you will have 5 years left to work
In 2023 you will have 4 years left to work
In 2024 you will have 3 years left to work
In 2025 you will have 2 years left to work
In 2026 you will have 1 years left to work
You will retire in 2027
$ _
```

Start by planning your test data and expected results in your logbook. Next, design the program, writing pseudo code in your logbook. As is generally true, you will learn most if you can avoid referring to the associated example while you do this, and only compare the two programs when you have finished.

Finally, implement the program – including suitable comments in the text, and test it. Record your results in the usual way.

5.10 Section / task 5.10 Home cooked Pi

- Aim of example: To introduce various shorthand operators for variable updates, have another example where we reveal the pseudo code design, and meet Math.abs() and
Math.PI.

- Coursework title: **Shorthand operators**
- Coursework summary: Go through all the programs before this point to see where shorthand operators could have been used.
- Question: Now that you know about the shorthand operators for updating variables, in this task you will go through all the examples in this chapter and identify all the places where they could have been used, recording your analysis in your logbook.
  
  **Optional extra:** Take the program from this section and try it with one more decimal place. Then try to improve it to extend its accuracy.

6  **Chapter 6 Control statements nested in loops**

6.2  **Section / task 6.2 Film certificate age checking the whole queue**

- Aim of example: To introduce the ideas of nesting an if statement within a for loop, and declaring a variable inside a compound statement. We also introduce the conditional operator.
- Coursework title: **MaxList**
- Coursework summary: Write a program to find the maximum of a given list of numbers.
- Question: In this task you will write a program, called MaxList, which finds the maximum of a given list of numbers. The numbers are supplied as command line arguments. The program should report the number together with its index in the list (counting from zero). If two or more are are jointly the maximum, it should report the one with the lowest index.
  
  You may assume that the arguments all represent valid double numbers.

  To find the maximum of a list of numbers, your program can start by regarding the first number as the maximum found so far, and then looping through the remaining numbers, comparing each with the maximum found so far and updating it as necessary.

  Take the usual steps of planning test data and expected results, and designing pseudo code in your logbook, before implementing the program, including suitable comments, and recording your results back in your logbook.

6.3  **Section / task 6.3 Dividing a cake (GCD)**

- Aim of example: To introduce the idea of nesting an if else statement within a while loop.
- Coursework title: **DivideCake3**
6.4 Section / task 6.4 Printing a rectangle

- Coursework summary: Write a program to compute the greatest common divisor of three numbers.
- Question: Suppose the mother has three daughters who share their birthday. In this task you will write a program, called DivideCake3, which finds the greatest common divisor of the three ages given as command line arguments and reports the number of portions the cake should be divided into, and the number of portions each girl should get.

You may assume that the arguments all represent positive int numbers.

To find the greatest common divisor of three numbers, your program can find the greatest common divisor of two of them, and then find the greatest common divisor of that result and the third one.

Take the usual steps of planning test data and expected results, and designing pseudo code in your logbook, before implementing the program, including suitable comments, and recording your results back in your logbook.

6.4 Section / task 6.4 Printing a rectangle

- Aim of example: To introduce the idea of nesting a for loop within a for loop. We also meet System.out.print() and revisit System.out.println().
- Coursework title: PrintHoledRectangle
- Coursework summary: Write a program to print out a rectangle with a hole in it.
- Question: In this task you will write a program, called PrintHoledRectangle, which prints a rectangle with a hole at the centre. This just means missing out one cell, printing spaces for it instead. The program takes the width and height arguments as before, but in order to ensure there is a centre cell, each of these have one added to them if necessary to make them an odd number.

You may assume that the arguments represent positive int numbers.

To ensure an integer number is odd you can simply divide it by two, multiply it by two and then add one! The simplest way to miss out the centre cell is to count all the cells as you print them, and check the sequence number of a cell just before you print it. The centre cell will have a sequence number which is the width times the height, divided by two, plus one.

Take the usual steps of planning test data and expected results, and designing pseudo code in your logbook, before implementing the program, including suitable comments, and recording your results back in your logbook.

6.5 Section / task 6.5 Printing a triangle

- Aim of example: To reinforce the idea of nesting a for loop within a for loop.
- Coursework title: PrintTriangleMirror
Coursework summary: Write a program to print out an isosceles right angled triangle, with a straight right edge, and the longest side at the top.

Question: In this task you will write a program, called PrintTriangleMirror, which prints an isosceles right angled triangle with its longest row at the top and the right hand side straight. The program is given the height as its argument – here is an example run.

```
$ java PrintTriangleMirror 10
[ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]
[ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]
[ ] [ ] [ ] [ ] [ ] [ ] [ ]
[ ] [ ] [ ] [ ] [ ] [ ]
[ ] [ ] [ ] [ ] [ ]
[ ] [ ] [ ] [ ]
[ ] [ ] [ ]
[ ] [ ]
[ ]
$ _
```

You may assume that the argument represents a positive int number.

Each row will consist of a number of space cells (each 3 spaces) followed by a number of brick cells ("[ ]"). This will require two loops inside the outer loop, one after the other.

Take the usual steps of planning test data and expected results, and designing pseudo code in your logbook, before implementing the program, including suitable comments, and recording your results back in your logbook.

6.6 Section / task 6.6 Multiple times table

Aim of example: To reinforce the idea of having nested statements within each other, and explore the idea of using multiple loops in sequence.

Coursework title: CommonFactorsTable

Coursework summary: Write a program to produce a table showing pairs of numbers which share common factors.

Question: In this task you will write a program, called CommonFactorsTable, which prints a 19 times 19 labelled table indicating which of all the pairs made up of integers between 2 and 20, inclusive, have common factors other than one. (That is, their greatest common divisor is greater than one.)

The program’s output will be as follows.
A "#" at the intersection of two numbers shows that their greatest common divisor is bigger than one, a "|" shows otherwise.

This program may reasonably be developed by making changes to the TimesTable program. Plan these changes in your logbook, before taking the usual steps of implementing the program, including suitable comments, and recording your results back in your logbook.

6.7 Section / task 6.7 Luck is in the air: dice combinations

- Aim of example: To introduce the idea of using nested loops to generate combinations.
- Coursework title: SumOfCubedDigits
- Coursework summary: Write a program that determines which 3 digit decimal whole numbers are equal to the sum of the cubes of their digits.
- Question: There are four numbers in the range 100 to 999 which have the property that the sum of the cubes of the three digits in the number is equal to the number itself. 153 is such a number because $1^3 + 5^3 + 3^3$ is equal to $1 + 125 + 27$ which is 153. In this task you will write a program, called SumOfCubedDigits, that finds all four such numbers.
Your program will work by looping through the numbers 100 to 999 using three nested loops, one for each digit. In the centre of the loops, your program can calculate the number represented by the three digits, and the sum of their cubes, and print out the number if these are equal.

Take the usual steps of planning test data and expected results, and designing pseudo code in your logbook, before implementing the program, including suitable comments, and recording your results back in your logbook.

7 Chapter 7 Additional control statements

8 Chapter 8 Separate methods and logical operators

8.2 Section / task 8.2 Age history with two people

- Aim of example: To further illustrate the inconvenience of having to copy a chunk of code which is used in different parts of a program, and thus motivate the need for separate methods.
- Coursework title: WorkFuture2
- Coursework summary: Write a program to print out all the years from the present day until retirement, for two people.
- Question: In this task you will write a program, called WorkFuture2, which shows the future working time of two people, assuming they retire at 68. The program will take three command line arguments, which you may assume are valid. The first is the present year, and the second and third are the birth years of the two people.

In case you have been reading ahead, you should not use a separate method – write all your code in the main method.

An example use of the program might be as follows.
8.3 Section / task 8.3 Age history with a separate method

- Aim of example: To introduce the idea of dividing a program into separate methods to enable the reuse of some parts of it. We meet the concepts private, method parameter, method call and void method.

- Coursework title: WorkFuture4

- Coursework summary: Write a program, with a separate method, to print out all the years from the present day until retirement, for four people.

- Question: In this task you will write another version of the work future program, called WorkFuture4, which shows the future working time of four people. The program will take five command line arguments, which you may assume are valid. The first is the present year, and the others are the birth years of the four people.

Your program should use a separate method to print the work future for one person, and call it four times.

Undertake the usual tasks of planning test data, designing the program, implementing and testing it, and finally recording your results.

8.4 Section / task 8.4 Dividing a cake with a separate method for GCD

- Aim of example: To introduce the idea of using methods merely to split the program into parts, making it easier to understand and develop. We also meet the return statement for use in non-void methods, and see that altering a method parameter does not change its argument.

- Coursework title: DivideCake4
Coursework summary: Write a program to compute the greatest common divisor of four numbers, using a separate method.

Question: In this task you will write a version of the cake dividing program for those very rare families that have four daughters sharing a birthday! This should be called DivideCake4. You may assume that the four arguments all represent positive int numbers. You should use a separate method to compute the greatest common divisor of two numbers.

Undertake the usual tasks of planning test data, designing the program, implementing and testing it, and finally recording your results.

8.5 Section / task 8.5 Multiple times table with separate methods

Aim of example: To introduce the concept of class variables, compared with local variables, and reinforce the ideas of using separate methods for reuse and for dividing a program into manageable chunks. We also meet System.out.printf().

Coursework title: CommonFactorsTable with methods

Coursework summary: Write a program, with separate methods, to produce a table showing pairs of numbers which share common factors.

Question: In this task you will write a new version of the CommonFactorsTable program from Section [6.6] on page 26. This will use separate methods to avoid repeated code, and may reasonably be developed by making changes to the previous one. Plan these changes in your logbook, before taking the usual steps of implementing the program and recording your results.

8.6 Section / task 8.6 Age history with day and month

Aim of example: To introduce the logical operators. We also see that a group of variables can be declared together.

Coursework title: Reasoning about conditions

Coursework summary: Do some reasoning to show that two different conditions have the same value.

Question: Complete the following truth table, in your logbook, and thereby show that the conditions
c1 = !(a1 < a2 || a1 == a2 && h1 <= h2)
and c2 = a1 > a2 || a1 == a2 && h1 > h2 are equivalent.
8.7 Section / task 8.7 Truth tables

<table>
<thead>
<tr>
<th>a1 &lt; a2</th>
<th>a1 == a2</th>
<th>a1 &gt; a2</th>
<th>h1 &lt;= h2</th>
<th>h1 &gt; h2</th>
<th>c1</th>
<th>c2</th>
</tr>
</thead>
<tbody>
<tr>
<td>true</td>
<td>false</td>
<td>false</td>
<td>true</td>
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<td>false</td>
<td>true</td>
<td>true</td>
<td>true</td>
<td>true</td>
</tr>
</tbody>
</table>

Optional extra: Try to show this by ‘simplifying’ from one condition to the other.

8.7 Section / task 8.7 Truth tables

- Aim of example: To introduce the boolean type, and reinforce logical operators. We also meet the String type and see that a for update can have multiple statements.

- Coursework title: TruthTable34

- Coursework summary: Write a program to test the equivalence of three propositional expressions, each having four variables.

- Question: In this task you will write another version of the truth table program, called TruthTable34, which shows a truth table for three propositional expressions which are hard coded as methods p1, p2 and p3 respectively, and which are expressions involving four propositional variables, a, b, c and d. Your table will thus have 16 lines plus titles and box lines, and 7 columns.

The three propositional expressions to hard code in your program are as follows.

| p1    | (((a | b) && c) | ((b | c) && d)) && (a | d) |
|-------|-----------------|-----------------------------|
| p2    | a && c | b && d | c && d |
| p3    | (b | c) && (c | d) && (a | d) |

If you have studied discrete mathematics you should be able to spot the relationship between the first of these propositional expressions and the other two. What are those relationships?

Undertake the usual tasks of designing the program, implementing and testing it, and finally recording your results.

8.8 Section / task 8.8 Producing a calendar

- Aim of example: To reinforce much of the material presented in this chapter. We also revisit System.out.printf().

- Coursework title: CalendarHighlight

- Coursework summary: Modify a calendar month printing program to produce a larger calendar format and to highlight a certain date.
Question: In this task you will write another version of the calendar program, called CalendarHighlight, which produces the calendar in a wider format and also takes a third command line argument, which is a day (1 to 31) that should be highlighted. The wider format is produced by using four characters per date instead of two. The desired date should be highlighted by placing a greater than sign (>) before it and a less than sign (<) after it. Here is an example run of the finished program.

```
Console Input / Output
$ java CalendarHighlight 3 28 9
----------------------------------
| Su | Mo | Tu | We | Th | Fr | Sa |
|------------------|------------------|------------------|------------------|------------------|------------------|
| 01 | 02 | 03 | 04 | 05 |     |     |
| 06 | 07 | 08 | >09< | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 |     |     |     |     |     |
|----------------------------------|
$ _
```

Undertake the usual tasks of planning test data, designing the program, implementing and testing it, and finally recording your results.

9 Chapter 9 Consolidation of concepts so far

10 Chapter 10 Separate classes

10.2 Section / task 10.2 Age history with Date class

- Aim of example: To introduce the principle of using more than one class in a program, and in particular, the idea of using a class as a template for the construction of objects. We also introduce instance variables, constructor methods, creating new objects, the fact that a class is a type and the use of references.

- Coursework title: AddQuadPoly

- Coursework summary: Write a class to store quadratic polynomials, and a program that adds together two quadratic polynomials to form a third.

- Question: In this task you will create a class called QuadPoly which will be used to represent quadratic polynomials, such as \(6x^2 + 4x + 2\). Don’t worry if Maths is not your favourite subject – you’re not going to do anything too Mathematical. The class will have three double instance variables, one for each of the three coefficients of a quadratic polynomial. These will be declared public. (If you have read ahead, then please do not yet make them private.) The class will also have a constructor method, which will
be passed the three coefficient values as its method parameters. (The variable in these polynomials will always be $x$, and so its name need not be stored.)

You will also write a program called AddQuadPoly. This will take six command line arguments, these being two triples of coefficients, each triple being the coefficients of one quadratic polynomial. It will create an instance of QuadPoly for each of the two given quadratic polynomials. It will then create a third instance, representing the addition of the two given polynomials. Finally it will print out a report showing the addition. The following is an example run.

```
$ java AddQuadPoly 6 4 2 3 2 1
Polynomial: 6.0x^2 + 4.0x + 2.0
added to: 3.0x^2 + 2.0x + 1.0
results in: 9.0x^2 + 6.0x + 3.0
$ _
```

Note how the three polynomials are to be printed using ordinary text, with a \(^\) character before the power instead of attempting to raise the 2 into a superscript, such as in $6.0x^2$. Each polynomial is printed as follows, where the three question marks in the format are replaced by the values of the three coefficients.

\[ ?x^2 + ?x + ? \]

If you are tempted to write the program without creating three instances of QuadPoly (because it would in fact be easier right now) then you are seriously missing the point!

Undertake the usual tasks of planning test data, designing the classes, implementing them, testing the program, and finally recording your results.

Optional extra: Extend the program so that it can add together any number of polynomials listed as command line arguments, displaying the intermediate resulting polynomials as it goes along. Make it be able to handle the cases of there being no arguments ($0x^2 + 0x + 0$), just one polynomial, and the erroneous cases of the number of arguments not being divisible by three!

10.3 Section / task 10.3 Improving the Date class: lessThan() and equals() methods

- Aim of example: To introduce the concept of instance methods. We also look at common misunderstandings about variables and references.
- Coursework title: CompareQuadPoly
- Coursework summary: Extend a class that stores quadratic polynomials, and write a program that compares the ‘size’ of two quadratic polynomials.
- Question: In this task you will copy the QuadPoly class from the previous task and extend it, by adding two instance methods. The first one will compare the instance of QuadPoly it belongs to with another one given as a method parameter, and return true
if and only if they are equivalent, i.e. they represent the same polynomial. The second instance method will also compare the QuadPoly object with another, but return true if and only if this one is less than the other one. For a quadratic polynomial, $a_1x^2 + b_1x + c_1$ to be less than another, $a_2x^2 + b_2x + c_2$ then $a_1$ must be less than $a_2$, or if they are equal, then $b_1$ must be less than $b_2$, or if they are also equal, then $c_1$ must be less than $c_2$. (If you have read ahead, then please do not yet add a toString() instance method.)

You will also write a program called CompareQuadPoly. This will take six command line arguments, this being two triples of coefficients, each triple being the coefficients of one quadratic polynomial. It will then use the two instance methods to compare them, to determine if they are equivalent, or the first one is less than, or greater than the second, and report the results. The following are some example runs.

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ java CompareQuadPoly 1 2 3 2 3 1</td>
</tr>
<tr>
<td>The polynomial: 1.0x^2 + 2.0x + 3.0</td>
</tr>
<tr>
<td>is smaller than: 2.0x^2 + 3.0x + 1.0</td>
</tr>
<tr>
<td>$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ java CompareQuadPoly 3 2 1 3 2 1</td>
</tr>
<tr>
<td>The polynomial: 3.0x^2 + 2.0x + 1.0</td>
</tr>
<tr>
<td>is the same as: 3.0x^2 + 2.0x + 1.0</td>
</tr>
<tr>
<td>$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ java CompareQuadPoly 3 2 1 1 2 3</td>
</tr>
<tr>
<td>The polynomial: 3.0x^2 + 2.0x + 1.0</td>
</tr>
<tr>
<td>is greater than: 1.0x^2 + 2.0x + 3.0</td>
</tr>
<tr>
<td>$</td>
</tr>
</tbody>
</table>

Undertake the usual tasks of planning test data, designing the classes, implementing them, testing the program, and finally recording your results.

Optional extra: Extend the program so that it can compare any number of polynomials listed as command line arguments, displaying the intermediate resulting polynomials as it compares each with the previous. At the end, it could report the smallest and largest polynomials encountered.

10.4  Section / task 10.4 Improving the Date class: toString() method

- Aim of example: To reinforce the concept of instance methods. We also note that a method might have no method parameters.

- Coursework title: AddQuadPoly and CompareQuadPoly with toString()

- Coursework summary: Extend a class that stores quadratic polynomials, and modify programs that add together, and compare the ‘size’ of, two quadratic polynomials.
10.5 Section / task 10.5 Improving the Date class: addYear() method

- Question: In this task you will copy the QuadPoly class from the previous task and further extend it, by adding an instance method called toString. This will return a String representing the polynomial in the format previously introduced.

You will also copy the programs AddQuadPoly and CompareQuadPoly from the previous tasks, and modify them to make appropriate use of the new instance method.

Undertake the usual tasks of planning test data (consider if it will be different to the previous version of each program), designing the modifications, implementing them, testing the programs, and finally recording your results.

10.5 Section / task 10.5 Improving the Date class: addYear() method

- Aim of example: To further reinforce instance methods, meet Java’s toString() convention and focus on the visibility of instance variables. We also see a return type which is a class.

- Coursework title: QuadPoly with an addition method

- Coursework summary: Further extend a class that stores quadratic polynomials, and modify a program that adds together two quadratic polynomials.

- Question: In this task you will copy the QuadPoly class from the previous task and make the instance variables have private visibility. You will also further extend it, by adding an instance method which takes a given other instance of QuadPoly as a method parameter and returns a new QuadPoly object, being the result of adding this QuadPoly instance to the given other one.

You will also copy the program AddQuadPoly from the previous task, and modify it to make appropriate use of the new instance method.

Undertake the usual tasks of planning test data (consider if it will be different to the previous version of the program), designing the modifications, implementing them, testing the program, and finally recording your results.

Optional extra: Add more instance methods to QuadPoly to subtract a given other polynomial, multiply this one by a constant and divide this one by a constant. Each of these will produce a new instance of QuadPoly. Then write a program called QuadPolyCalculator which permits arbitrary polynomial calculations. This will be based on the idea of an accumulator polynomial, which starts off as being \(0x^2 + 0x + 0\). The command line arguments consist of a sequence of operation codes, each followed by an operand, which would either be a polynomial in the next three arguments, or a single number. For example, you might choose code 0 to represent addition, and this would be followed by three arguments representing a polynomial to be added to the accumulator. Code 2 might be multiplication, which would be followed by a single number to be multiplied by the accumulator. Each operation will produce output as it happens, and place its result back in the accumulator. At the end, the value of the accumulator will be reported. You could allow the less than operation to compare the accumulator with the following polynomial operand, and store whichever is the smallest in the accumulator. This would permit the program to be used to find the smallest of a sequence of polynomials, by preceding the
first one with the addition operation code, and the subsequent ones with the less than operation code! You might add a greater than operation code too.

Hint: this would be a good use of a switch statement.

11 Chapter 11 Object oriented design

11.2 Section / task 11.2 Age history revisited

- Aim of example: To introduce the principles of object oriented design. We also meet Scanner, standard input, Java’s package structure and import statement, the null reference, final variables, multiple return statements, the line separator system property, and take a look at making stubs of classes and using multi-line comments.

- Coursework title: ShapeShift

- Coursework summary: Write a program to create and process two-dimensional shapes.

- Question: Here you will create a program called ShapeShift which does calculations and manipulations of simple shapes. The main class has been written for you – here it is.

```java
001: import java.util.Scanner;
002:
003: /* This program performs simple calculations and manipulations of simple shapes expressed in two-dimensional coordinate geometry.
004: 
005: First it asks the user to choose a shape, from a choice of three.
006: Then it prompts for details of the shape.
007: * A circle is specified by giving the X and then Y coordinate
008: of its centre, followed by its radius.
009: * A Triangle is specified by giving the X and Y coordinates
010: of each of its three corner points.
011: * A rectangle is specified by giving the X and Y coordinates
012: of two of its diagonally opposite corner points.
013: 
014: Following this data, the user is prompted to specify an X offset
015: and a Y offset.
016: 
017: The program creates the specified shape, and also a similar one,
018: in which each point has been shifted by the X and Y offsets.
019: 
020: The program then reports the following on the standard output.
021: * The details of the original shape -- giving all the points
022: (one, three, or four) and, for a circle, its radius.
023: * The area and perimeter of the shape.
024: * The details of the shifted shape.
025: */
026: */
027: public class ShapeShift
028: {
```
// A scanner to interact with the user.
private static Scanner inputScanner = new Scanner(System.in);

// Helper method to read a point from the input.
private static Point inputPoint(String prompt)
{
    System.out.print(prompt);
    double x = inputScanner.nextDouble();
    double y = inputScanner.nextDouble();
    return new Point(x, y);
}

// The X and Y amount to shift the first shape to get the second.
private static double xShift, yShift;

// Helper method to read the X and Y shifts.
private static void inputXYShifts()
{
    System.out.print("Enter the offset as X Y: ");
    xShift = inputScanner.nextDouble();
    yShift = inputScanner.nextDouble();
}

// The main method.
public static void main(String[] args)
{
    // Obtain shape choice.
    System.out.print("Choose circle (1), triangle (2), rectangle (3): ");
    int shapeChoice = inputScanner.nextInt();

    // Process the shape based on the choice.
    switch (shapeChoice)
    {
        case 1:
        // Circle.
            Point centre = inputPoint("Enter the centre as X Y: ");
            System.out.print("Enter the radius: ");
            double radius = inputScanner.nextDouble();
            Circle originalCircle = new Circle(centre, radius);
            inputXYShifts();
            Circle shiftedCircle = originalCircle.shift(xShift, yShift);
            System.out.println();
            System.out.println(originalCircle);
            System.out.println("has area "+ originalCircle.area() + ",
            perimeter " + originalCircle.perimeter());
System.out.println("and when shifted by X offset " + xShift + " and Y offset " + yShift + ", gives");
break;

// Triangle.
case 2:
    Point pointA = inputPoint("Enter point A as X Y: ");
    Point pointB = inputPoint("Enter point B as X Y: ");
    Point pointC = inputPoint("Enter point C as X Y: ");
    Triangle originalTriangle = new Triangle(pointA, pointB, pointC);
    inputXYShifts();
    Triangle shiftedTriangle = originalTriangle.shift(xShift, yShift);
    System.out.println();
    System.out.println(originalTriangle);
    System.out.println("has area " + originalTriangle.area()
        + ", perimeter " + originalTriangle.perimeter());
    System.out.println("and when shifted by X offset " + xShift
        + " and Y offset " + yShift + ", gives");
    System.out.println(shiftedTriangle);
    break;

// Rectangle.
case 3:
    Point diag1End1 = inputPoint("Enter one corner as X Y: ");
    Point diag1End2 = inputPoint("Enter opposite corner as X Y: ");
    Rectangle originalRectangle = new Rectangle(diag1End1, diag1End2);
    inputXYShifts();
    Rectangle shiftedRectangle = originalRectangle.shift(xShift, yShift);
    System.out.println();
    System.out.println(originalRectangle);
    System.out.println("has area " + originalRectangle.area()
        + ", perimeter " + originalRectangle.perimeter());
    System.out.println("and when shifted by X offset " + xShift
        + " and Y offset " + yShift + ", gives");
    System.out.println(shiftedRectangle);
    break;

// Bad choice.
default:
    System.out.println("That wasn’t 1, 2 or 3!");
    break;
} // switch
} // main

All you have to do is write the other classes.

The following are example runs of the program to help clarify the requirements.
Console Input / Output

$ java ShapeShift
Choose circle (1), triangle (2), rectangle (3): 1
Enter the centre as X Y: 0 0
Enter the radius: 1
Enter the offset as X Y: 2 2
Circle((0.0,0.0),1.0)
has area 3.141592653589793, perimeter 6.283185307179586
and when shifted by X offset 2.0 and Y offset 2.0, gives
Circle((2.0,2.0),1.0)

Console Input / Output

$ java ShapeShift
Choose circle (1), triangle (2), rectangle (3): 2
Enter point A as X Y: 0 0
Enter point B as X Y: 10 0
Enter point C as X Y: 0 20
Enter the offset as X Y: 5 10
Triangle((0.0,0.0),(10.0,0.0),(0.0,20.0))
has area 100.0, perimeter 52.3606797749979
and when shifted by X offset 5.0 and Y offset 10.0, gives
Triangle((5.0,10.0),(15.0,10.0),(5.0,30.0))

Console Input / Output

$ java ShapeShift
Choose circle (1), triangle (2), rectangle (3): 3
Enter one corner as X Y: 0 0
Enter opposite corner as X Y: 10 20
Enter the offset as X Y: 0 0
Rectangle((0.0,0.0),(10.0,0.0),(10.0,20.0),(0.0,20.0))
has area 200.0, perimeter 60.0
and when shifted by X offset 0.0 and Y offset 0.0, gives
Rectangle((0.0,0.0),(10.0,0.0),(10.0,20.0),(0.0,20.0))

Start by designing your test data in your logbook.

Your program will consist of five classes, Point, Circle, Triangle, Rectangle and the already given ShapeShift. Next identify and record the public instance methods and class methods for each of the four classes you will write. Endeavour to associate behaviour (i.e. methods) with the most appropriate classes. Here are some hints.

- Which classes should have a toString() instance method?
- Should shape classes have methods to find the area and perimeter of a shape?
– Should they additionally have a method to create a shifted shape from an existing one?

– Shifting shapes requires creating **new** points which are shifts of old ones. Where is that shifting best done?

– Perimeters of certain shapes are based on distances between points – does that suggest an instance method in the **Point** class?

– Are the points **mutable objects** or **immutable objects**? What about the shapes?

– All instance variables should be **private**, so you may need some instance methods in some classes, to give read access to the instance variables. For example, **Point** might have `getX()` and `getY()`.

Next you should write **stubs** for the three shape classes, so that you can **compile** and try out the main class.

Now **design** the implementations of your classes (at a level of **abstraction** that is appropriate to you) and then implement them. Do you want to think about the order of implementation so you can compile them as you proceed? Will you use a stub for **Point**?

Here are some implementation hints.

– To calculate the area of a triangle, you can use Hero’s formula. Let $a$, $b$ and $c$ be the lengths of the sides of the triangle. Then the semi-perimeter, $s$ is

$$ s = \frac{a+b+c}{2} $$

and the **area** is

$$ area = \sqrt{s(s-a)(s-b)(s-c)} $$

– Given two opposite corners of a rectangle, i.e. both ends of one diagonal, $(x_1,y_1)$ and $(x_2,y_2)$ the other two corners are found as $(x_1,y_2)$ and $(x_2,y_1)$.

Finally record your results. It may well be that during your implementation, you changed your plan of which class should have what method. This is okay, but you should record such changes, and the reason for them.

**Optional extra:** Dare you consider having another shape, which is an irregular four sided polygon? Assuming the points are given in a sensible order, then computing the perimeter would not be too hard, but how would you get the area?

### 11.3 Section / task 11.3 Greedy children

- Aim of example: To reinforce **object oriented design**, particularly with **mutable objects**. We also meet multiple **constructor methods**, **class constants**, the **return statement** with no value, **accessor methods**, **mutator methods**, the dangers of **method parameters** which are **references**, converting the **null reference** to a string, and **Math.random()**.

- Coursework title: **StudentsCalling**
• Coursework summary: Write a program that simulates the behaviour of students using their mobile phones.

• Question: In this task you will create a program called StudentsCalling which simulates a simple scenario in which students purchase and use mobile phones.

  – A student has a name which cannot be changed, and a mobile phone, although not to begin with.
  
  – A phone has a name (i.e. make and model number) and an account, both of which are fixed. It also keeps track of the total number of seconds of phone calls made on it, starting with zero.
  
  – An account has a provider (i.e. the name of the service provider) which is fixed and a balance, in whole pence, which starts off as zero.
  
  – A student may purchase a mobile phone, in which case they discard their previous one if they have previously purchased one.
  
  – A student may top up their phone with a whole number of pounds. If they have no phone, then an attempt to top up their phone is ignored!
  
  – A student may make a call of desired duration, in seconds, on their phone. If they have no phone, then an attempt to make a call is ignored!
  
  – A phone may be topped up with a whole number of pounds, which simply causes its account to be topped up with that same amount.
  
  – A phone can have a call made on it, of a desired duration, which causes it to request that call on its account. The account returns the actual duration of the call, which may be less than that desired (i.e. when there is not enough balance to pay for it). The phone keeps track of the total actual duration of all the calls made on it.
  
  – An account may be topped up with a whole number of pounds. This adds to the current balance.
  
  – An account may have a call requested on it for a desired duration. In this wonderful world, all account providers charge only one penny per second for any call! The actual call duration will be limited to the current balance on the account. The balance is reduced by the actual duration. The actual duration is also returned as the result of the call request.
  
  – The main program will create some students, create some phones with accounts, which the students purchase, and cause the students to make calls. At each stage the behaviour of the program will be reported to the standard output.

The following is an example run of the program to help clarify the requirements.
Console Input / Output

```java
$ java StudentsCalling
Creating student Chatty Charlie
Result: Student(Chatty Charlie, null)

Creating student Norman No Friends
Result: Student(Norman No Friends, null)

Creating student Popular Penny
Result: Student(Popular Penny, null)

This next call has no effect, as has no phone!
Student(Chatty Charlie, null)
is making a call for desired 300 seconds
Result: Student(Chatty Charlie, null)

This next top up has no effect, as has no phone!
Student(Norman No Friends, null)
is topping up by 20
Result: Student(Norman No Friends, null)

Student(Chatty Charlie, null)
is buying phone Snotia BIFR
with account World@1
Result: Student(Chatty Charlie, Phone(Snotia BIFR, 0, Account(World@1, 0)))
```

(Continued ...)
Student(Norman No Friends, null) is buying phone Cyoo L8TR0N with account 4FRN Touch
Result:
Student(Norman No Friends, Phone(Cyoo L8TR0N, 0, Account(4FRN Touch, 0)))

Student(Popular Penny, null) is buying phone Tisonly 14U with account Foney Friends
Result:
Student(Popular Penny, Phone(Tisonly 14U, 0, Account(Foney Friends, 0)))

Student(Chatty Charlie, Phone(Snotia BIFR, 0, Account(World@1, 0))) is topping up by 10
Result:
Student(Chatty Charlie, Phone(Snotia BIFR, 0, Account(World@1, 1000)))

Student(Norman No Friends, Phone(Cyoo L8TR0N, 0, Account(4FRN Touch, 0))) is topping up by 20
Result:
Student(Norman No Friends, Phone(Cyoo L8TR0N, 0, Account(4FRN Touch, 2000)))

Student(Popular Penny, Phone(Tisonly 14U, 0, Account(Foney Friends, 0))) is topping up by 30
Result:
Student(Popular Penny, Phone(Tisonly 14U, 0, Account(Foney Friends, 3000)))

Student(Chatty Charlie, Phone(Snotia BIFR, 0, Account(World@1, 1000))) is making a call for desired 300 seconds
Result:
Student(Chatty Charlie, Phone(Snotia BIFR, 300, Account(World@1, 700)))

This next call should be truncated to 700 seconds.
Student(Chatty Charlie, Phone(Snotia BIFR, 300, Account(World@1, 700))) is making a call for desired 1200 seconds
Result:
Student(Chatty Charlie, Phone(Snotia BIFR, 1000, Account(World@1, 0)))

Student(Chatty Charlie, Phone(Snotia BIFR, 1000, Account(World@1, 0))) is making a call for desired 10 seconds
Result:
Student(Chatty Charlie, Phone(Snotia BIFR, 1000, Account(World@1, 0)))

(Continued ...)
11.3 Section / task 11.3 Greedy children

(...cont.)

Student(Norman No Friends,Phone(Cyoo L8TR0N,0,Account(4FRN Touch,2000)))
is making a call for desired 10 seconds
Result:
Student(Norman No Friends,Phone(Cyoo L8TR0N,10,Account(4FRN Touch,1990)))

Student(Popular Penny,Phone(Tisonly 14U,0,Account(Foney Friends,3000)))
is making a call for desired 65 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,65,Account(Foney Friends,2935)))

Student(Popular Penny,Phone(Tisonly 14U,65,Account(Foney Friends,2935)))
is making a call for desired 115 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,180,Account(Foney Friends,2820)))

Student(Popular Penny,Phone(Tisonly 14U,180,Account(Foney Friends,2820)))
is making a call for desired 488 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,668,Account(Foney Friends,2332)))

Student(Popular Penny,Phone(Tisonly 14U,668,Account(Foney Friends,2332)))
is making a call for desired 302 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,970,Account(Foney Friends,2030)))

Student(Popular Penny,Phone(Tisonly 14U,970,Account(Foney Friends,2030)))
is making a call for desired 510 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,1480,Account(Foney Friends,1520)))

Student(Popular Penny,Phone(Tisonly 14U,1480,Account(Foney Friends,1520)))
is making a call for desired 250 seconds
Result:
Student(Popular Penny,Phone(Tisonly 14U,1730,Account(Foney Friends,1270)))

Now let us discard a phone.
Student(Popular Penny,Phone(Tisonly 14U,1730,Account(Foney Friends,1270)))
is buying phone Simm UL8R
with account VerTuleTyat
Result:
Student(Popular Penny,Phone(Simm UL8R,0,Account(VerTuleTyat,0)))

$ _$

Your program will consist of four classes, Student, Phone, Account and StudentsCalling. The latter will contain the main method.

Start by designing these classes in your logbook, identifying the public instance methods
and class methods for each of them. Endeavour to associate behaviour (i.e. methods) with the most appropriate classes.

Next you should design your ‘story’, that is, the sequence of operations you wish the simulation to undertake. You should make your ‘story’ significantly different to the example one above! That is, have different student names, phone names, account names, different number of students, different order and number of calls, etc..

Next design the implementations of your classes (at a level of abstraction that is appropriate to you). Then implement them. Do you want to think about the order of implementation so you can compile them as you proceed? Will you use stubs?

Here are some implementation hints.

– You can use the null reference, null, as the value for a student’s phone to begin with.

– The toString() method of Student can rely on the toString() method of Phone which in turn can use the toString() method of Account.

– Use private helper methods in the StudentsCalling class, to save you repeating code that prints out what is happening at each stage.

After implementation you should record your results. It may well be that during your implementation, you changed your plan of which class should have what method. This is okay, but you should record such changes, and the reason for them, in your logbook.

Optional extra: You can think of ways to make the simulation more realistic. For example:

– Suddenly there is a period of inflation again, and account providers have to charge more than one penny per second. Change your program so that an account has a rate, expressed in pence per minute.

– Perhaps rates vary depending on what time of day the call is made?

– Accounts ought to have a unique account number, assigned when they are created.

– Consider having a Provider class, so an account has a provider. Perhaps all the accounts for a particular provider have the same rate, but different providers have different rates.

– Now the providers are in competition again, perhaps it should be possible to change the account on an existing phone?

12 Chapter 12 Software reuse and the standard Java API

12.2 Section / task 12.2 A reusable Date class, with doc comments

- Aim of example: To explore the notion of software reuse and introduce doc comments. We also introduce the convention of having a compareTo() instance method.
Coursework title: **StudentsCalling with doc comments**

Coursework summary: Add **doc comments** to an existing **class**.

Question: Copy your **classes** from the coursework in Section 11.3 on page 41 and add **doc comments** to the **public** items in them. Then run the javadoc program and examine the results. In particular, look at the summary sections and note how the first sentence of each doc comment has been used there.

### 12.5 Section / task 12.5 Simple Encryption

#### Aim of example:
To take a look at **String** manipulation, such as extracting individual **char** values from a **String**. We also look at how comparisons between two **char** values can be achieved, and the way we can **cast** between **char** and **int** values, and meet **overloaded methods**.

#### Coursework title: **RomanNumber**

#### Coursework summary: Write a **class** that allows for the conversion between decimal and Roman numbers.

Question: In this task you will create a reusable **class** called **RomanNumber** which can be used to convert between Roman Numbers and decimal numbers.

You will provide **two constructor methods** for this class. One will take an **int** and build a **RomanNumber** corresponding to that number. The other will take a **String** of Roman digits and build a **RomanNumber** corresponding to that number.

The class will also provide two **instance methods**. One will **return** an **int**, being the decimal number corresponding to the **RomanNumber** instance. The other instance method will return a **String**, which is the Roman number representation of the **RomanNumber** instance.

For the purposes of this exercise, you may assume your constructors will never be given a non-positive number, or a **String** which is not a legal Roman number.

This class can be used to convert an **integer** to its Roman equivalent string by **constructing** an instance of **RomanNumber** from the integer, and then accessing the string value of it. To convert the other way, one could create an instance of **RomanNumber** from a string of Roman digits, and then access the integer value of it.

The rules of Roman numbers are explained below.

To help you choose names for the two instance methods, you should look at the API documentation of the **Integer** class. That class can be used to convert between **int** values and **String** representations in decimal, so it would be sensible to be consistent in style of names in your class.

In order to test your class, write a program called **RomanNumberTest**. This will accept a Roman number string from the first **command line argument**, convert it to an integer and then using a **loop**, print that number and the next 19 numbers, each with its Roman
number equivalent, on the **standard output**. The program may assume that the argument is a legal Roman Number. Here is an example **run**.

<table>
<thead>
<tr>
<th>$ java RomanNumberTest MMX</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Output shown using multiple columns to save space.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roman for 2010 is MMX</th>
<th>Roman for 2020 is MMXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roman for 2011 is MMXI</td>
<td>Roman for 2021 is MMXXI</td>
</tr>
<tr>
<td>Roman for 2012 is MMXII</td>
<td>Roman for 2022 is MMXXII</td>
</tr>
<tr>
<td>Roman for 2013 is MMXIII</td>
<td>Roman for 2023 is MMXXIII</td>
</tr>
<tr>
<td>Roman for 2014 is MMXIV</td>
<td>Roman for 2024 is MMXXIV</td>
</tr>
<tr>
<td>Roman for 2015 is MMXV</td>
<td>Roman for 2025 is MMXXV</td>
</tr>
<tr>
<td>Roman for 2016 is MMXVI</td>
<td>Roman for 2026 is MMXXVI</td>
</tr>
<tr>
<td>Roman for 2017 is MMXVII</td>
<td>Roman for 2027 is MMXXVII</td>
</tr>
<tr>
<td>Roman for 2018 is MMXVIII</td>
<td>Roman for 2028 is MMXXVIII</td>
</tr>
<tr>
<td>Roman for 2019 is MMXIX</td>
<td>Roman for 2029 is MMXXIX</td>
</tr>
<tr>
<td>$ _</td>
<td></td>
</tr>
</tbody>
</table>

### 12.5.1 The Roman number system

In Roman numbers, there is no zero, nor any negative number. There are 7 digits and 6 pairs of digits, with values as follows.

<table>
<thead>
<tr>
<th>Digit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1000</td>
</tr>
<tr>
<td>D</td>
<td>500</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
</tr>
<tr>
<td>L</td>
<td>50</td>
</tr>
<tr>
<td>X</td>
<td>10</td>
</tr>
<tr>
<td>V</td>
<td>5</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digit pair</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>900</td>
</tr>
<tr>
<td>CD</td>
<td>400</td>
</tr>
<tr>
<td>XC</td>
<td>90</td>
</tr>
<tr>
<td>XL</td>
<td>40</td>
</tr>
<tr>
<td>IX</td>
<td>9</td>
</tr>
<tr>
<td>IV</td>
<td>4</td>
</tr>
</tbody>
</table>

These are placed next to each other, with largest values on the left, and smallest on the right. The number represented is simply the sum of the values of the digits and digit pairs. The sample output from the test program (above) shows examples. Notice how each digit pair consists of a digit followed by a greater valued digit, and that the value is the value of the greater minus the value of the lesser. E.g. the value of "CM" is 1000 – 100. Perhaps contrary to your intuition, the Romans did not have other pairs than these 6. One cannot write "MIM" to mean 1999, instead it is written as "MCMXCIX": 1000 plus 900 plus 90 plus 9.

### 12.5.2 How to convert to and from Roman numbers

To convert a Roman number into an integer, we can scan the **characters** in the **String** from left to right and add the values of the characters to the **int** number being thus accumulated. So we start this accumulation with the value zero. However, if the value of any
character is **greater than** that of the previous one, then we have just had the second character of a digit pair. In this case we subtract the value previously added, twice, and then add the value of this character. You may wish to treat the first character of the Roman number **String** differently from the others, as it has no previous one. For all the other characters, we shall compare the value with the value of the previous character. Some examples follow.

<table>
<thead>
<tr>
<th>Roman</th>
<th>X</th>
<th>I</th>
<th>V</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>XIV</td>
<td>C</td>
<td>D</td>
<td>L</td>
<td>10 +1 -2 +5</td>
</tr>
<tr>
<td>CDXLIV</td>
<td>C</td>
<td>M</td>
<td>X</td>
<td>100 -200 +500 +10</td>
</tr>
<tr>
<td>CMXCIX</td>
<td>M</td>
<td>I</td>
<td>M</td>
<td>1000 +1 -2 +1000</td>
</tr>
<tr>
<td>MIM</td>
<td>M</td>
<td>I</td>
<td>M</td>
<td>1000 +1 -2 +1000</td>
</tr>
</tbody>
</table>

Notice that the last line is an illegal Roman number string, yet the **algorithm** suggested will still produce a result, and effectively behaves as though "IM" actually is a legal digit pair with the value 999. As said above, you may assume your constructors are not given illegal strings, so there is no need for you to write code that checks legality.

Converting an integer into a Roman number is a little easier. We accumulate the sequence of Roman digits in a result **String**, starting with an empty string, as follows. While the number is **greater than or equal** to 1000, subtract a 1000 from it and append "M" to the result. Now do this for 900 with "CM", 500 with "D", 400 with "CD" and so on.

### 12.5.3 Implementation tips

You may find it easiest to have two **instance variables**, one an **int** and the other a **String**. Each constructor simply copies its given argument to one of the instance variables, and then calculates the value of the other. You should consider having **private methods** to assist in the conversions, and perhaps reduce the amount of repeated code.

### 12.5.4 Deliverables

First design your **test data** in your logbook, then **design pseudo code** for your two conversion algorithms, before implementing the classes. During implementation you should document your **RomanNumber** class with **doc comments**. After completing the test program, you should run the javadoc program and browse the resulting **index.html file**.
13  Chapter 13 Graphical user interfaces

13.2  Section / task 13.2 Hello world with a GUI

- Aim of example: To give a first introduction to Java graphical user interface (GUI) programs, in particular, the classes JFrame, Container and JLabel, together with the java.awt and javax.swing packages they belong to. We also talk about the idea of a class extending another class.

- Coursework title: HelloWorld GUI in French

- Coursework summary: Write a GUI program to greet the world, in French.

- Question: In this task, you will take the HelloWorld GUI example and change it to greet the world in French (or some other language).
  
  Optional extra: Make two greeting windows appear (with the same greeting).

13.3  Section / task 13.3 Hello solar system with a GUI

- Aim of example: To introduce the notion of layout manager and, in particular, FlowLayout.

- Coursework title: HelloFamily GUI

- Coursework summary: Write a GUI program to greet your family.

- Question: The coursework in Section 2.5 on page 8 asked you to produce a program called HelloFamily which greeted a number of your relatives. In this task you will write a version of that program which produces a window and greets the same relatives using labels. Each greeting should use a separate label. Use a FlowLayout object to manage the layout of the components in the window.

13.4  Section / task 13.4 Hello solar system with a GridLayout

- Aim of example: To introduce the layout manager called GridLayout.

- Coursework title: HelloFamily GUI with GridLayout

- Coursework summary: Write a GUI program to greet your family, using a GridLayout.

- Question: In this task, you will copy and change your HelloFamily program to use a GridLayout. Experiment with different values for the row and column method parameters in order to see how these effect the layout.

In order to make it easier to try out different values for the parameters, design the code so that the program takes two integer command line arguments – the values for the number of rows and number of columns. These will then be passed to the constructor method and used by it to create an appropriate GridLayout object.
Optional extra: Make your program produce 10 windows, each having a different gap between the components. The row gaps should range from 2 to 20 in steps of 2 pixels and the column gaps from 4 to 40 insteps of 4.

13.5 Section / task 13.5 Adding JLabels in a loop

- Aim of example: To illustrate the idea of creating graphical user interface (GUI) components in a loop.
- Coursework title: TimesTable using JLabels
- Coursework summary: Write a program to display a times table, using a GUI with JLabel objects.
- Question: In this task you will write a program, called TimesTable, which takes two integer command line arguments, \(m\) and \(n\). It displays an \(m\)-times table with \(n\) entries, in a window. You can assume that \(m\) and \(n\) will be integers, and that \(n\) is non-negative. Choose better names for your variables than \(m\)! Use JLabel objects to display the numbers and symbols and a GridLayout object to manage the layout. Choose horizontal and vertical gaps so that the window is laid out nicely.

For example, when given the arguments 3 and 10, we should see something like the following.

![Times Table](image)

Optional extra: Find out how to set the colour of components, and choose a different colour to be used for alternating rows.
13.7 Section / task 13.7 Stop clock

- **Aim of example:** To reinforce the Java listener model together with JButton, ActionEvent and ActionListener. We also introduce the idea of having the ActionListener object be the JFrame itself, and meet System.currentTimeMillis().

- **Coursework title:** StopClock with split time

- **Coursework summary:** Modify a stop clock program so that it has a split time button.

- **Question:** In this task you will take the StopClock program and change it to add a split time button. Your program should still be called StopClock, and behave as follows.
  
  - The GUI has two buttons: Start/Stop and Split.
  
  - It has four output displays: the start time, stopped time, split time and elapsed time. Each of these is a JLabel and each also has a fixed JLabel to explain it.
  
  - The clock starts when the Start/Stop button is pressed. The current time is shown as the start time.
  
  - If the Split button is pressed while the clock is running, the clock will show the elapsed time as the split time.
  
  - If the Split button is pressed again while the clock is running, the split time will be updated.
  
  - The clock is stopped by pressing the Start/Stop button, at which point it will display the current time as the stopped time, and calculate, and display the elapsed time. The split time will be unchanged.
  
  - If the Split button is pressed while the clock is not running, nothing happens.

In order to implement this program, you will need to make use of the getSource() instance method of ActionEvent. This takes no method arguments and returns a reference to the object which was responsible for causing the event. So, for example, you may have code like the following.

```java
if (event.getSource() == startStopJButton)
    ...
```

You will need to turn the method variable startStopJButton into an instance variable. Why is that?

**Optional extra:** Improve the GUI, from an end user’s point of view, by removing the start and stop times: show just the status instead.

**Optional extra:** Extend the program to allow the recording of several split times, with a button for each split time.

**Optional extra:** Also, why not add a facility to pause and resume the clock?
13.8 Section / task 13.8 GCD with a GUI

- Aim of example: To introduce JTextField.
- Coursework title: GCD GUI for three numbers
- Coursework summary: Modify a GCD program that has a GUI, so that it finds the GCD of three numbers.
- Question: In this task you will produce a version of the GCD program with a GUI, that calculates the GCD of three numbers rather than two. This will require you to add an additional field to the interface, and alter the code of the class so that it calculates the appropriate value. As with the example in the section, the code for obtaining the GCD should reside in a separate MyMath class.

Optional extra: The GCD program requires that the user enters integer values. What happens if he or she supplies values that are not integers? How might you go about addressing this issue?

13.9 Section / task 13.9 Enabling and disabling components

- Aim of example: To explore the principle of enabling and disabling graphical user interface (GUI) components, and revisit JButton and JTextField.
- Coursework title: StopClock using a text field and disabled split button
- Coursework summary: Modify a stop clock program so that the split time button is disabled when the clock is not running.
- Question: In this task you will change your StopClock program as follows.
  - Have the start/stop button labelled Start when the clock is not running, and Stop when it is.
  - Disable the split button when the clock is not running, enable it when the clock is running.
  - Use JTextField objects rather than JLabel objects to display the times. Make it so that the end user cannot edit the text showing in these text fields.

Optional extra: Make the stop clock more pretty by using colours appropriately.

13.12 Section / task 13.12 Single times table with a ScrollPane

- Aim of example: To introduce the use of JScrollPane and revisit JTextField.
- Coursework title: ThreeWeights GUI
- Coursework summary: Write a GUI version of the program to show the weights that are obtainable on a balance scale using three weights.
• Question: In this task you will write a GUI version of the ThreeWeights coursework example from Section 3.7 on page 13. The program should offer the same functionality as the original one, that is, the user provides three weights and is then shown the possible values that can be weighed using them.

The user input should be through the use of text fields, and the results should be displayed in a scrollable text area.

Rather than have 27 System.out.println() calls as in the previous version of the exercise, a simpler way to compute the results is to use three nested loops, one for each weight. Each loop variable will be a multiplier for the corresponding weight, going through the values -1, 0 and 1. -1 represents placing that weight in the same pan as the gold, 0 represents not using that weight, and 1 represents placing that weight in the pan opposite the gold.

14 Chapter 14 Arrays

14.2 Section / task 14.2 Salary analysis

• Aim of example: To introduce the basic concepts of arrays, including array type, array variables, array creation, array element access, array length and empty arrays. We also meet Math.round() and revisit System.out.printf() and division by zero.

• Coursework title: Mark analysis

• Coursework summary: Write a program that analyses student coursework marks.

• Question: Write a program, called MarkAnalysis, that takes a list of student coursework marks and produces a report. The scores are entered by the user, after he or she has been prompted to say how many there are. Each score is a whole number greater than or equal to 0. The program should output the mean average, minimum and maximum of the scores, and a list of the scores, each along with their absolute difference from the mean average score, shown to two decimal places (using System.out.printf()).

In your main method, you should first read the scores into an int array using one loop, before finding the minimum, maximum and mean using a second, and then printing the results using a third. (You could combine the first two loops into one, but perhaps that would be less clear?)

You may assume that any input values are valid. However, if the number of scores is not at least one, your program should display a suitable message and exit.

Here is an example run of the program.
$ java MarkAnalysis
Enter the number of marks: 6
Enter mark # 1: 8
Enter mark # 2: 6
Enter mark # 3: 9
Enter mark # 4: 8
Enter mark # 5: 5
Enter mark # 6: 4

The mean mark is:  6.666666666666667
The minimum mark is: 4
The maximum mark is: 9

<table>
<thead>
<tr>
<th>Person</th>
<th>Score</th>
<th>difference from mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>1.33</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>-0.67</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>2.33</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>1.33</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>-1.67</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>-2.67</td>
</tr>
</tbody>
</table>

Hint: Use the following format specifier string. "%6s | %5s | %6.2f%n"

14.3  Section / task 14.3 Sorted salary analysis

- Aim of example: To reinforce arrays and introduce the idea of sorting, together with one simple sorting algorithm. We also introduce the for-each loop, and have an array as a method parameter to a method.

- Coursework title: Mark analysis with sorting

- Coursework summary: Write a program that analyses student coursework marks, and presents the results in a sorted order.

- Question: Modify your program from the last task so that it presents the results in ascending order of mark. (Could this change the way you find your maximum and minimum?)

Here is an example run of the program.
### 14.4 Section / task 14.4 Get a good job

- **Aim of example:** To examine *arrays* in which the *array elements* are *references* to *objects*. In particular, we see how this impacts on *sorting* with the use of a `compareTo()` *instance method*. We also revisit `System.out.printf()` and meet `String.format()`.

- **Coursework title:** *Mark analysis with student names and sorting*

- **Coursework summary:** Write a program that analyses named student coursework marks, and presents the results in a *sorted* order.

- **Question:** Modify your program from the last task so that each mark has an associated named student. You will need to create a `class` called `Student` with two *instance variables*, one for the name of a student and the other for his or her mark. This should provide a `compareTo()` *instance method* which you will use in your *sort* code, and a `toString()` to help produce the report.

Here is an example *run* of the program.
14.5 Section / task 14.5 Sort out a job share?

You should make appropriate use of for-each loops. Hint: Use the following format specifier string. "%-10s got %3d"

14.5 Section / task 14.5 Sort out a job share?

- Aim of example: To introduce partially filled arrays with array extension, array copying to make a shallow copy and returning an array from a method. We also look at object sharing as we have three arrays containing references to the same objects. Along the way we meet the use of a Scanner on a file, enum types and split() on a String.

- Coursework title: Random order text puzzle

- Coursework summary: Write a random order text line sorting puzzle program.

- Question: In this coursework you will write a program that sets an interactive puzzle for the user to solve. The program is run with a command line argument which is the name of a file containing a few lines of text. These are read in and presented in a random order to the user, who is invited to pick one line to be swapped with the last one, repeatedly, until they are back in their original order.
The text might be part of the lyrics of a song, or a poem, or a quote, etc., or may have some other quality about it that gives a clue for working out the correct order.

Here is an example run of the program.

```
$ java RandomOrderPuzzle test-data.txt
0 are sorted as they started off,
1 it obvious
2 what the correct
3 Is
4 should be now that they
5 i.e. in order of increasing word count?
6 order of these lines

Enter a line number to swap with the last one: 3
0 are sorted as they started off,
1 it obvious
2 what the correct
3 order of these lines
4 should be now that they
5 i.e. in order of increasing word count?
6 Is

Enter a line number to swap with the last one: 0
0 Is
1 it obvious
2 what the correct
3 order of these lines
4 should be now that they
5 i.e. in order of increasing word count?
6 are sorted as they started off,

Enter a line number to swap with the last one: 5
0 Is
1 it obvious
2 what the correct
3 order of these lines
4 should be now that they
5 are sorted as they started off,
6 i.e. in order of increasing word count?

Game over in 3 moves.
$ _
```

Write your solution in a class called RandomOrderPuzzle. The main method will create a Scanner for the file, and pass it to the constructor method to make an instance of RandomOrderPuzzle. Then it will make another Scanner for the textual user interface.

The constructor method will read in the text, and store it in an array of Strings, using
array extension as required. Then it will make a copy of this array into a second array, and randomize the order of this copy.

The class will also provide three instance methods for use in the main method. One will swap a given line of the copied array with its last line. Another will check to see whether the lines of the copy array are (now) in the same order as the original one. The third is a toString() which list the lines from the randomized copy in their current order.

Here is the main method, and a private instance method to randomize the order of a given array.

```java
011: public static void main(String[] args) throws Exception
012: {
013:     Scanner fileScanner = new Scanner(new File(args[0]));
014:     RandomOrderPuzzle puzzle = new RandomOrderPuzzle(fileScanner);
015:     Scanner inputScanner = new Scanner(System.in);
016:     System.out.println(puzzle);
017:     int moveCount = 0;
018:     while (! puzzle.isSorted())
019:     {
020:         System.out.print("Enter a line number to swap with the last one: ");
021:         puzzle.swapLine(inputScanner.nextInt());
022:         System.out.println(puzzle);
023:         moveCount++;
024:     } // while
025:     System.out.println("Game over in " + moveCount + " moves.");
026: } // main
027: ...
028: private void randomizeStringArrayOrder(String[] anArray)
029: {
030:     for (int itemsRemaining = anArray.length;
031:         itemsRemaining > 0; itemsRemaining--)
032:     {
033:         int anIndex = (int) (Math.random() * itemsRemaining);
034:         String itemAtAnIndex = anArray[anIndex];
035:         anArray[anIndex] = anArray[anArray.length - 1];
036:         anArray[anArray.length - 1] = itemAtAnIndex;
037:     } // for
038: } // randomizeStringArrayOrder
```

14.6 Section / task 14.6 Diet monitoring

- Aim of example: To reinforce ideas met so far, and introduce array initializer and array searching, for which we revisit the logical operators.
- Coursework title: Viewing phone call details
Coursework summary: Write a program to allow the user to view certain phone call details.

Question: Here you will write a program that reads in a file of phone call details, and allows the user to see some of those calls with a total cost and duration. The first command line argument is the name of a text file containing the details of one phone call per line, comprising the phone number, including spaces at the appropriate places, the duration of the call, in the format hh:mm:ss, and the cost of the call, in pounds, as a decimal number. These three items are separated by single tab characters. Here is some sample data.

<table>
<thead>
<tr>
<th>Phone Number</th>
<th>Duration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>07571 78764</td>
<td>00:00:16</td>
<td>0.120</td>
</tr>
<tr>
<td>01537 82608</td>
<td>00:00:04</td>
<td>0.070</td>
</tr>
<tr>
<td>01492 88229</td>
<td>01:02:58</td>
<td>0.860</td>
</tr>
<tr>
<td>08479 88844</td>
<td>00:03:56</td>
<td>0.070</td>
</tr>
<tr>
<td>08901 24241</td>
<td>00:00:33</td>
<td>0.060</td>
</tr>
<tr>
<td>07546 88323</td>
<td>00:02:40</td>
<td>0.250</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:07:12</td>
<td>0.910</td>
</tr>
<tr>
<td>08474 02751</td>
<td>00:05:37</td>
<td>0.150</td>
</tr>
<tr>
<td>0161 296 410</td>
<td>00:03:02</td>
<td>0.190</td>
</tr>
<tr>
<td>0161 296 682</td>
<td>00:00:57</td>
<td>0.090</td>
</tr>
<tr>
<td>01537 82608</td>
<td>00:00:20</td>
<td>0.070</td>
</tr>
<tr>
<td>01537 82608</td>
<td>00:30:10</td>
<td>0.450</td>
</tr>
<tr>
<td>08479 77777</td>
<td>00:02:50</td>
<td>0.070</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:06:23</td>
<td>0.800</td>
</tr>
<tr>
<td>07728 50344</td>
<td>00:04:20</td>
<td>0.380</td>
</tr>
<tr>
<td>0161 296 682</td>
<td>00:00:06</td>
<td>0.070</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:44:28</td>
<td>2.930</td>
</tr>
<tr>
<td>0161 803 487</td>
<td>00:15:59</td>
<td>0.260</td>
</tr>
<tr>
<td>0161 297 617</td>
<td>00:13:24</td>
<td>0.530</td>
</tr>
<tr>
<td>08476 05080</td>
<td>00:00:14</td>
<td>0.060</td>
</tr>
<tr>
<td>08476 05080</td>
<td>00:04:09</td>
<td>0.130</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:00:03</td>
<td>0.120</td>
</tr>
<tr>
<td>0161 803 487</td>
<td>00:00:48</td>
<td>0.070</td>
</tr>
<tr>
<td>08479 88844</td>
<td>00:01:05</td>
<td>0.060</td>
</tr>
<tr>
<td>08901 27274</td>
<td>00:02:30</td>
<td>0.090</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:08:18</td>
<td>0.630</td>
</tr>
<tr>
<td>0161 297 629</td>
<td>00:01:05</td>
<td>0.120</td>
</tr>
<tr>
<td>07936 84350</td>
<td>00:11:13</td>
<td>1.330</td>
</tr>
<tr>
<td>07936 84350</td>
<td>00:01:59</td>
<td>0.270</td>
</tr>
<tr>
<td>0161 297 629</td>
<td>00:00:01</td>
<td>0.090</td>
</tr>
<tr>
<td>07571 78764</td>
<td>00:46:27</td>
<td>3.060</td>
</tr>
<tr>
<td>08479 77777</td>
<td>00:03:17</td>
<td>0.070</td>
</tr>
<tr>
<td>07955 65414</td>
<td>00:20:41</td>
<td>1.400</td>
</tr>
<tr>
<td>01492 88229</td>
<td>01:24:12</td>
<td>0.850</td>
</tr>
</tbody>
</table>

The user selects a subset of the calls by entering a prefix of the phone numbers he or she wishes to view. Here is an example run.
Section / task 14.6 Diet monitoring

Console Input / Output

$ java PhoneCalls test-phone-calls.txt
Enter phone number prefix, or Q to quit: 075
07571 78764  00:00:16  0.12
07546 88323  00:02:40  0.25
07571 78764  00:07:12  0.91
07571 78764  00:06:23  0.80
07571 78764  00:44:28  2.93
07571 78764  00:00:03  0.12
07571 78764  00:08:18  0.63
07571 78764  00:46:27  3.06

Calls matched: 8
Total duration: 01:55:47
Total cost: 8.82

Enter phone number prefix, or Q to quit: 0161 2
0161 296 410  00:03:02  0.19
0161 296 682  00:00:57  0.09
0161 296 682  00:00:06  0.07
0161 297 617  00:13:24  0.53
0161 297 629  00:01:05  0.12
0161 297 629  00:00:01  0.09

Calls matched: 6
Total duration: 00:18:35
Total cost: 1.09

Enter phone number prefix, or Q to quit: 0161 8
0161 803 487  00:15:59  0.26
0161 803 487  00:00:48  0.07

Calls matched: 2
Total duration: 00:16:47
Total cost: 0.33

Enter phone number prefix, or Q to quit: Q

$ _

You should create four classes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhoneCalls</td>
<td>The main class containing the <strong>main method</strong>. It will make an <strong>instance</strong></td>
</tr>
<tr>
<td></td>
<td>of PhoneCallList and then prompt the user for input.</td>
</tr>
<tr>
<td>PhoneCallList</td>
<td>An instance of this will represent the <strong>list</strong> of phone calls and will contain</td>
</tr>
<tr>
<td></td>
<td>instances of PhoneCall.</td>
</tr>
</tbody>
</table>
Here is the main method to get you started.

```java
... public static void main(String[] args) throws Exception
016:     
017:         callList = new PhoneCallList(new Scanner(new File(args[0])));
018:         Scanner inputScanner = new Scanner(System.in);
019:         String userInput;
020:         do
021:             System.out.print("Enter phone number prefix, or Q to quit: ");
022:             userInput = inputScanner.nextLine();
023:             if (! userInput.equals("Q"))
024:                 System.out.println(callList.matchingCallsReport(userInput));
025:             } while (! userInput.equals("Q"));
026:     } // main
... 
```

You should think carefully where the logic to decide whether a particular phone call matches the user’s input should go: is it to reside in `PhoneCallList` or `PhoneCall`? (Hint: is it about a phone call, or about a list?) Either way, you can use the `startsWith()` instance method of the `String` class.

To help you further, here is the code for the `Duration` class.

```java
001:     // Representation of a time duration.
002:     public class Duration
003:     {
004:         // Represented as a hh:mm:ss string and as total seconds.
005:         private final String stringRep;
006:         private final int totalSeconds;
007:     
008:         // Constructs from a hh:mm:ss string.
009:     public Duration(String requiredStringRep)
010:     {
011:         stringRep = requiredStringRep;
012:         String[] parts = requiredStringRep.split(":");
013:         int hours = Integer.parseInt(parts[0]);
014:         int minutes = Integer.parseInt(parts[1]);
```
```java
int seconds = Integer.parseInt(parts[2]);
totalSeconds = (hours * 60 + minutes) * 60 + seconds;
} // Duration

// Constructs from a total number of seconds.
public Duration(int requiredNoOfSeconds) {
    totalSeconds = requiredNoOfSeconds;
    int hours = totalSeconds / 3600;
    int minutes = (totalSeconds % 3600) / 60;
    int seconds = totalSeconds % 60;
    stringRep = String.format("%02d:%02d:%02d", hours, minutes, seconds);
} // Duration

// Returns the hh:mm:ss representation.
public String toString() {
    return stringRep;
} // toString

// Adds this to another to create a new.
public Duration add(Duration other) {
    return new Duration(totalSeconds + other.totalSeconds);
} // add
```

Optional extra: Instead of merely a leading prefix of phone numbers, why not allow the user to enter any pattern? (Hint: look at the matches() instance method of the String class.)

Optional extra: Add the date and time of calls to the program (and its data).

14.7 Section / task 14.7 A weekly diet

- Aim of example: To introduce two-dimensional arrays.
- Coursework title: Maze solver
- Coursework summary: Write a program that finds the shortest path through a maze.
- Question: The program you are going to write here will read in textual representations of mazes and solve them. Mazes consist of a matrix of cells, each of which can be an entrance, an exit, a hedge, or a space. Each maze must have at least one entry point, at least one exit point, and at least one path of space cells between some entrance and exit. Paths can only turn 90 degrees, that is, there is no use of diagonal movement. The job of
14.7 Section / task 14.7 A weekly diet

the program is to print out each maze showing the shortest path from any entrance to its nearest exit.

Here is sample data, showing three very similar mazes, each stored in a text file. A hedge cell is represented by a #, an entrance by a ?, an exit by a ! and a space by a space.

And here is the result of running the program on that data, where the shortest path is shown using dot (.) characters.

14.7.1 How will it work?

The solution is based on repeatedly making moves from entrances, fanning outwards in all possible directions, until we reach an exit. We start the search at every entrance simultaneously. In move one we fan out to every cell accessible from each entrance. In move two we further fan out to every (new) cell accessible from each cell we accessed in move one, and so on. In order to know which cells we have accessed in which move, we set up a two-dimensional array of numbers, the same dimensions as the maze, and store the move count at each cell as we reach it. So, the entrances have a move count of
zero, those next to the entrances contain the number one, the neighbours of those contain a two, and so on.

The following diagram shows this process for the first example maze above.

And this one shows it for the third example maze.

Note that, depending on the maze, it might be that not every space cell gets visited before an exit is found.

Having reached an exit, we stop fanning out and instead work backwards along the short-
est path to mark it.

Here is pseudo code for the algorithm.

```java
move-count = 0
found-exit = false
while !found-exit
    consider every cell in turn
    if the cell value == move-count
        consider each of its four neighbours in turn or until found exit
        if the neighbour cell is an exit
            found-exit = true
            mark the path back to the start from this cell
        else if the neighbour cell is an unreached space
            neighbour cell value = move-count + 1
    move-count++
end-while
```

To mark the path back from the neighbour of the exit which has been reached, you do something like the following.

```java
path position is given as row and column of the exit’s neighbour
move-count = the value at this path position
while moveCount != 0
    mark this path position as part of the path
    move-count--
    find the neighbour which holds the value move-count
    path position = that neighbour’s row and column
```

### 14.7.2 Implementation help

You will find the following code useful to help you loop through the four neighbours of each cell. (You may recall the remainder operator, %, from Section ?? on page ??.)

```java
private int[] neighbourOffsets = {-1, 0, 1, 0};
...

for (int neighbour = 0; !foundAnExit && neighbour <= 3; neighbour++)
{
    int neighbourColumn = column + neighbourOffsets[neighbour];
    int neighbourRow = row + neighbourOffsets[(neighbour + 1) % 4];
    ...
} // for
```

Here is some of the solution to get you started.

```java
001: import java.io.File;
002: import java.util.Scanner;
003:
004: /* Reads a maze representation from each file given as an argument
005:    and prints it out showing the shortest route from any entrance to an exit.
```
public class MazeSolver
{
    public static void main(String[] args) throws Exception
    {
        for (String filename : args)
            System.out.print(new MazeSolver(new Scanner(new File(filename))));
    }

    private static final int HEIGHT = 10;
    private static final int WIDTH = 20;

    private static final int SPACE = -1;
    private static final int HEDGE = -2;
    private static final int PATH = -3;
    private static final int END = -4;

    private static final char SPACE_REP = ' ';
    private static final char HEDGE_REP = '#';
    private static final char START_REP = '?';
    private static final char END_REP = '!';
    private static final char PATH_REP = '.';

    private final int[][] maze = new int[HEIGHT + 2][WIDTH + 2];

    public MazeSolver(Scanner input)
    {
        // First we place a surround of HEDGE cells.
        for (int row = 0; row < HEIGHT + 2; row++)
            for (int column = 0; column < WIDTH + 2; column++)
            {
                maze[row][0] = maze[row][WIDTH + 1] = HEDGE;
                maze[0][column] = maze[HEIGHT + 1][column] = HEDGE;
            }

        // Next we read the maze, assuming the file is valid.
for (int row = 1; row <= HEIGHT; row++)
{
    String mazeLine = input.nextLine();
    for (int column = 1; column <= WIDTH; column++)
    {
        char inputChar = mazeLine.charAt(column - 1);
        switch (inputChar)
        {
            case SPACE_REP: maze[row][column] = SPACE; break;
            case HEDGE_REP: maze[row][column] = HEDGE; break;
            case START_REP: maze[row][column] = START; break;
            case END_REP: maze[row][column] = END; break;
        }
    }
    // Then we solve it.
    solve();
} // MazeSolver

// Each cell has four neighbours: these offsets help us find them.
private int[] neighbourOffsets = {-1, 0, 1, 0};

// Find the shortest path from any START to any END.
// There must exist such a path or else....
private void solve()
{
...

// Mark the path backwards from row, column.
private void markPathBackFrom(int row, int column)
{
...

// The correct line separator for this platform.
private static final String NLS = System.getProperty("line.separator");

// Return a text representation of the maze.
public String toString()
{

```java
String result = "";
for (int row = 1; row <= HEIGHT; row++) {
    for (int column = 1; column <= WIDTH; column++)
        switch (maze[row][column]) {
            case HEDGE: result += HEDGE_REP; break;
            case START: result += START_REP; break;
            case END: result += END_REP; break;
            case PATH: result += PATH_REP; break;
            default: result += SPACE_REP;
        }
    // switch
    result += NLS;
} // for
return result;
} // toString

// class MazeSolver

Note: your solution will probably have a different line count.

Coffee time: What happens if the program is run on a maze that does not have a path from an entrance to an exit?

Optional extra: Improve your program so that it deals sensibly with bad mazes.

Optional extra: Perhaps using int values for the cells is not a good object oriented design approach. So, posh up your program by making it have a Cell class, which contains an instance variable for the cell type and a separate move count if it is a space cell. You could take this further, e.g. each cell could also contain its row and column array index, and an array of references to the four neighbouring cells to make looping through them even easier.

15  Chapter 15 Exceptions

15.2  Section / task 15.2 Age next year revisited

- Aim of example: To take a closer look at run time errors, or as Java calls them, exceptions.
- Coursework title: FishTankVolume robustness analysis
- Coursework summary: Take a program you have seen before and analyse where it can go wrong.
- Question: Take another look at the FishTankVolume program from Section ?? on page ???. Make a list of all the circumstances that can cause an exception and another list of
circumstances which merely produce inappropriate results.

15.3 Section / task 15.3 Age next year with exception avoidance

- Aim of example: To show how we can avoid exceptions using conditional execution. We also meet the Character class.
- Coursework title: FishTankVolume exception avoidance
- Coursework summary: Take a program you have seen before and make it avoid exceptions.
- Question: Despite what we have just said about not being satisfied with the approach, you are here going to try it. Write a version of the FishTankVolume program from Section ?? on page ?? which avoids exceptions.

15.4 Section / task 15.4 Age next year with exception catching

- Aim of example: To introduce exception catching using the try statement. We also take a look at standard error.
- Coursework title: FishTankVolume exception catching
- Coursework summary: Take a program you have seen before and make it catch exceptions.
- Question: Write another version of the FishTankVolume program from Section ?? on page ??.. This should not avoid exceptions, but instead catch them in a single catch clause. (In the next task you can improve it by having multiple catch clauses.)

15.5 Section / task 15.5 Age next year with multiple exception catching

- Aim of example: To observe that there are many kinds of exception and introduce the idea of multiple exception catching by having a try statement with many catch clauses.
- Coursework title: FishTankVolume multiple exception catching
- Coursework summary: Take a program you have seen before and make it catch multiple exceptions.
- Question: Write yet another version of the FishTankVolume program from Section ?? on page ??.. This time it should catch exceptions in appropriate multiple catch clauses.

15.6 Section / task 15.6 Age next year throwing an exception

- Aim of example: To introduce the idea of creating an exception and throwing an exception when we have detected a problem, using the throw statement.
Coursework title: FishTankVolume throwing exceptions

Coursework summary: Take a program you have seen before and make it throw its own exceptions and catch them.

Question: Write one more version of the FishTankVolume program from Section ?? on page ???. This will throw exceptions for inappropriate inputs which would otherwise not cause an exception, and catch all the exceptions in appropriate multiple catch clauses.

15.7  Section / task 15.7 Single times table with exception catching

Aim of example: To illustrate the use of exception catching in graphical user interface (GUI) programs.

Coursework title: TimesTable with a ScrollPane catching exceptions

Coursework summary: Take a program with a GUI, that you have seen before, and make it catch exceptions.

Question: Write a version of the TimesTable with a ScrollPane program from Section ?? on page ?? that caches the exception caused by the user entering data which is not a valid representation of an int.

15.8  Section / task 15.8 A reusable Date class with exceptions

Aim of example: To introduce the throws clause together with its associated doc comment tag. We also look at supplying an exception cause when we create an exception, and discuss the use of RuntimeExceptions.

Coursework title: Date class with nested try statements

Coursework summary: Modify a class so that it uses nested try statements.

Question: Recall the alternative addDay() instance method from a coffee time on page ???. Modify the Date class from this section to make it use that alternative nested try statements approach for all instance methods which create a new Date.

Write a program called TestRelativeDates to test your implementation. This should contain a main method with hard-coded test data. One simple approach would be to create a ‘reference’ date, and then have a loop which takes it forwards one day at a time, over a, say, two year period (including a leap year). Inside the loop you print out the reference date together with five dates constructed relatively from it.
Chapter 16 Inheritance

Section / task 16.3 The Person class

- Aim of example: To introduce the ideas of superclass, subclass, inheritance, and is a relationships.

- Coursework title: Stock control system

- Coursework summary: Write a class that can be used to keep track of stock items, and test it.

- Question: Imagine you are setting up a computer parts shop, and will need software to keep track of stock and prices. You will have various kinds of stock item, but to start with you will implement a class called StockItem with the following properties. In later coursework tasks you will make various subclasses of this. An instance of StockItem represents a particular thing which the shop sells, with a fixed stock code, variable quantity in stock and variable price.

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructor</td>
<td></td>
<td>int, int</td>
<td>Create a StockItem with the given int price (in whole pence) and int initial quantity in stock. The price is exclusive of VAT (sales tax). Each StockItem object is allocated a unique fixed int stock code.</td>
</tr>
<tr>
<td>getStockCode</td>
<td>int</td>
<td></td>
<td>Returns the stock code for this stock item.</td>
</tr>
<tr>
<td>getStockType</td>
<td>String</td>
<td></td>
<td>Returns the string &quot;Stock item type&quot;. This will be redefined in subclasses.</td>
</tr>
<tr>
<td>getDescription</td>
<td>String</td>
<td></td>
<td>Returns the string &quot;A description of the stock item&quot;. This will be redefined in subclasses.</td>
</tr>
<tr>
<td>getQuantityInStock</td>
<td>int</td>
<td></td>
<td>Returns the quantity in stock of this stock item.</td>
</tr>
<tr>
<td>increaseStock</td>
<td>void</td>
<td>int</td>
<td>Increases the stock level by the given amount. If it is less than one, an IllegalArgumentException is thrown with a suitable message.</td>
</tr>
<tr>
<td>sellStock</td>
<td>boolean</td>
<td>int</td>
<td>Attempts to reduce the stock level by the given amount. If it is less than one, an IllegalArgumentException is thrown with a suitable message. If the amount is otherwise less than or equal to the stock level, then the reduction is successful and true is returned. Else there is no effect, but false is returned.</td>
</tr>
</tbody>
</table>
### Public method interfaces for class `StockItem`

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>setPriceExVat</code></td>
<td><code>void</code></td>
<td><code>int</code></td>
<td>Set the price of this item to the given <code>int</code>. This is the price before VAT.</td>
</tr>
<tr>
<td><code>getPriceExVat</code></td>
<td><code>int</code></td>
<td></td>
<td>Returns the price before VAT.</td>
</tr>
<tr>
<td><code>getVatRate</code></td>
<td><code>double</code></td>
<td></td>
<td>Returns the standard percentage VAT rate, which is currently 17.5. This may be re-defined in some subclasses.</td>
</tr>
<tr>
<td><code>getPriceIncVat</code></td>
<td><code>int</code></td>
<td></td>
<td>Returns the price including VAT (as specified by <code>getVatRate()</code>) rounded to the nearest penny.</td>
</tr>
<tr>
<td><code>toString</code></td>
<td><code>String</code></td>
<td></td>
<td>Returns a string giving the stock code, the stock type, the description, the quantity in stock, the price excluding VAT and the price including VAT. It uses the appropriate methods above to obtain the stock type, description, quantity and prices.</td>
</tr>
</tbody>
</table>

To allocate a unique fixed stock code to each `StockItem` object you might have the following code.

```java
007: // The number of stock items created so far.
008: private static int noOfStockItemsCreated = 0;
009:
010: // The fixed stock code of this item.
011: private final int stockCode;
```

```java
021: public StockItem(int initialPriceExVat, int initialQuantityInStock) {
023: noOfStockItemsCreated++;
024: stockCode = noOfStockItemsCreated;
```

You will test this with a program called `TestStockItem`. This will make some instances of `StockItem`, increase stock, sell some stock and change the price, whilst printing out the items in between.

An example run might be as follows.
16.4 Section / task 16.4 The AudienceMember class

- Aim of example: To finish introducing superclass, subclass and inheritance, and briefly meet UML. Also, to introduce the principles of invoking the constructor method of the superclass, and having instance methods that override one from the superclass.

- Coursework title: Your first stock item!

- Coursework summary: Write a subclass which overrides some instance methods.

- Question: Your new computer parts shop has obtained a load of very cheap mouse mats, which are going to be your first item on sale. Create a class MouseMat which is a subclass of StockItem. This will override the instance methods getStockType() and getDescription() with ones that return "Mouse mat" and "Plain blue cloth, foam backed" respectively.

Test this with a program called TestMouseMat which makes an instance of MouseMat (you would probably not want more than one instance), increasing and then selling some stock and changing the price, whilst printing out the item in between.

16.5 Section / task 16.5 The Punter class

- Aim of example: To reinforce the ideas of superclass, subclass, inheritance, invoking the superclass constructor method, and instance methods that override another.

- Coursework title: Your catalogue

- Coursework summary: Write another subclass which overrides some instance methods.
16.6 Section / task 16.6 The Person abstract class

- Question: Your mouse mats are selling like hot cakes and you dream of the days soon to come when you will sell other things too. In fact, you decide it is time to have a catalogue!

Create a class Catalogue which is a subclass of StockItem. This will override the instance methods getStockType() and getDescription() with ones that return "Catalogue" and "List of all items and prices" respectively.

Your new class will also override getVatRate() with one that returns zero, because books do not have VAT charged on them.

Test this with a program called TestCatalogue which makes an instance of Catalogue (you would probably not want more than one instance) increasing and then selling some stock and changing the price, whilst printing out the item in between.

16.7 Section / task 16.7 The remaining simple subclasses of Person

- Aim of example: To reinforce the concepts covered in the chapter so far, and introduce the ideas of polymorphism and dynamic method binding. We also meet final classes and final methods.

- Coursework title: More stock items

- Coursework summary: Make some more subclasses and explore polymorphism and dynamic method binding.

- Question: You have obtained a big box of CPUs, a bin bag full of keyboards and a crate of hard discs. Create the classes CPU, Keyboard and HardDisc, returning the following values from getStockType() and getDescription().

<table>
<thead>
<tr>
<th>Class</th>
<th>Result from getStockType()</th>
<th>Result from getDescription()</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>&quot;CPU&quot;</td>
<td>&quot;Really fast&quot;</td>
</tr>
<tr>
<td>Keyboard</td>
<td>&quot;Keyboard&quot;</td>
<td>&quot;Cream, non-click&quot;</td>
</tr>
<tr>
<td>HardDisc</td>
<td>&quot;Hard disc&quot;</td>
<td>&quot;Lots of space&quot;</td>
</tr>
</tbody>
</table>
Write a program called `TestStockItemSubclasses` which has a class method to test just one instance of a `StockItem` given to it as a method parameter. This will increase the stock, sell some stock and change the price, printing out the item in between.

The class will also have a main method which builds an array containing one instance of each subclass of `StockItem` you have written so far, and then, in a loop, calls the class method to test each one.

16.8 Section / task 16.8 The MoodyPerson classes

- Aim of example: To introduce the ideas of adding more object state and instance methods in a subclass, testing for an instance of a particular class, and casting to a subclass. We also see how a constructor method can invoke another from the same class.

- Coursework title: Lots of different mouse mats!

- Coursework summary: Have additional state in some subclasses.

- Question: Your shop is really beginning to take off – you now have several kinds of mouse mat! This causes you to think again about your `MouseMat` class. Only your first ones fit the description which you previously hard coded, and so you decide that a description suitable to particular mouse mats should be given when an instance of `MouseMat` is created. You realize that there may be other kinds of stock item that have similar simple variations in their descriptions, and so you decide to create another abstract class which is a subclass of `StockItem`, called `TextDescriptionStockItem`, and have `MouseMat` be a subclass of that. An instance of `TextDescriptionStockItem` will be given its description when it is created. Also, because you anticipate that descriptions might be refined due to customer feedback, they can be changed later.

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructor</td>
<td>String, int, int</td>
<td>String, int, int</td>
<td>Creates an instance of <code>TextDescriptionStockItem</code> with the given textual description, int initial price (in whole pence) and int initial quantity. The price is exclusive of VAT (sales tax).</td>
</tr>
<tr>
<td>getDescription</td>
<td>String</td>
<td>String</td>
<td>Returns the description that was given to the constructor method.</td>
</tr>
<tr>
<td>setDescription</td>
<td>void</td>
<td>String</td>
<td>Sets the description to the given string.</td>
</tr>
</tbody>
</table>

Read the rest of this task, and then draw a UML class diagram showing the full inheritance hierarchy, from `StockItem` downwards, as it will be when you have finished the task.
After drawing your diagram, implement the TextDescriptionStockItem class.

Now change MouseMat so that it is a subclass of TextDescriptionStockItem and remove getDescription() from it.

Alter TestStockItemSubclasses so that it makes two instances of MouseMat with different descriptions and prices. Add an extra class method that tests a TextDescriptionStockItem by making some change to its description (e.g. adding some text to it). Alter the existing class method that tests a StockItem so that, if the StockItem is also an instance of TextDescriptionStockItem, it will call your new class method to perform those additional tests.

You have also obtained various books about building computers that you would like to sell. Create the class Book which is another subclass of TextDescriptionStockItem. Remember that books are zero rated for VAT. Get rid of your Catalogue class – you have decided that your catalogue is better off being an instance of Book. Alter your test program so that it also creates some instances of Book – including one for your catalogue.

16.11 Section / task 16.11 The Game class

- Aim of example: To illustrate the difference between is a and has a relationships.

- Coursework title: Shopping baskets

- Coursework summary: Write a class each instance of which has a number of instances of another class stored in it.

- Question: As always, read the whole of this task and then plan in your logbook what classes you need, including what methods they will have, before starting your implementation.

Your computer parts shop has so many customers now that you wish to computerize the selling of your products. Write a class called StockItemPurchaseRequest which has a StockItem and an int quantity of that stock item required by a customer.

Write another class called ShoppingBasket which can contain any number of stock item purchase requests, using array extension. This should have an add() instance method which takes (a reference to) a StockItem and an int required quantity, and adds a corresponding StockItemPurchaseRequest to the shopping basket.

It will also have a toString() giving the contained stock item purchase requests, one per line.

And finally, it will have another instance method called checkout. This will go through the stock item purchase requests and sell them (reducing the stock quantities), if there are enough quantity in stock, or not otherwise. The successful purchase requests will be removed from the shopping basket, leaving only those that were not purchased. The result will be a String indicating for each purchase request whether it was purchased or not, along with the details of it, all followed by the total price with and without VAT. Test this with a program called TestShoppingBasket. Here is a sample implementation for that – feel free to alter it if you wish.
public class TestShoppingBasket {
    public static void main(String[] args) {
        StockItem[] stockItems =
        { /* 0 */ new MouseMat("Plain blue cloth, foam backed", 150, 10),
          /* 1 */ new MouseMat("Pink vinyl with fluffy trim", 350, 10),
          /* 2 */ new Book("List of all items and prices", 150, 10),
          /* 3 */ new Book("Build a gaming monster", 1799, 0),
          /* 4 */ new CPU(1500, 10),
          /* 5 */ new HardDisc(5500, 10),
          /* 6 */ new Keyboard(200, 10)
        ];

        System.out.println("Stock before purchase:");
        for (StockItem stockItem : stockItems)
            System.out.println(stockItem);
        System.out.println();

        ShoppingBasket shoppingBasket = new ShoppingBasket();
        shoppingBasket.add(stockItems[0], 2);
        shoppingBasket.add(stockItems[2], 1);
        shoppingBasket.add(stockItems[4], 8);
        shoppingBasket.add(stockItems[5], 9);
        shoppingBasket.add(stockItems[4], 3);
        shoppingBasket.add(stockItems[6], 8);
        shoppingBasket.add(stockItems[3], 1);

        System.out.println("Shopping basket filled up:");
        System.out.println(shoppingBasket);
        System.out.println();

        System.out.println("Performing Checkout:");
        System.out.println(shoppingBasket.checkout());
        System.out.println();

        System.out.println("Shopping basket after checkout:");
        System.out.println(shoppingBasket);
        System.out.println();

        System.out.println("Stock after checkout:");
        for (StockItem stockItem : stockItems)
            System.out.println(stockItem);
    } // main
} // class TestShoppingBasket

Here is a sample run of the above code.
$ java TestShoppingBasket

Stock before purchase:
SC1: Mouse mat, Plain blue cloth, foam backed (10 @ 150p/176p)
SC2: Mouse mat, Pink vinyl with fluffy trim (10 @ 350p/411p)
SC3: Book, List of all items and prices (10 @ 150p/150p)
SC4: Book, Build a gaming monster (0 @ 1799p/1799p)
SC5: CPU, Really fast (10 @ 1500p/1763p)
SC6: Hard disc, Lots of space (10 @ 5500p/6463p)
SC7: Keyboard, Cream, non-click (10 @ 200p/235p)

Shopping basket filled up:
Shopping basket:
2 of SC1: Mouse mat, Plain blue cloth, foam backed (10 @ 150p/176p)
1 of SC3: Book, List of all items and prices (10 @ 150p/150p)
8 of SC5: CPU, Really fast (10 @ 1500p/1763p)
9 of SC6: Hard disc, Lots of space (10 @ 5500p/6463p)
3 of SC5: CPU, Really fast (10 @ 1500p/1763p)
8 of SC7: Keyboard, Cream, non-click (10 @ 200p/235p)
1 of SC4: Book, Build a gaming monster (0 @ 1799p/1799p)

Performing Checkout:
Checkout report:
Purchased 2 of SC1: Mouse mat, Plain blue cloth, foam backed (8 @ 150p/176p)
Purchased 1 of SC3: Book, List of all items and prices (9 @ 150p/150p)
Purchased 8 of SC5: CPU, Really fast (2 @ 1500p/1763p)
Purchased 9 of SC6: Hard disc, Lots of space (1 @ 5500p/6463p)
Not purchased 3 of SC5: CPU, Really fast (2 @ 1500p/1763p)
Purchased 8 of SC7: Keyboard, Cream, non-click (2 @ 200p/235p)
Not purchased 1 of SC4: Book, Build a gaming monster (0 @ 1799p/1799p)
Total price ex vat: 63550p
Total price inc vat: 74653p

Shopping basket after checkout:
Shopping basket:
3 of SC5: CPU, Really fast (2 @ 1500p/1763p)
1 of SC4: Book, Build a gaming monster (0 @ 1799p/1799p)

(Continued ... )
16.12 Section / task 16.12 The Worker classes

Stock after checkout:
SC1: Mouse mat, Plain blue cloth, foam backed (8 @ 150p/176p)
SC2: Mouse mat, Pink vinyl with fluffy trim (10 @ 350p/411p)
SC3: Book, List of all items and prices (9 @ 150p/150p)
SC4: Book, Build a gaming monster (0 @ 1799p/1799p)
SC5: CPU, Really fast (2 @ 1500p/1763p)
SC6: Hard disc, Lots of space (1 @ 5500p/6463p)
SC7: Keyboard, Cream, non-click (2 @ 200p/235p)

Hint: in order to delete successfully purchased items from the ShoppingBasket, checkout() might create another (empty) ShoppingBasket into which it adds the StockItem and required quantity of unsuccessful requests. At the end it can copy the instance variables of this temporary ShoppingBasket to replace those of the original one.

As usual, record in your logbook any changes you needed to make to your plan.

16.12 Section / task 16.12 The Worker classes

- Aim of example: To show an example of a superclass which is (appropriately) not an abstract class. We also show how we can use an instance method defined in the superclass, from a subclass which overrides it.

- Coursework title: Loads of disc space

- Coursework summary: To write a non-abstract class which has a subclass, and use an instance method defined in the superclass from a subclass which overrides it.

- Question: Read the whole of this task, and then draw a UML class diagram showing the full inheritance hierarchy, from StockItem downwards, as it will be when you have finished the task.

Your shop just keeps getting better – now you have a whole variety of different sizes of hard disc on offer. Alter your HardDisc class so that the constructor method takes an additional method parameter which is the size of the disc in gigabytes. Alter the getDescription() instance method so that it returns, for example, "500GB of space" – the actual number being the given size, of course.

And then you get a delivery of an amazing new kind of hard disc that is so reliable it is guaranteed to keep data safe from disc crash for a specified number of years. Write a subclass of HardDisc called ReliableHardDisc. Its constructor method takes one extra parameter which is the guarantee period. It overrides getDescription() with one that appends, for example, ", guaranteed 20 years" to the string obtained by the same instance method in the superclass – the actual number being the given guarantee period, of course.

Alter your TestStockItemSubclasses class to include the size for the HardDiscs and also add at least one ReliableHardDisc.
16.13 Section / task 16.13 The CleverPunter class

- Aim of example: To reinforce inheritance concepts, and complete the model classes of the Notional Lottery program.
- Coursework title: Making it more realistic
- Coursework summary: Add more complexity to an inheritance hierarchy at appropriate places.
- Question: The computer parts shop example has been a little over simplified so far. In this task you will add more complexity to make it all a bit more realistic. You can add what you like, but here are some suggestions.
  - CPUs have a vendor, architecture and speed.
  - Hard discs have a physical size, vendor, rotational speed and cache/buffer size.
  - Keyboards have colour, vendor, number of keys, and possible special features description.
  - Perhaps every stock item could have a changeable part of its description, rather than just the TextDescriptionStockItem class.

Think of more ideas. Then identify the most appropriate place in the inheritance hierarchy to add each complexity, and implement them. You will add more instance variables, instance methods and alter existing instance methods as required. For example, getDescription() should perhaps incorporate the additional instance variables in its result.

16.15 Section / task 16.15 The Object class and constructor chaining

- Aim of example: To introduce the class Object and the fact that the constructor method of the superclass is invoked implicitly by default. We also take a more thorough look at constructor chaining.
- Coursework title: Exploring constructor chaining
- Coursework summary: Add tracing to existing constructor methods in order to explore constructor chaining.
- Question: Add System.out.println() calls to the constructor method of each StockItem class printing the name of the class. Add each call at the earliest point in the body of the constructor method that the compiler will let you. Once you have successfully compiled the classes, predict what the additional output will be from your TestStockItemSubclasses program before you run it. Then run it and see if you were right.
16.16 Section / task 16.16 Overloaded methods versus override

- Aim of example: To take a closer look at overloaded methods and in particular how an intended override can accidentally become an overload. We revisit the overloaded methods System.out.println(), and look at toString() from the Object class.

- Coursework title: Using the @Override annotation

- Coursework summary: Add to your instance methods that override another, an annotation which helps protect against errors.

- Question: Go through your solutions to the tasks in this Chapter and add the @Override override annotation to all instance methods which override another.
  Also identify all the places where we should have put it in the example code.

17 Chapter 17 Making our own exceptions

17.3 Section / task 17.3 The Date class with its own exceptions

- Aim of example: To introduce the idea of making our own exceptions.

- Coursework title: GreedyChildren with exceptions

- Coursework summary: Add your own exceptions to the GreedyChildren example.

- Question: Copy the classes GreedyChild and IceCreamParlour from the example in Section 11.3 starting on page 40 Add two new classes GreedyChildException and IceCreamParlourException, both subclasses of RuntimeException. These should be able to handle causes, even though you might not need to use them at this stage.

  Identify all the places in GreedyChild and IceCreamParlour where the methods might be given bad method arguments, and make them throw appropriate exceptions. (Hint: bear in mind that some of these arguments are references.) Recall that Java does not force you to have throws clauses for unchecked exceptions, but you nevertheless should do so for this task when such are possible.

  Test the new features of each class using dedicated programs called TestGreedyChildExceptions and TestIceCreamParlourExceptions respectively. These should contain separate try statements for each possible exceptional situation.

17.4 Section / task 17.4 The Notional Lottery with exceptions

- Aim of example: To reinforce the idea of defining our own exceptions, and further it by having two of our own exception classes, where one is a subclass of the other.

- Coursework title: MobileIceCreamParlour with exceptions
Coursework summary: Add a subclass of your own exception to the GreedyChildren example.

Question: Now we have a subclass of IceCreamParlour representing what is, in effect, an ice cream van!

```
// An IceCreamParlour with the additional feature of needing to use fuel.
public class MobileIceCreamParlour extends IceCreamParlour
{
    // The amount of fuel left in the tank.
    private double fuelLeft = 0;

    // Construct a mobile ice cream parlour -- given the required name.
    public MobileIceCreamParlour(String name)
    {
        super(name);
    } // MobileIceCreamParlour

    // Put fuel in the tank.
    public void obtainFuel(double amount)
    {
        fuelLeft += amount;
    } // obtainFuel

    // Use some fuel by driving.
    public void drive(double desiredFuelUsed)
    {
        double fuelUsed = desiredFuelUsed <= fuelLeft ? desiredFuelUsed : fuelLeft;
        fuelLeft -= fuelUsed;
    } // drive

    // Return a String giving the name and state.
    @Override
    public String toString()
    {
        return super.toString() + "[fuel " + fuelLeft + "]";
    } // toString
}
```
18 Chapter 18 Files

18.2 Section / task 18.2 Counting bytes from standard input

- Aim of example: To introduce the principle of reading bytes from standard input using InputStream, meet the try finally statement and see that an assignment statement is actually an expression – and can be used as such when appropriate. We also meet IOException and briefly talk about initial values of variables.

- Coursework title: A check sum program

- Coursework summary: Write a program to produce a check sum of the standard input.

- Question: The problem of being able to detect whether a file of data has changed since a previous version has many applications in computing. For example, if you download a file from the Internet, how can you be sure that your copy of it is correct and has not been corrupted? Or, imagine a program, run every night, that generates individual timetables for students, compares each of them with the timetable from the day before, and emails the latest copy if it has changed.

You might expect that the only way to see if a file has changed is to compare it byte by byte with the original, but this is not so. An alternative is to calculate some kind of check sum of the file and compare it with the number obtained from the original file. A check sum is a number that is a function of the file contents, computed in such a way that even a tiny change in the file causes a difference to the number. Perhaps the website could tell you what the number should be (as long as you use the same check sum algorithm). Similarly, the timetable program need remember only the check sum for each student from the night before.

In this task you will write a program called CheckSum which reads all the bytes from standard input and outputs a single number on standard output. You should handle exceptions in the same way as we did for the example in this section. You will use the BSD check sum algorithm which has been around for many years. There are more sophisticated and complex alternatives available nowadays, however this simple one is still fairly good.

For each byte in the input, the check sum computed so far is subjected to a rotate right, and then that byte is added to it. A rotate right means each bit of the number moves one place to the right, with the rightmost bit rotating to the leftmost place. For example, the 16-bit number 1100110011001100 becomes 0110011001100110, and 0011001100110011 becomes 1001100110011001.

The BSD algorithm computes a 16-bit check sum, which you will store in a 32-bit int. So you need to take care that the rotation is done on only the lower 16 bits and the upper 16 always remain zero. Here is the algorithm expressed in pseudo code.

```java
int checkSum = 0
for every byte from the input
    rotate checkSum right by one bit, treating it as a 16 bit number.
    checkSum += byte
    restrict checkSum to 16 bits.
```
To rotate checkSum right by one bit, whilst treating it as a 16 bit number, you can use the following pseudo code. (Note that 32768 is $2^{15}$.)

```java
if checkSum is even
    checkSum /= 2
else
    checkSum /= 2
    checkSum += 32768
```

You may prefer to express 32768 in your Java code as a **hexadecimal integer literal**, in the form 0x8000. (Also, you may prefer to find out about the bit **shift operators** and use one of those instead of **division**).

To restrict checkSum to 16 bits you can use the following code, which works because you have just added a value **less than** 256 to a value that was less than 65536 (which is $2^{16}$).

```java
if checkSum >= 65536
    checkSum -= 65536
```

You may prefer to express 65536 as 0x10000. (Also, you may prefer to find out about the **integer bitwise operators** and use one of those instead of an **if statement**.)

To perform a check sum of the data in a file, rather than input typed at the keyboard, you can redirect standard input to come from that file, using < on the **command line**. If you are using a Unix environment, you can probably test your program by comparing its output with that obtained from the sum command (which also outputs the size of the file as a number of one kilobyte blocks). Otherwise the book website has some example files for you to try, along with their correct check sums.

### Console Input / Output

```
$ java CheckSum < CheckSum.java
51871
$ sum CheckSum.java
51871 2
$ _
```

(The check sum for your program code will probably not be the same as the one above.)

---

### 18.3 Section / task 18.3 Counting characters from standard input

- **Aim of example:** To introduce the principle of reading **characters**, instead of **bytes**, from **standard input**, using InputStreamReader.

- **Coursework title:** Counting words

- **Coursework summary:** Write a program to count the number of words in its **standard input**.
Question: Write a program, WordCount which reads the characters from its standard input, counting how many words that contains, and reports the number on its standard output. You should handle exceptions in the same way as we did for the example in this section.

A character is either a white space character, such as space character, tab character, or new line character; or it is part of a word. To determine whether a char c is white space, you can use Character.isWhitespace(c).

A word is a non-empty sequence of any non-white space characters, preceded either by the beginning of the file, or a white space character, and followed either by the end of the file, or a white space character. There may be more than one white space character before and/or after a word, including before the first word, and after the last one.

Hint: the start of a word is at a character which is itself not white space, and which is either the first character in the input, or was preceded by a white space character.

Alternatively, think of the input as being:

- A possibly empty sequence of white space characters.
- A possibly empty sequence of words, each being:
  * A non-empty sequence of non-white space characters.
  * A possibly empty sequence of white space characters.

As usual, design test data in advance of designing your program.

18.4 Section / task 18.4 Numbering lines from standard input

Aim of example: To introduce the principle of reading lines from standard input, using BufferedReader.

Coursework title: Deleting a field

Coursework summary: Write a program to delete a field in tab separated text from the standard input.

Question: Write a program called DeleteField which copies its standard input to its standard output, line by line, except that it deletes one of the fields on each line. The fields are separated by a single tab character, and are numbered from one upwards. The number of the field to be deleted is given as a command line argument.

Here is an example run.
(Of course, in practice the program would be most useful if the input was being redirected from a file, rather than literally being typed in line by line – the above is really just for testing.)

You might find the following code helpful.

```java
024:   // Divide the line into fields using tab as a delimiter.
025:   String[] fields = inputLine.split("\t");
026:   String editedLine = "";
027:   if (fields.length < fieldToDelete)
028:       editedLine = inputLine;
029:   else
030:       {
031:           // We build the new line in parts.
032:           // Add the fields before the one to be deleted.
033:           for (int index = 0; index < fieldToDelete - 1; index++)
034:               if (editedLine.equals("")) editedLine = fields[index];
035:               else editedLine += "\t" + fields[index];
036:           // Add the fields after the one to be deleted.
037:           for (int index = fieldToDelete; index < fields.length; index++)
038:               if (editedLine.equals("")) editedLine = fields[index];
039:               else editedLine += "\t" + fields[index];
040:       } // else
```

You should handle exceptions in the same way as we did for the example in this section (except you will need to consider problems relating to the command line argument).

If you wanted to delete two fields, and also your data was in a text file, then you could redirect the standard input to come from it, and pipe the standard output into the input of another run of your program.
18.5  Section / task 18.5 Numbering lines from text file to text file

- Aim of example: To introduce the principle of reading from a text file and writing to another, using BufferedReader with FileReader and PrintWriter with FileWriter. We also meet FileInputStream, OutputStream, FileOutputStream and OutputStreamWriter.

- Coursework title: Deleting a field, from file to file

- Coursework summary: Write a program to delete a field in tab separated text from a file, with the results in another file.

- Question: Write a version of your DeleteField program from Section 18.4 on page 85, that takes its input from a named file and puts its output in another named file. You should handle exceptions in the same way as we did for the example in this section.

18.6  Section / task 18.6 Numbering lines from and to anywhere

- Aim of example: To illustrate that reading from text files and from standard input is essentially the same thing, as is writing to text files and to standard output. We also look at testing for the existence of a file using the File class, and revisit PrintWriter and PrintStream.

- Coursework title: Deleting a field, from anywhere to anywhere

- Coursework summary: Write a program to delete a field in tab separated text either from standard input or a file, with the results going to either standard output or another file.

- Question: Write a version of your DeleteField program from Section 18.4 on page 85 that takes its input from standard input or a named file, and puts its output on standard output or in another named file. You should handle exceptions in the same way as we did for the example in this section.
18.7 Section / task 18.7 Text photographs

- Aim of example: To see an example of reading binary files, where we did not choose the file format. This includes the process of turning bytes into ints, using a shift operator and an integer bitwise operator.

- Coursework title: Encoding binary in text

- Coursework summary: Write a program to encode a binary file as an ASCII text file, so that it can be sent in an email.

- Question: Have you ever wondered how it is that you can send a binary file, such as an image, as an attachment inside an email message, when in fact an email is actually an ASCII text file? The answer is simple: the binary file is coded as ASCII text when the email is constructed, and decoded back to binary again when the email is opened at the other end.

Search on the Internet to find out about a program called uuencode and how it codes sequences of 3 bytes, each using all 8 bits as in a binary file, into sequences of 4 ASCII characters, each using only 6 bits. (3 \times 8 = 4 \times 6.) Or, if you are using Unix then there is a good chance the program is already installed and you can find out about it using man -a uuencode.

Write your own program called Uuencode which performs this function. Its command line argument should be the name of the file to be encoded, and the result should go to standard output. You should handle exceptions using the same style as the example in this section. You can test your program by converting a binary file to ASCII, converting it back to binary again using a standard uudecode program (take care not to replace the original with the decoded one!), and comparing that result with the original. uudecode is available from the Internet or is probably installed if you are using Unix. You could use your CheckSum program to undertake the comparison (or on Unix you could use the cmp program).

The following pseudo code might help (after you have found out about the format that uuencode produces).

```plaintext
write the header -- assume file mode 600
create an array to hold the bytes for one line (partially filled)
read next byte
while next byte is not -1
    process a line of bytes and read next byte
output a line representing zero number of bytes
output the trailer line
```

We can refine this to the following.

```plaintext
write the header -- assume file mode 600
create an array to hold the bytes for one line (partially filled)
read next byte
while next byte is not -1
    while next byte is not -1 and array is not full
        put next byte in the array
```

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18.8 Section / task 18.8 Contour points

read next byte
end-while
output the number of bytes on this line
loop over the line array in groups of 3 bytes
calculate the 4 output bytes for those 3 bytes
output the 4 output bytes
end-loop
output an end of line
end-while
output a line representing zero number of bytes
output the trailer line

You will also find the following code fragments helpful!

... 009: // Write a single result byte as a printable character.
010: // Each byte is 6-bit, i.e. range 0..63.
011: // Thus adding 32 makes it printable, except for 0 which would become space
012: // and so we add 96 instead -- a left single quote ('').
013: private static void writeByteAsChar(int thisByte)
014: {
015:     System.out.print((char) (thisByte == 0 ? 96 : thisByte + 32));
016: } // writeByteAsChar
...
056: // Calculate 4 result bytes from the 3 input bytes.
057: int byte1 = lineBytes[byteGroupIndex] >> 2;
058: int byte2 = (lineBytes[byteGroupIndex] & 0x3) << 4
059:     | (lineBytes[byteGroupIndex + 1] >> 4);
060: int byte3 = (lineBytes[byteGroupIndex + 1] & 0xf) << 2
061:     | lineBytes[byteGroupIndex + 2] >> 6;
062: int byte4 = lineBytes[byteGroupIndex + 2] & 0x3f;
063: // Now write those result bytes.
064: writeByteAsChar(byte1);
065: writeByteAsChar(byte2);
066: writeByteAsChar(byte3);
067: writeByteAsChar(byte4);
...

Optional extra: Write the Uudecode program too!

18.8 Section / task 18.8 Contour points

- Aim of example: To show an example of writing and reading binary files where we choose the data format, using DataOutputStream and DataInputStream classes.
- Coursework title: Saving greedy children
- Coursework summary: Add features to some existing model classes so they can be written and read back from binary files.
Question: Copy the GreedyChild and IceCreamParlour classes from Section [11.3] starting on page 40 and add code so they can be written to a DataOutputStream and read back from a DataInputStream. You do not need to save the IceCreamParlour that a GreedyChild is in – so when a GreedyChild is read back, he or she will always not be in a parlour. Test your new features with a program called TestGreedyChildrenIO.

Optional extra: Figure out how to save and restore the IceCreamParlour that a GreedyChild is in. Perhaps each IceCreamParlour could have a unique ID number? Maybe that number would also be an array index? You may want to ensure that all IceCreamParlours are read (and hence written) before any GreedyChild is read.

Optional extra: (Challenge!) Find out about ObjectInputStream and ObjectOutputStream and use those instead.

19 Chapter 19 Generic classes

19.2 Section / task 19.2 A pair of any objects

Aim of example: To explore potential problems of having a container object that can hold instances of any class, in particular that we need protection against us erroneously getting the type wrong when we extract items from the container. We also introduce the idea of boxing an int within an Integer.

Coursework title: A triple

Coursework summary: Write a class that can store a triple of objects, and use it.

Question: Write a class called Triple, similar to Pair, except that its instances each store three objects.

Write a class called IntArrayStats containing a class method getStats() which takes an array of ints and returns a Triple containing the maximum integer in the array, the minimum, and also the mean of all the values. You will need to box the first two inside Integer objects, and the third inside a Double.

Test your work with the following program which measures how much the mean of a set of numbers differs from the average of its minimum and maximum.

```
001: // Program to measure how much the mean of the integer command line arguments
002: // differs from the average of their minimum and maximum.
003: // (Warning: this program does not catch RuntimeExceptions.)
004: public class MeanMinMaxMinusMean
005: {
006:     public static void main(String[] args) throws RuntimeException
007:     {
008:         int[] array = new int[args.length];
009:         for (int index = 0; index < args.length; index++)
010:             array[index] = Integer.parseInt(args[index]);
011:             
012:         Triple stats = IntArrayStats.getStats(array);
```
013:  int max = ((Integer)stats.getFirst()).intValue();
014:  int min = ((Integer)stats.getSecond()).intValue();
015:  double mean = ((Double)stats.getThird()).doubleValue();
016:  System.out.println((min + max) / 2.0 - mean);
017:  } // main
018:
019: } // class MeanMinMaxMinusMean

If you run the program with a set of consecutive numbers, the result should come out as 0.0.

Coffee time: What common bug could cause the result to be 0.5 when the program is given a list of consecutive numbers of a length which is even?

Experiment to see what happens when you make the same kind of mistake in the above program as we did in the example in this section.

19.3 Section / task 19.3 A generic pair of specified types

- Aim of example: To introduce the idea of generic classes, and show how it can be used to avoid the problems explored in the previous section.

- Coursework title: A generic triple

- Coursework summary: Write a generic class that can store a triple of specific kinds of objects, and use it.

- Question: Rewrite your classes from Section 19.2 on page 90 so that Triple becomes a generic class, and the other classes are altered appropriately.

  (If you have read ahead, please do not use autoboxing – you will learn more by saving that for a separate task.)

19.4 Section / task 19.4 Autoboxing and auto-unboxing of primitive values

- Aim of example: To expose Java’s implicit conversion between values of primitive types and instances of the corresponding wrapper classes.

- Coursework title: A generic triple, used with autoboxing

- Coursework summary: Write a generic class that can store a triple of specific kinds of objects, and use it; this time using autoboxing and auto-unboxing.

- Question: Rewrite your classes from Section 19.3 on page 91 so that autoboxing and auto-unboxing is used appropriately.
19.5  Section / task 19.5 A conversation of persons

- Aim of example: To introduce the idea of a bound type parameter, in particular, one that must extend some other type.
- Coursework title: A moody group
- Coursework summary: Write a generic class that can store a collection of a particular kind of MoodyPerson objects, from the Notional Lottery example, and make them all happy or unhappy at the same time.
- Question: This coursework is set in the context of the Notional Lottery game from Section ?? on page ??.

Write a generic class called MoodyGroup that contains a collection of some subclass of MoodyPerson objects, rather like the Conversation class does with Person. However, instead of a speak() instance method, MoodyGroup should have setHappy(). This will take a boolean and pass it to the instance method of the same name belonging to each of the MoodyPersons in the group. You will recall that only MoodyPersons have the setHappy() instance method, whereas the more general Person does not.

Test your class with a program called TestMoodyGroup. This will do the following.
- Create an instance of MoodyGroup<Teenager> and populate it with a small number of Teenagers.
- Invoke setHappy() with false and print out the group.
- Invoke setHappy() with true and print out the group again.
- Create a second moody group which can contain any kind of MoodyPerson, and populate it with a Worker and one of the same Teenagers which was put into the first group.
- Invoke setHappy() on the second group with true and print out the group.
- Invoke setHappy() on the second group with false and print out the group.
- Print out the first group one more time to show that the teenager which is in both groups stands out from the others.

20  Chapter 20 Interfaces, including generic interfaces

20.3  Section / task 20.3 Sorting a text file using an array

- Aim of example: To introduce the idea of total order and the Comparable interface. We also meet the Arrays class.
- Coursework title: Sort a text file
- Coursework summary: Implement the program to sort a text file.
20.4 Section / task 20.4 Translating documents

- **Question:** Write the program `Sort` as described in the example for this section. The following fragments may help you.

```java
import java.util.Arrays;
...
Arrays.sort(lineArray, 0, noOfLinesReadSoFar);
...
```

20.4 Section / task 20.4 Translating documents

- **Aim of example:** To explore **generic interfaces**, observe that `Comparable` is generic, see that `String` implements it, meet `equals()` from `Object` and talk about consistency with `compareTo()`. We also introduce **generic methods**, **binary search**, revisit `Arrays` and note that an **interface** can **extend** another.

- **Coursework title:** **Minimum and maximum Comparable**

- **Coursework summary:** Write a **generic method** to find the minimum and maximum items in an **array** of `Comparable` items.

- **Question:** Write a **class** called `MinMaxArray` which has one **class method** that takes an **array**. It will be a **generic method** with one **type parameter** that is comparable with itself, and the array shall have that **array base type**. It will **return** an **instance** of the **generic class** `Pair` from Section ?? on page ??, comprising the minimum and the maximum items from the array, based on the **natural ordering** of the items. It should **throw** an `IllegalArgumentException` if the array is empty or non-existent.

Test your class with a program called `TestMinMaxArray`.

20.5 Section / task 20.5 Sorting valuables

- **Aim of example:** To introduce the idea that a **class** can **implement** many **interfaces**, and explore what it means for an **interface** to **extend** another. We also take another look at having consistency between `compareTo()` and `equals()`.

- **Coursework title:** **Analysis of `compareTo()` and `equals()`**

- **Coursework summary:** Undertake an analysis of previous uses of `compareTo()` and `equals()` **instance methods**.

- **Question:** We saw examples of `compareTo()` and `equals()` **instance methods** in various **classes** before this chapter. Now that you know about the `Comparable` **interface** and the `equals()` instance method from the `Object` class – which takes (a **reference** to) an `Object` as a **method parameter**, find all those previous places and identify the changes we should make. Record them in your logbook.
21 Chapter 21 Collections

21.2 Section / task 21.2 Reversing a text file

- Aim of example: To introduce the Java collections framework, and in particular the idea of list collections, the List interface and the ArrayList class.

- Coursework title: Sorting election leaflets

- Coursework summary: Write a program to sort election information leaflets into delivery order.

- Question: Being disillusioned with the main political parties, you have recently joined the newly formed “Sort it out” party. As an election is looming, they have asked you to distribute campaign material in your area. They have sent you a stack of leaflets for each street, each with a label on the front showing the names of its recipients. Here are examples of two labels.

| Augustus Belcher, Regents Crescent | Joanne Smith and Lionel Brown, Regents Crescent |

How ‘sorted out’, they think. That is, until you tell them they have failed to print the house numbers on the leaflets, only the street names! They quickly email you a text file for each street, containing the recipient names for each house, in house number order. For example, the file for Regents Crescent is called regents-crescent.txt, and contains the following.

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ cat regents-crescent.txt</td>
</tr>
<tr>
<td>1 Joanne Smith and Lionel Brown</td>
</tr>
<tr>
<td>2 Augustus Belcher</td>
</tr>
<tr>
<td>3 Fatima Bacon and Gaynor White</td>
</tr>
<tr>
<td>4 Celina Simmons and Rupert Rodgers-Smythe</td>
</tr>
<tr>
<td>5 Ahmed Hussain</td>
</tr>
<tr>
<td>6 Samuel Peacock and Sarah Peacock</td>
</tr>
<tr>
<td>7 Hsin Cheng Liu</td>
</tr>
<tr>
<td>8 Blanche Peacock and Harry Peacock</td>
</tr>
<tr>
<td>$</td>
</tr>
</tbody>
</table>

The first line is the names of the people who live at number one Regents Crescent, the second is the names for number two, and so on. The party officials tell you to sort the leaflets into this order before delivering them.

However, you are cleverer than that. You will write a program to sort a file into delivery order, that is, the order of walking up one side of the street and down the other. As it happens, you know that all the streets in your area are symmetrical, with odd numbered houses on the left, and even numbered ones on the right, both ascending in the same direction.\(^1\)

\(^1\) In this simplistic world, obviously the houses on the outer curve of Regents Crescent have bigger gardens.
In this task you will write the delivery order sorting program, calling it `StreetOrder`. It should take two command line arguments, the name of the original file, and the sorted file to be created. It should work by reading the lines from the input file into an `ArrayList` of `String`s. Then it should loop forwards through all the even indices of the list, printing the lines to the output file. That will be the details for the odd numbered houses. Finally it should loop backwards through the odd indices of the list and print those lines. So the output for the above input would be as follows.

```java
java StreetOrder regents-crescent.txt regents-crescent-sorted.txt
$ cat regents-crescent-sorted.txt
1 Joanne Smith and Lionel Brown
3 Fatima Bacon and Gaynor White
5 Ahmed Hussain
7 Hsin Cheng Liu
8 Blanche Peacock and Harry Peacock
6 Samuel Peacock and Sarah Peacock
4 Celina Simmons and Rupert Rodgers-Smythe
2 Augustus Belcher
$ _
```

The program should be able to handle files which have an odd number of lines – some of the streets are a cul-de-sac of detached houses with one in the middle at the bottom.

Here is a reasonable set of test cases for the program.

<table>
<thead>
<tr>
<th>#</th>
<th>Test case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No command line arguments.</td>
</tr>
<tr>
<td>2</td>
<td>Only one command line argument.</td>
</tr>
<tr>
<td>3</td>
<td>An input file that does not exist.</td>
</tr>
<tr>
<td>4</td>
<td>An output file that has a leading directory that does not exist.</td>
</tr>
<tr>
<td>5</td>
<td>An output file that has a leading directory which is not writable</td>
</tr>
<tr>
<td></td>
<td>(e.g. the root directory on Unix, <code>/</code>).</td>
</tr>
<tr>
<td>6</td>
<td>An input file with no odd numbered houses and no even numbered houses</td>
</tr>
<tr>
<td></td>
<td>(e.g. <code>/dev/null</code> or <code>null</code>).</td>
</tr>
<tr>
<td>7</td>
<td>An input file with one odd numbered house and no even numbered houses</td>
</tr>
<tr>
<td></td>
<td>(i.e. one line).</td>
</tr>
<tr>
<td>8</td>
<td>An input file with one odd numbered house and one even numbered house</td>
</tr>
<tr>
<td></td>
<td>(i.e. two lines).</td>
</tr>
<tr>
<td>9</td>
<td>An input file with two odd numbered houses and one even numbered house</td>
</tr>
<tr>
<td></td>
<td>(i.e. three lines).</td>
</tr>
<tr>
<td>10</td>
<td>An input file with two odd numbered houses and two even numbered houses</td>
</tr>
<tr>
<td></td>
<td>(i.e. four lines).</td>
</tr>
<tr>
<td>11</td>
<td>An input file with three odd numbered houses and two even numbered houses</td>
</tr>
<tr>
<td></td>
<td>(i.e. five lines).</td>
</tr>
<tr>
<td>12</td>
<td>An input file with three odd numbered houses and three even numbered houses</td>
</tr>
<tr>
<td></td>
<td>(i.e. six lines).</td>
</tr>
</tbody>
</table>
As usual, devise test data, before designing the program, and create input files ready for testing. Record this in your logbook.

Now design and implement the program. You should handle exceptions in the same way as we did for the example in this section. After implementation, run the program with the tests you designed beforehand. Record in your logbook the outcome and any unexpected results together with their cause and how you fixed any bugs.

21.3 Section / task 21.3 Sorting a text file using an ArrayList

- Aim of example: To reinforce the use of ArrayList, in particular, showing uses of the set() instance method of a List. We also note that an array can be created from a List, and vice versa. Finally, we look at the Collections class and observe that it has a sort() generic method.

- Coursework title: Sorting election leaflets, with compareTo()

- Coursework summary: Write a program to sort election information leaflets into delivery order, using a compareTo() instance method.

- Question: In this task you will write the same program as in the coursework for Section 21.2 on page 94, but in a different way.

Create a class called DeliveryHouseDetails, which is Comparable with itself. This will store a house number in an instance variable, and the person name details (including the house number) in another. It will have an accessor method to obtain the person names. It will also have another instance method, compareTo(), which orders DeliveryHouseDetails objects by delivery order. Here is some pseudo code.

```java
cmpareTo (other) {
    if both house numbers are odd
        return this house number minus the other one
    else if both house numbers are even
        return the other house number minus this one
    else if this house number is odd
        return -1
    else
        return 1
}
```

This will cause a List of DeliveryHouseDetails objects, when processed by Collections.sort(), to be sorted into the required delivery order, as described in the coursework for Section 21.2 on page 94. Convince yourself this is true and write notes about it in your logbook.

Copy your StreetOrder class from the previous version, and modify it so that it creates a DeliveryHouseDetails object for each input line and stores it in the ArrayList. You can simply count the lines to obtain the house number – there is no need to extract it from the details on the line. After loading the details the program will use sort() from the
Implement the DeliveryHouseDetails class. Note, you should also include an equals() instance method which is consistent with compareTo(). The following code should do the trick.

```java
043: // Equivalence test, consistent with compareTo.
044: @Override
045: public boolean equals(Object other)
046: {
047:     if (other instanceof DeliveryHouseDetails)
048:         return houseNumber == ((DeliveryHouseDetails)other).houseNumber;
049:     else
050:         return super.equals(other);
051: } // equals
...```

After implementation, run the program with the same tests you used for the first version, and record the results in your logbook. Now, think about which approach is best, and write notes in your logbook.

### 21.4 Section / task 21.4 Prime numbers

- **Aim of example:** To introduce the idea of set collections, the Set interface and the HashSet class. For this we explore hash tables and meet hashCode() from Object. We also see that the class Integer implements Comparable<Integer>.

- **Coursework title:** Finding duplicate voters

- **Coursework summary:** Write a program to detect people voting more than once in voting records.

- **Question:** The government have been encouraging more people to vote, and one of the features of a new system is that voters are allowed to do so in any polling station within a certain radius of their home, rather than just one. The idea is that more people can vote at lunch time, near to where they work. Unfortunately, this opens up additional potential for multiple voting, by people visiting more than one station! The officials have collected data from across the region, and want you to write a program to detect multiple votes. The input is in the form of a text file consisting of two lines per vote. The first line uniquely identifies the voter by their name, house number and post code. The second line records the time and location of the vote cast. The location is the name of a polling station, in the form of an area name and an identity number, such as Manchester 538. For example, here is a (cut down) set of data.
They simply want your program to detect and report duplicate voter identifications, followed by the number of duplicates found. So, the output for the above input would be as follows.

Your program should use a HashSet to store the voter identifications, i.e. the first line of each pair of lines. (It will just skip over and ignore the second line of each pair – in this version.) If when adding to this set, using add(), the result of the addition is false, then the voter was already present and so the voter identification being added must be a duplicate.
The program should be called $\textit{DuplicateVoters}$, and take two \textit{command line arguments}, the first being the name of the input file, the second being the name of the resulting report file.

To save time, you may test your program using just the above sample data.

### 21.5 Section / task 21.5 Sorting a text file using a TreeSet

- **Aim of example:** To introduce the \textit{TreeSet} \texttt{class}, for which we explore \textit{ordered binary trees} and \textit{tree sort}. We also meet the \texttt{Iterator interface}, together with how it is used on a \textit{List} and a \textit{Set}, especially a \textit{TreeSet}.

- **Coursework title:** \textit{Sorting election leaflets, using a TreeSet}

- **Coursework summary:** Write a program to sort election information leaflets into delivery order, using a \textit{TreeSet}.

- **Question:** In this task you will write the same program as in Section 21.2 on page 94 in a third way. You will use your \textit{DeliveryHouseDetails class} again, but instead of building a \textit{List of the objects}, you will insert them into a \textit{TreeSet}. Then, instead of \texttt{sort()} from the \texttt{Collections class}, you will access the elements via the \texttt{Iterator} of the \textit{TreeSet}.

Copy your \textit{StreetOrder class} from the previous version, and modify it. After implementation, \texttt{run} the program with the same tests you used for the previous versions, and record the results in your logbook. If all three programs are working, then their outputs should be identical – there are, of course, no duplicate lines in the input \texttt{data}.

### 21.8 Section / task 21.8 Word frequency count sorted by frequency

- **Aim of example:** To introduce the \textit{HashMap} \texttt{class}, and the fact that a \textit{collection} can be built to initially contain the same values as some other collection. We also take a look at how we can go about making a good \texttt{override} of the \texttt{hashCode()} \texttt{instance method} of \texttt{Object}.

- **Coursework title:** \textit{Finding duplicate voters, using a HashMap}

- **Coursework summary:** Write a program to detect people voting more than once in voting records, using a \textit{HashMap}.

- **Question:** The election officials are very pleased with your work from the task in Section 21.4 on page 97 but they have found so many duplicate votes that they would now like you to modify the way the results are presented, to make them easier to process!

All they ask is that each time a duplicate vote is found, your program outputs it, together with the time and location of the duplicate \textit{and} the time and location of the \textit{first} occurrence of the naughty voter. So, the output for the input shown in Section 21.4 on page 97 would be as follows.
Your program should use a \texttt{HashMap} to store the voter identifications processed so far, each mapped on to their \textit{first} occurring time and location. So, the voter identifications will be \texttt{keys}, and the time and locations will be values in the map. Your program will read through the \texttt{file} as before, but this time it will not ignore the time and location lines. For each vote, it will check in the \texttt{HashMap} to see if that voter identification is already present – by using \texttt{get()} to try and retrieve the time and location of their first vote. If this is the first occurrence of the voter identification (i.e. the result from \texttt{get()} is the \texttt{null reference}) then all is well, and the voter identification mapped to the time and location is \texttt{put()} into the \texttt{map}. If on the other hand the voter identification is already in the map, then it is to be printed, along with the new time and location and the first time and location (retrieved from the map).

21.9 \hspace{1cm} \textbf{Section / task 21.9 Collections of collections}

- \textbullet\ Aim of example: To explore the idea that the elements of a \texttt{collection} can themselves be collections, and so quite complex \texttt{data structures} can be built.

- \textbullet\ Coursework title: \textbf{Finding duplicate voters, using a HashMap of LinkedLists}

- \textbullet\ Coursework summary: Write a program to detect people voting more than \texttt{QNonce} in voting records, \texttt{QNonce}, using a \texttt{HashMap} of \texttt{objects} containing a \texttt{LinkedList}.

- \textbullet\ Question: The election officials are very sorry to bother you again, but they have a new idea to make the processing of duplicate voting even more easy. They now would like the results grouped by fraudulent voter! (Of course, if you had been given the opportunity, you may well have pointed this out during requirements analysis at the start!)
This version of the program should produce the following results from the data shown in Section 21.4 on page 97.

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>java DuplicateVoters voting.txt voting-duplicates.txt</code></td>
</tr>
<tr>
<td><code>cat voting-duplicates.txt</code></td>
</tr>
<tr>
<td>Rupert Rodgers-Smythe, 4, M25 7QZ</td>
</tr>
<tr>
<td>07:37 Manchester 538</td>
</tr>
<tr>
<td>12:27 Manchester 099</td>
</tr>
<tr>
<td>Sarah Peacock, 6, M25 7QZ</td>
</tr>
<tr>
<td>10:25 Manchester 538</td>
</tr>
<tr>
<td>14:59 Manchester 537</td>
</tr>
<tr>
<td>19:01 Manchester 539</td>
</tr>
<tr>
<td>20:59 Manchester 540</td>
</tr>
<tr>
<td>Margaret Chopin, 9, M37 9MP</td>
</tr>
<tr>
<td>12:14 Manchester 299</td>
</tr>
<tr>
<td>19:30 Manchester 308</td>
</tr>
<tr>
<td><code>$_</code></td>
</tr>
</tbody>
</table>

The order of the voters might be different. Also note that your customers no longer desire to have a count of the duplicate votes.

Your program should use a HashMap to store the voter identifications, each mapped on to an object which contains a LinkedList of all the time and location lines for that voter identification. Once the input file has been read, your program will iterate through the values of this map looking for ones which have more than one vote, and reporting those it finds.

A LinkedList is arguably better than an ArrayList for storing the vote details of each voter, as each list just gets items added on the end, and then finally scanned via its Iterator. This means we do not get the inefficiency of LinkedList, because we are not accessing its elements in a random order, but we do benefit from each one being the exact size needed – most of them will contain only one item, and there will be very many of them.

The elements of the HashMap should be instances of a class called VoterRecord, which you will write. This will contain two instance variables, the identity of a voter, and a LinkedList of his or her voting times and locations, in the order found in the file. Its constructor method will be given the identity of the voter. It will have an instance method to add a voting time and location. Another instance method will return the number of times the person has voted. The toString() instance method should give a multi-line String representing the VoterRecord object, including the identity of the voter and the times and locations of voting, ready for use in the output of the program.

To obtain the efficiency of using LinkedLists, you must use an Iterator when scanning through the LinkedList in a VoterRecord to build the result of its toString(), rather than accessing each element by its list index.

Optional extra: Predict the effect of changing your HashMap to a TreeMap, and try it.
22 Chapter 22 Recursion

22.3 Section / task 22.3 Lecture attendance

- Aim of example: To introduce the idea of a recursive algorithm, with an example of one that is not intended for use on a computer.
- Coursework title: Finding the most populated row
- Coursework summary: Describe a recursive algorithm to be followed by humans.
- Question: Describe a recursive algorithm for finding from the lecture theatre the size of the row which contains the most people.
  
  Optional extra: Also find the number of the row with most people in it – assume the rows are numbered from one, from front to back, and that every row has at least one person in it. (You cannot just assume the answer is the back row...!)

22.4 Section / task 22.4 Sum of ages of descendants

- Aim of example: To reinforce the idea of a recursive algorithm, with another example of one that is not intended for use on a computer. This one would not be easy to perform iteratively.
- Coursework title: An iterative sum of ages algorithm
- Coursework summary: Attempt to write an iterative algorithm that does the same work as a complex recursive algorithm.
- Question: Attempt to write an iterative version of the instructions to obtain the sum of the ages of the woman’s descendants. It has to be instructions that would really work (albeit the woman herself only exists in fantasy). Hint: try hard, but be prepared to give up.

22.5 Section / task 22.5 Factorial

- Aim of example: To introduce the idea of a recursive method, present a simple example and talk about common misunderstandings. We also look at what it means for a recursive method to be well defined and compare recursion with iteration.
- Coursework title: Reversing lines
- Coursework summary: Write a program to copy standard input to standard output but with the lines in reverse order, so that the first input line comes out last.
- Question: Write a program called ReverseLines to copy standard input to standard output but with the lines in reverse order, so that the first input line comes out last. Your
main method will set up a BufferedReader and a PrintWriter, and pass these as method arguments to another class method, which shall be a recursive method.

The recursive method will read the input lines and output them. It will not use tail recursion, in that it will perform some work after the recursive method call.

Think of an abstract sequence, seq, as either being empty, or being a head, seq.head, followed by a tail, seq.tail, itself a possibly empty sequence. Here is pseudo code for printing such an abstract sequence, inputSeq, in reverse.

```java
if inputSeq is not empty
    recursively output inputSeq.tail
    output inputSeq.head
end-if
```

In this case, you are using a BufferedReader to obtain the sequence of lines, line by line, and the act of reading a line tells you whether you have read them all, and if not, moves the input onto the remaining lines, i.e. the tail. You will need a variable to save the head line. So we can recast the above general pseudo code as follows.

```java
String head line
if trying to read the head line does not yield null
    recursively read and output the tail lines
    output the head line
end-if
```

For brevity, you may be skimpy with exception handling – just declare that each method throws Exception.

### 22.6 Section / task 22.6 Fibonacci

- **Aim of example:** To show an example of a recursive method which has multiple recursion.
- **Coursework title:** A more efficient Fibonacci
- **Coursework summary:** Implement Fibonacci using an array to remember the results.
- **Question:** Write a version of the Fibonacci class with a recursive method that has the same structure as the one here, but is made efficient by storing the result for $\text{fib } n$ in an array at array index $n$. This technique to avoid recomputing results is sometimes known as a memo function.

### 22.7 Section / task 22.7 Number puzzle

- **Aim of example:** To solve a problem, using a recursive method with multiple recursion, which would be quite tricky to solve iteratively. Along the way, we look at the process of designing a recursive algorithm.
- **Coursework title:** Extending NumberPuzzle
Coursework summary: Add two more recursive method calls to a doubly recursive method.

Question: Extend our NumberPuzzle program so that the other two arithmetic operators are included. Hint: for multiplication, there is no point making a recursive method call if the target is not divisible by the number being ignored – in fact doing so would lead to erroneous solutions (due to integer truncation).

Optional extra: For a real challenge, why not allow brackets in the sequence?

22.8 Section / task 22.8 Dice combinations

Aim of example: To show an example of a recursive method which has multiple recursion with recursive method calls inside a loop.

Coursework title: Anagrams

Coursework summary: Write a program to output all the anagrams of a word given as a command line argument.

Question: Write a program called Anagrams which outputs all the permutations of a string given as a command line argument. The main method will, for efficiency, turn the first (and only) command line argument into a char array, using the toCharArray() instance method of the String class. It will also set up two other arrays of the same length, one, of type char[] to build the current permutation, and another, of type boolean[], to record whether characters from the given string have been used so far in the permutation being constructed. It will then call a recursive method to print all the permutations.

Here is pseudo code for the recursive method.

```java
printPermutations(int currentIndex)
{
    if currentIndex has gone past the end of the permutation array
        print out the permutation
    else
        for each index in the char array made from the given string
            if the character at that index is not already used in the permutation
                mark it as being in use (using the boolean array)
                put that character in the permutation at currentIndex
                printPermutations(currentIndex + 1)
                mark the character as NOT being used in the permutation
            end-if
        end-for
    end-else
}
```

Note that if the given string contains duplicate characters, then there will be duplicate permutations produced. This is fine.

Optional extra: Do it in a different recursive way, which does not need the boolean array nor a second char array. (Hint: swap the character at the given array index with each
other one at a greater index, in turn.)

Optional extra: Do it without using recursion.

### 22.10 Section / task 22.10 Tower of Hanoi

- Aim of example: To devise a remarkably short recursive method solution to a seemingly very tricky puzzle.
- Coursework title: Tower of Hanoi with peg values
- Coursework summary: Extend a Hanoi solving program to show the state of the pegs.
- Question: Write a version of the Tower of Hanoi program which actually models the discs on the pegs and prints them out at each move. You should have a separate class called Peg which models the actual discs on a particular peg. The disc sizes could be stored in a partially filled array, the value at array index \( i \) being the size of the disc at location \( i \) on the peg. Or you could perhaps find out about the standard class java.util.Stack, and make a subclass of that.

Here is sample output from running the program with a command line argument of 4.

```
$ java Hanoi 4
0 Start: L=< 4 3 2 1 > M=< > R=< >
1 L to M: L=< 4 3 2 > M=< 1 > R=< >
2 L to R: L=< 4 3 > M=< 1 > R=< 2 >
3 M to R: L=< 4 3 > M=< > R=< 2 1 >
4 L to M: L=< 4 > M=< 3 > R=< 2 1 >
5 R to L: L=< 4 1 > M=< 3 > R=< 2 >
6 R to M: L=< 4 1 > M=< 3 2 > R=< >
7 L to M: L=< 4 > M=< 3 2 1 > R=< >
8 L to R: L=< > M=< 3 2 1 > R=< 4 >
9 M to R: L=< > M=< 3 2 > R=< 4 1 >
10 M to L: L=< 2 > M=< 3 > R=< 4 1 >
11 R to L: L=< 2 1 > M=< 3 > R=< 4 >
12 M to R: L=< 2 1 > M=< > R=< 4 3 >
13 L to M: L=< 2 > M=< > R=< 4 3 >
14 L to R: L=< > M=< 1 > R=< 4 3 2 >
15 M to R: L=< > M=< > R=< 4 3 2 1 >
$ _
```

### 22.11 Section / task 22.11 Friend book

- Aim of example: To show an example of recursion based on walking through a recursive data structure. We also have a private constructor method.
- Coursework title: Family trees
Coursework summary: Write a program to model family ancestry.

Question: Write a program that enables the ancestry of people to be stored and printed out. You will want objects of type Person with a name and a set of other persons who are that person’s immediate children. There’s no need to model marriage (after all in modern life, many family ‘tree’s are not that simple). So if we wish to store two parents of a collection of children then we have those children contained separately in each of the parent’s objects. (This permits the two parents of one child to have different sets of children.)

Your other class, containing the main method should be called FamilyTree.

The data should be stored in a text file called parent-children.txt. Each line consists of the name of a parent, followed by a list of his or her children, all separated by spaces.

The program should read this text file and take the name of a person as the first command line argument. It will then print out that person and his or her descendants as a ‘family tree’. In theory the data should not contain any cycles (a person being their own descendant), however it might – so you should ensure the recursion cannot attempt to proceed forever.

To avoid distraction, you may ignore exception catching if you wish.

Here is some sample data (based on the UK Royal Family[?]).

<table>
<thead>
<tr>
<th>Console Input / Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ cat parent-children.txt</td>
</tr>
<tr>
<td>George-V Edward-VIII George-VI Mary Henry George John</td>
</tr>
<tr>
<td>Victoria-Mary Edward-VIII George-VI Mary Henry George John</td>
</tr>
<tr>
<td>Edward-VIII Wallis-Simpson</td>
</tr>
<tr>
<td>George-VI Elizabeth-II Margaret</td>
</tr>
<tr>
<td>Elizabeth-Bowes-Lyon Elizabeth-II Margaret</td>
</tr>
<tr>
<td>Elizabeth-II Charles Anne Andrew Edward</td>
</tr>
<tr>
<td>Philip Charles Anne Andrew Edward</td>
</tr>
<tr>
<td>Charles William Harry</td>
</tr>
<tr>
<td>Diana William Harry</td>
</tr>
<tr>
<td>$ _</td>
</tr>
</tbody>
</table>

And here is the corresponding output for George-V.
Optional extra: What simple change could you make so that the children of a person are listed in the order they were added (which would probably be the order of birth), rather than alphabetically by name? (Hint: look at the application program interface (API) documentation for java.util.LinkedHashSet.)

23 Chapter 23 The end of the beginning