AQA

A-level
COMPUTER SCIENCE

Paper 1

Friday 16 June 2017 Morning Time allowed: 2 hours 30 minutes

Materials
For this paper you must have:
- a computer
- a printer
- appropriate software
- the Electronic Answer Document
- an electronic version and a hard copy of the Skeleton Program
- an electronic version and a hard copy of the Preliminary Material.

You must **not** use a calculator.

Instructions
- Type the information required on the front of your Electronic Answer Document.
- Before the start of the examination make sure your **Centre Number**, **Candidate Name** and **Candidate Number** are shown clearly **in the footer** of every page (not the front cover) of your Electronic Answer Document.
- Enter your answers into the Electronic Answer Document.
- Answer **all** questions.
- Save your work at regular intervals.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- No extra time is allowed for printing and collating.
- The question paper is divided into **four** sections.

Advice
You are advised to allocate time to each section as follows:
Section A – 45 minutes; **Section B** – 20 minutes; **Section C** – 15 minutes; **Section D** – 70 minutes.

At the end of the examination
Tie together all your printed Electronic Answer Document pages and hand them to the Invigilator.

Warning
It may not be possible to issue a result for this paper if your details are not on every page of your Electronic Answer Document.

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Section A

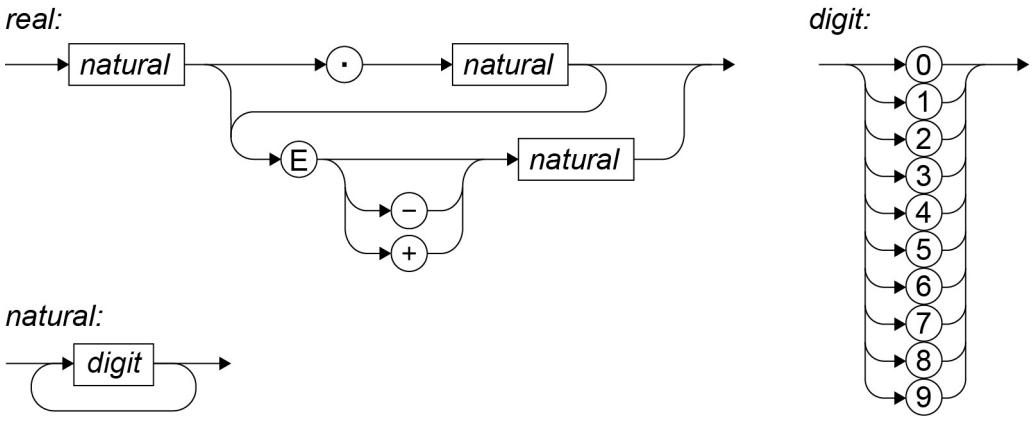
You are advised to spend no longer than **45 minutes** on this section.

Type your answers to **Section A** in your Electronic Answer Document.

You **must save** this document at regular intervals.

0 1 In a particular programming language, the correct syntax for a real number, natural number and digit is defined by the syntax diagrams in **Figure 1**.

Figure 1



0 1 . 1 Write **Yes** or **No** in the unshaded cells in **Table 1** to identify whether or not the numbers listed in the table are valid real numbers which conform to the correct syntax for this language.

[3 marks]

Table 1

Real number	Valid? (Yes/No)
87.000	
97+12	
12.31E+12	

Copy the contents of the unshaded cells in **Table 1** into the table in your Electronic Answer document.

0 1 . 2 In Backus-Naur Form (BNF) the following production rule has been written to define a digit:

```
<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
```

Write a BNF production rule to define a natural number that is equivalent to the definition in the syntax diagram in **Figure 1**.

[2 marks]

Turn over ►

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0 2 Postcodes are used to aid the sorting of mail and help to ensure that mail being sent arrives at the correct destination as quickly as possible.

The format of a UK postcode (ignoring any spaces) is shown in **Figure 2**.

Figure 2

- 1 or 2 letters
- followed by:
  - 1 numeric digit or
  - 2 numeric digits or
  - 1 numeric digit then 1 letter
- followed by 1 numeric digit
- followed by 2 letters

When a post box is emptied in the town of Ipswich the mail in the post box is taken to a central sorting office. Each item is looked at and placed in one of three vans depending upon the postcode written on the envelope.

Postcodes that begin with IP1, IP2, IP3 or IP4 followed by one numeric digit and two letters, eg IP2 8QY, are for mail being sent to an address in the town of Ipswich and go in Van A. Other postcodes that begin with IP, eg IP5 3QW, are for areas not in the town but near to Ipswich and go in Van B. Postcodes that start with anything other than IP, eg CO3 5FN, are not for the Ipswich area and go in Van C. IP postcodes do not use the full range of formats available for UK postcodes.

A finite state machine (FSM) could be used to sort mail using postcodes. **Figure 3** shows a state transition diagram for an FSM used at the Ipswich sorting office.

In **Figure 3**, if a transition is not defined from a state for a particular input symbol then the FSM will stop processing the input and it will be rejected.

0 2 . 1 If the FSM in **Figure 3** reaches state S12 what does it mean?

[1 mark]

0 2 . 2 If the FSM in **Figure 3** finishes at state S11 what does it mean?

[1 mark]

0 2 . 3 Assuming that the FSM in **Figure 3** can be used to recognise any valid IP postcode, state **one** format used for UK postcodes that IP postcodes do **not** use.

[1 mark]

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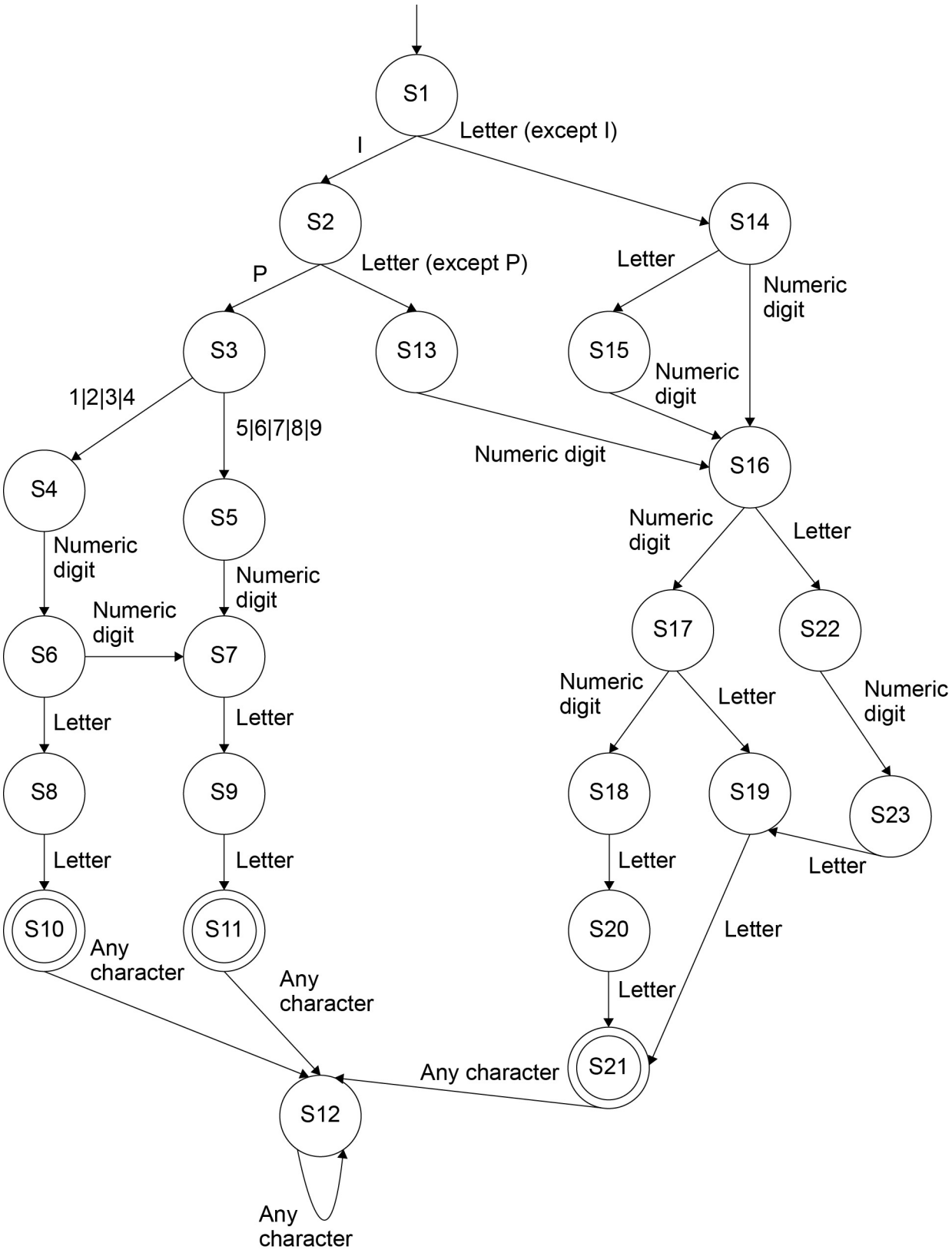
Figure 3



Question 02 continues on the next page

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Figure 2 is repeated below.

Figure 2

- 1 or 2 letters
- followed by:
  - 1 numeric digit or
  - 2 numeric digits or
  - 1 numeric digit then 1 letter
- followed by 1 numeric digit
- followed by 2 letters

0 2 . 4 The language recognised by an FSM can also be represented by a regular expression. When writing regular expressions `\d` is used to represent any numeric digit and `\a` is used to represent any alphabetic character.

For example, the regular expression `\d \d \a \d` describes the language of all strings that contain two numeric digits followed by one letter and then one numeric digit.

Write a regular expression that represents a valid UK postcode as described in **Figure 2**. In your answer you should only use the `|` metacharacter once.

[4 marks]

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0 3 **Table 2** lists some well-known algorithms.

Table 2

Algorithm
Linear search
Merge sort
Binary search
Post-order tree-traversal

0 3 . 1 Which of the algorithms listed in **Table 2** has $O(n \log n)$ time complexity?

[1 mark]

0 3 . 2 How many of the algorithms listed in **Table 2** are algorithms used to solve tractable problems?

[1 mark]

0 3 . 3 State the time complexity for the bubble sort algorithm in terms of n, where n is the number of items in the list to be sorted.

[1 mark]

0 3 . 4 Explain why the bubble sort algorithm has the time complexity stated in your answer to **0 3 . 3**

[2 marks]

Turn over for the next question

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0 4 **Figure 4** shows the data Norbert, Phil, Judith, Mary, Caspar and Tahir entered into a binary search tree.

Figure 5 contains pseudo-code for a recursive binary tree search algorithm.

Figure 4

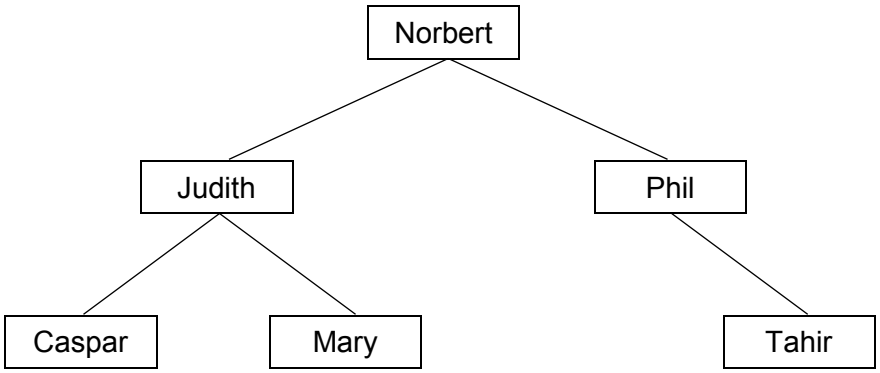

Figure 5

```
FUNCTION TreeSearch(target, node)
  OUTPUT 'Visited ', node
  IF target = node THEN
    RETURN True
  ELSE IF target > node AND Exists(node, right) THEN
    RETURN TreeSearch(target, node.right)
  ELSE IF target < node AND Exists(node, left) THEN
    RETURN TreeSearch(target, node.left)
  ENDIF
  RETURN False
ENDFUNCTION
```

The subroutine `Exists` takes two parameters – a node in the binary tree and a direction (`left` or `right`). It returns a Boolean value indicating if the node given as a parameter has a child node in the direction specified by the second parameter. For instance, `Exists(Mary, left)` will return a value of `False` as there is no node to the left of `Mary` in the binary tree.

`node.right` evaluates to the child node to the right of `node`,
eg `Judith.right` is `Mary`.

`node.left` evaluates to the child node to the left of `node`,
eg `Judith.left` is `Caspar`.

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0 4 . 1 What is meant by a recursive subroutine?

[1 mark]

0 4 . 2 There are two base cases for the subroutine `TreeSearch`. State **one** of the base cases.

[1 mark]

0 4 . 3 Complete the unshaded cells of **Table 3** to show the result of tracing the `TreeSearch` algorithm shown in **Figure 5** with the function call `TreeSearch(Olivia, Norbert)`. You may not need to use all of the rows.

[3 marks]

Table 3

Function call	Output
`TreeSearch(Olivia, Norbert)`	

Copy the contents of the unshaded cells in **Table 3** into the table in your Electronic Answer Document.

Turn over for the next question

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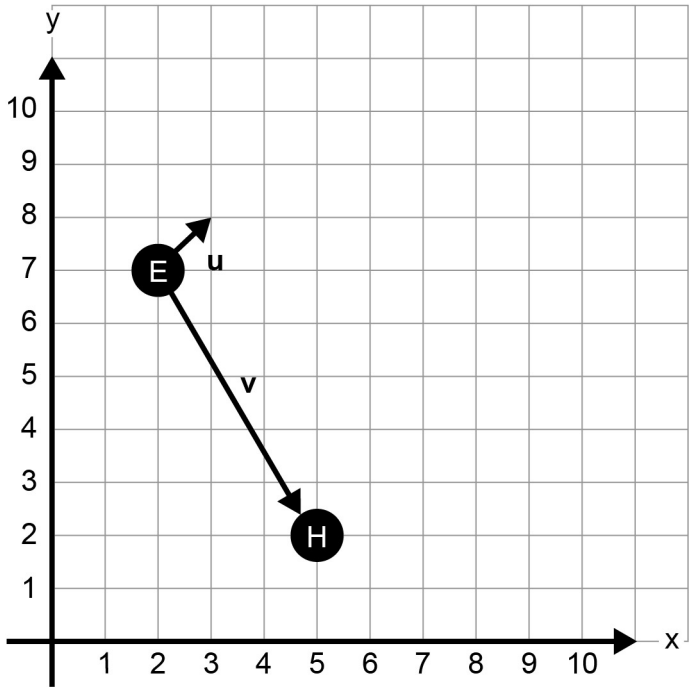
0 5 In a simple two-dimensional game the game mechanics are handled by the use of vectors.

In **Figure 6** you can see the current position of the enemy E and the hero H.

Figure 6



The enemy is currently looking in the direction shown by the vector **u** in **Figure 6**. Vector **u** can be described as [1, 1].

The vector from the enemy to the hero can be represented by the vector **v** in **Figure 6**. Vector **v** can be described as [3, –5].

0 5 . 1 Calculate the dot product of **u** and **v**.

[1 mark]

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The hero is going to move.

The current position of the hero can be described by the vector [5, 2].

The movement of the hero can be described by the vector [3, 1].

To process the movement the game updates the screen using the following operation:

new position = current position vector + movement vector

The dot product can be used to calculate if the enemy can see the hero by using the algorithm given in **Figure 7**.

Figure 7

```
u ← [1, 1]
v ← [position of hero] - [position of enemy]
IF u.v > 0 THEN
  EnemyCanSee ← True
ELSE
  EnemyCanSee ← False
ENDIF
```

0 5 . 2 Perform vector addition to calculate the **new position** of the hero.

[1 mark]

0 5 . 3 Complete the unshaded cells of **Table 4** to work out if the enemy can see the hero in this **new position**.

[3 marks]

Table 4

Calculation	Result
u	[1, 1]
v = [position of hero] - [position of enemy]	
u.v	
EnemyCanSee	

Copy the contents of the unshaded cells in **Table 4** into the table in your Electronic Answer Document.

Question 05 continues on the next page

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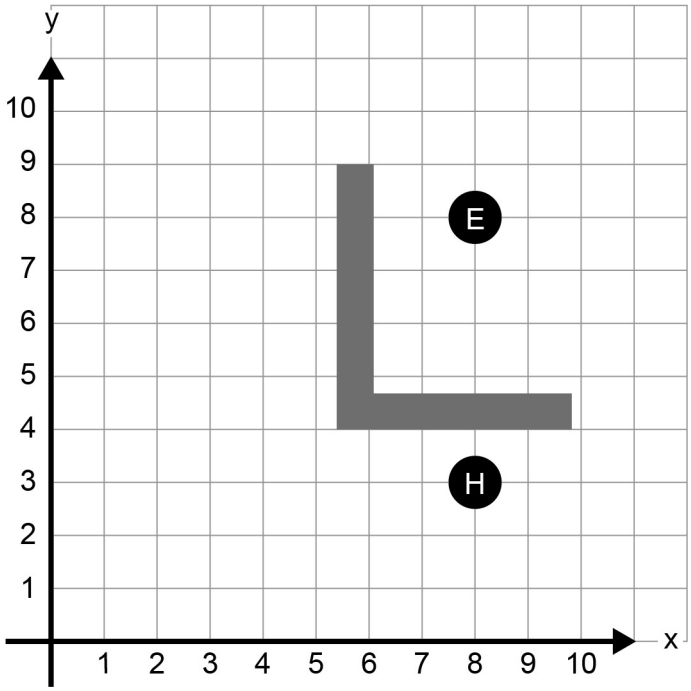
Figure 8 shows the scene later on in the game. The route between the enemy and the hero is blocked by a solid wall indicated by shading.

Figure 8



To move the enemy the game has an algorithm that computes the shortest path between the enemy and the hero. To find the shortest path it looks at every possible path between the enemy and the hero.

This algorithm currently struggles to compute the shortest path quickly enough and it has been suggested that the use of a heuristic technique might help.

0 5 . 4 Explain what is meant by a heuristic technique, giving an example of a heuristic technique that might reduce the time taken by the shortest path algorithm.

[2 marks]

The data structures used by the game could be static or dynamic.

0 5 . 5 Explain the differences between static and dynamic data structures.

[2 marks]

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0 6 Two frequently completed actions when using a particular piece of software are **undo** and **repeat**.

The **undo** action results in the state changing from the current state to the state previous to the user's most recent action, eg if the last action the user completed was to change the font of a selected piece of text from `Courier New` to Chiller then if the **undo** action is selected the result will be to change the font of that text back to `Courier New`.

The user is able to keep using the **undo** action to go back through all previous states.

The **repeat** action results in the user's most recent action being applied again, eg if the last action the user completed was to change the font of a piece of text to Chiller then if the **repeat** action is selected the result will be to change the font of the currently selected text to Chiller.

The user is able to keep using the **repeat** action to apply the most recent action multiple times. The **repeat** action will only work when there is a most recent action that can be applied again.

0 6 . 1 Explain how a single stack can be used in the implementation of the repeat action **and** the undo action.

[5 marks]

0 6 . 2 State the type of error that occurs if the user tries to complete an undo action before they have completed any other actions.

[1 mark]

Turn over for Section B

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Section B

You are advised to spend no more than **20 minutes** on this section.

Enter your answers to **Section B** in your Electronic Answer Document.
You **must save** this document at regular intervals.

The question in this section asks you to write program code **starting from a new program/project/file**.

You are advised to save your program at regular intervals.

0 7 One method that can be used to compress text data is run length encoding (RLE). When RLE is used the compressed data can be represented as a set of character/frequency pairs. When the same character appears in consecutive locations in the original text it is replaced in the compressed text by a single instance of the character followed by a number indicating the number of consecutive instances of that character. Single instances of a character are represented by the character followed by the number 1.

Figure 9 and **Figure 10** show examples of how text would be compressed using this method.

Figure 9

Original text: `AAARRRRGGGHH`
Compressed text: `A 3 R 4 G 3 H 2`

Figure 10

Original text: `CUTLASSES`
Compressed text: `C 1 U 1 T 1 L 1 A 1 S 2 E 1 S 1`

What you need to do

Task 1
Write a program that will perform the compression process described above. The program should display a suitable prompt asking the user to input the text to compress and then output the compressed text.

Task 2
Test the program works by entering the text `AAARRRRGGGHH`.

Task 3
Test the program works by entering the text `A`.

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Evidence that you need to provide
Include the following in your Electronic Answer Document.

0 7 . 1 Your PROGRAM SOURCE CODE.

[12 marks]

0 7 . 2 SCREEN CAPTURE(S) for the test showing the output of the program when `AAARRRRGGGHH` is entered.

[1 mark]

0 7 . 3 SCREEN CAPTURE(S) for the test showing the output of the program when `A` is entered.

[1 mark]

Turn over for Section C

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Section C

You are advised to spend no more than **15 minutes** on this section.

Type your answers to **Section C** into your Electronic Answer Document.
You **must save** this document at regular intervals.

.

These questions refer to the **Preliminary Material** and the **Skeleton Program**, but do not require any additional programming.

Refer **either** to the **Preliminary Material** issued with this question paper **or** your electronic copy.

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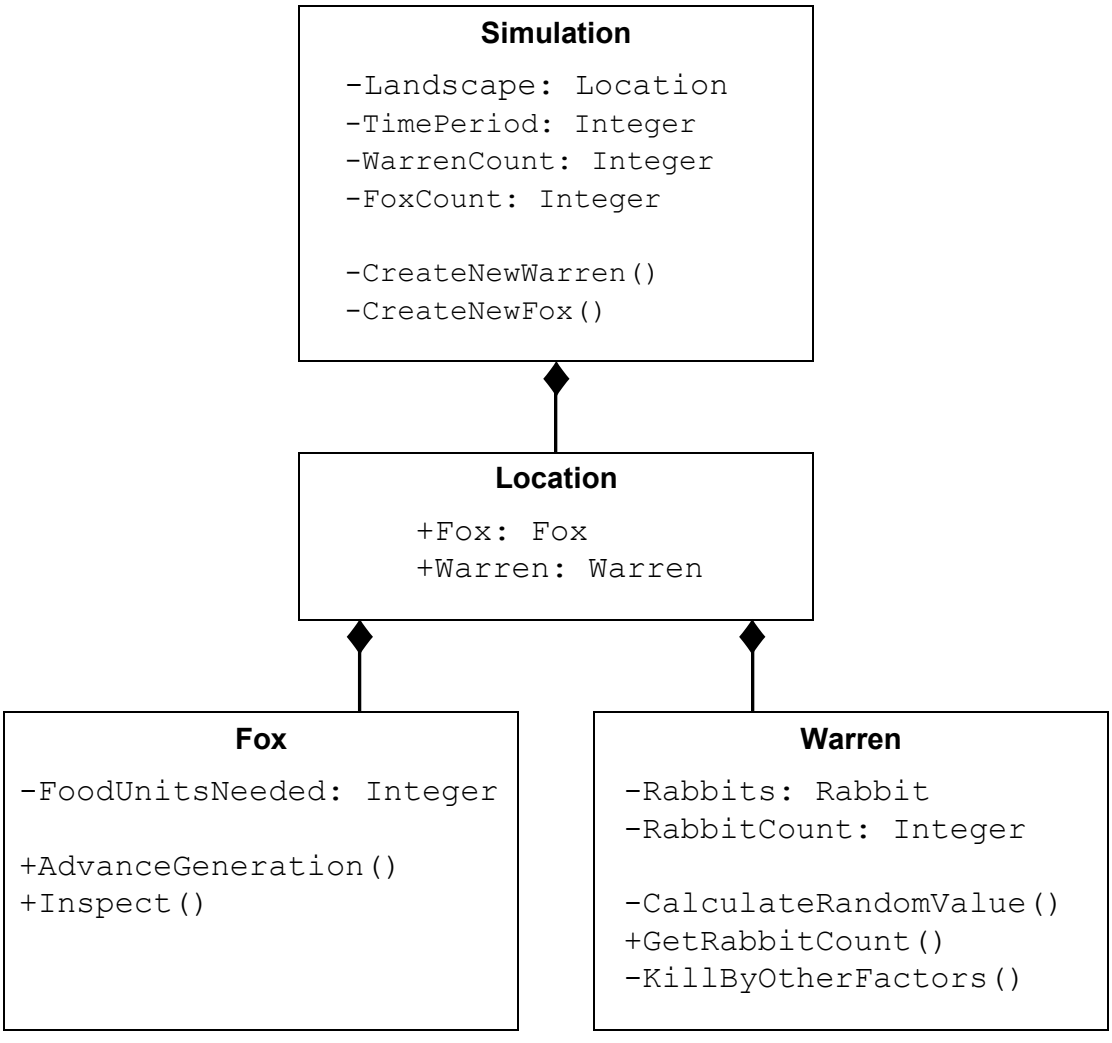
0 8 The class diagram in **Figure 11** is a partial representation of the relationships between some of the classes in the **Skeleton Program**.

Note: In **Figure 11** a + sign denotes a public attribute/method.

Figure 11



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A class diagram can show a variety of features used in object-oriented programming.

0 8 . 1 Write **Yes** or **No** in the unshaded cells in **Table 5** to identify if the given feature is present in the class diagram shown in **Figure 11**.

[3 marks]

Table 5

Feature	Is present in Figure 11? (Yes/No)
Inheritance	
Protected method	
Private attribute	

Copy the contents of the unshaded cells in **Table 5** into the table in your Electronic Answer Document.

0 8 . 2 State the name of an identifier for a subclass in the **Skeleton Program**.

[1 mark]

0 8 . 3 Explain the difference between a protected attribute and a private attribute.

[2 marks]

0 8 . 4 In the `Warren` class there is an attribute `RabbitCount` and a method `GetRabbitCount`.

Explain the need for the `GetRabbitCount` method **and** explain why this approach is favoured in object-oriented programming.

[2 marks]

0 8 . 5 During the simulation rabbits will die for a variety of reasons. One of these reasons is old age and at the end of the `KillByOtherFactors` method there is a call to `CompressRabbitList`.

Explain the need for the `CompressRabbitList` method.

[2 marks]

Question 08 continues on the next page

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Part of the class definition for `Rabbit` has been represented in **Figure 12**.

Figure 12

```
Rabbit = Class(Animal)
  Private:
    ReproductionRate: Real
    Gender: Genders
  Public:
    Procedure Inspect()
    Function IsFemale()
    Function GetReproductionRate()
End Class
```

A new animal is to be introduced into the simulation. This animal is the `HDRabbit`, which represents a rabbit with haemorrhagic disease. The class `HDRabbit` is to be a subclass of the `Rabbit` class. When an `HDRabbit` is inspected it should display all the information shown for a normal rabbit plus the additional information stored about an `HDRabbit`.

An `HDRabbit` has the following additional attributes:

- `InfectionRate`: stores a value that represents the probability of a rabbit that is bred from an `HDRabbit` being infected
- `Generation`: stores a value that represents how many generations have had this disease in this rabbit's family.

An `HDRabbit` has additional methods including:

- `IsInfertile()`: returns `True` if the haemorrhagic disease has been in this rabbit's family for three generations.

0 8 . 6 Write the class definition for `HDRabbit`, using similar notation to that used in **Figure 12**. You are **not** expected to make any changes to the Skeleton Program.

[4 marks]

Turn to page 20 for Section D

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Turn over for the next question

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Section D

You are advised to spend no more than **70 minutes** on this section.

Type your answers to **Section D** in your Electronic Answer Document.
You **must save** this document at regular intervals.

These questions require you to load the **Skeleton Program** and to make programming changes to it.

0 9 This question refers to the subroutine `InputCoordinate` in the `Simulation` class.

The warren and fox inspection options in the **Skeleton Program** do not currently check if the coordinates entered by the user are on the landscape. This behaviour needs to be improved so that an error message is displayed if the user inputs coordinates for a location that is not on the landscape.

If the user runs a simulation with default settings then the landscape size is 15, so valid locations have an x coordinate between 0 and 14, inclusive.

What you need to do

Modify the `InputCoordinate` subroutine in the `Simulation` class so that, if a coordinate outside the range defined by the landscape size is input, the error message "`Coordinate is outside of landscape, please try again.`" is displayed and the user is forced to re-input the coordinate.

To achieve full marks for this question, the `InputCoordinate` subroutine should work correctly for any landscape size, not just the default size of 15.

Test

Test your changes work by running the **Skeleton Program** and selecting the following options:

- "1. Run simulation with default settings"
- "3. Inspect fox"

Then input these three x coordinates for the location of the fox to inspect:

- `-1`
- `15`
- `0`

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Evidence that you need to provide
Include the following in your Electronic Answer Document.

0 9 . 1 Your PROGRAM SOURCE CODE for the amended subroutine `InputCoordinate`.

[4 marks]

0 9 . 2 SCREEN CAPTURE(S) for the described test.

Ensure that in your SCREEN CAPTURE(S) it can be seen that the x coordinates `-1` and `15` are rejected **and** that the x coordinate `0` is accepted, **and** that after the `0` is input the **Skeleton Program** advances to ask the user to input the y coordinate.

[1 mark]

Turn over for the next question

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1 0 The simulation is to be made more realistic by increasing the probability that a rabbit will die as a result of other causes, such as disease or injury, as the rabbit ages.

The default probability of death by another cause for a rabbit is 0.05.

- The probability of a male rabbit dying by another cause should increase by a factor of 50% after every time period.
- The probability of a female rabbit dying by another cause should remain constant until the rabbit reaches the age of 2. At the age of 2, and after every time period beyond this, the probability of a female rabbit dying by another cause should increase by 0.05.

Table 6 below summarises the probability of death by other causes for a rabbit of each gender, up to the age of 5. The probabilities will continue to increase beyond this age.

Table 6

	Probability of death by other causes	
Age	**Male (2dp)**	**Female**
0	0.05	0.05
1	0.08	0.05
2	0.11	0.1
3	0.17	0.15
4	0.25	0.2
5	0.38	0.25

What you need to do

Create a new subroutine, `CalculateNewAge`, in the `Rabbit` class, that overrides the `CalculateNewAge` subroutine in the `Animal` class.

The new `CalculateNewAge` subroutine in the `Rabbit` class should recalculate the probability of death for a rabbit as the rabbit ages. The subroutine should also call the subroutine that it has overridden in the `Animal` class to ensure that the standard ageing process for a rabbit continues to be carried out as well.

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Test

Check that the changes you have made work by conducting the following test:

- Select option "1. Run simulation with default settings" from the main menu.
- Then select option "2. Advance to next time period hiding detail" **twice**, to advance the simulation to time period 2.
- Then select option "4. Inspect warren" and enter the x coordinate `1` and the y coordinate `1`.
- When asked "View individual rabbits (y/n)?" enter `y`.

Evidence that you need to provide
Include the following in your Electronic Answer Document.

1 0 . 1 Your PROGRAM SOURCE CODE for the new subroutine `CalculateNewAge` from the `Rabbit` class.

[5 marks]

1 0 . 2 SCREEN CAPTURE(S) for the described test.

Your SCREEN CAPTURE(S) must clearly show the probability of death by other causes of both a male and a female rabbit of age 2. SCREEN CAPTURE(S) do **not** need to show the options that you have selected or the probability of death by other causes for rabbits of other ages.

[1 mark]

Turn over for the next question

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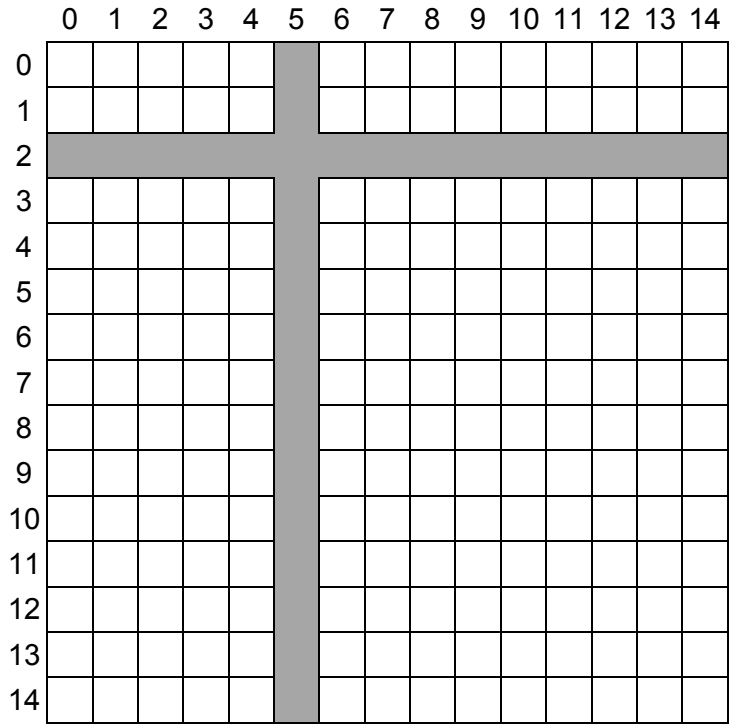
1 1 The simulation is to be extended to represent the landscape that the animals live in. Most of the landscape will be land, but two rivers will run through it. The locations of the rivers are shaded in **Figure 13**.

Figure 13



Each of the individual locations, eg (12, 7), within the landscape will be assigned to be an area of either land or river.

What you need to do

Task 1
Modify the `Location` class so that it can store a representation of the type of terrain at the location. This representation should be as a character, with "L" representing land and "R" representing river.

Task 2
Modify the constructor subroutine of the `Location` class so that when a location is created, the constructor is passed the type of terrain that the location will be and this is stored appropriately.

Task 3
Modify the `CreateLandscapeAndAnimals` subroutine in the `Simulation` class so that when the landscape is created the appropriate type of terrain, as shown in **Figure 13**, is stored in each location. The terrain should be represented as a character, with "L" representing land and "R" representing river.

Task 4
Modify the `DrawLandscape` subroutine in the `Simulation` class so that the correct type of terrain at each location is displayed when the landscape is drawn.

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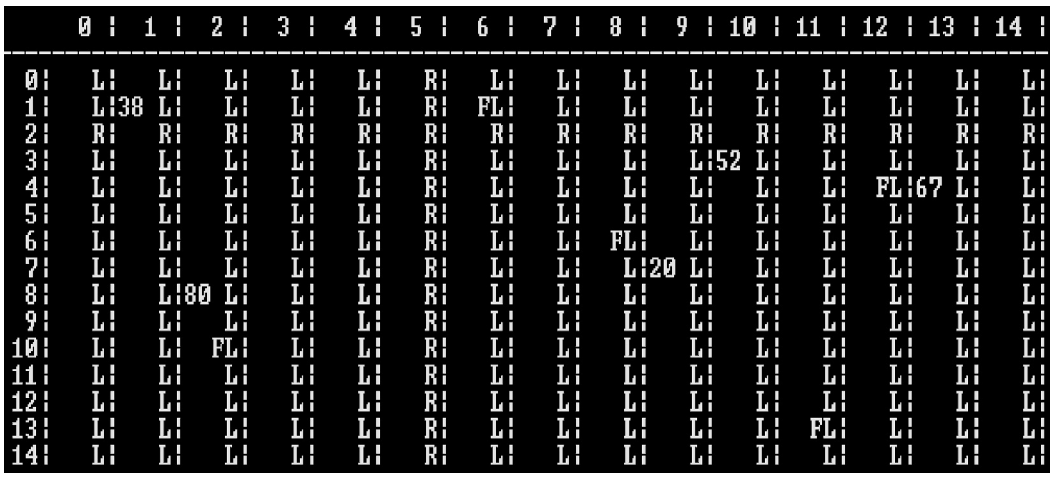
Figure 14 shows one example of how the landscape could be drawn, with a letter "L" indicating that a location contains land, and a letter "R" indicating that a location contains part of a river. However, you are free to indicate the type of terrain at a location in any way that you choose, so long as this is clear to the user.

Figure 14



Task 5

Modify the `CreateNewWarren` and `CreateNewFox` subroutines in the `Simulation` class so that warrens and foxes cannot be created in locations that are part of a river.

Test

Check that the changes you have made in Tasks 1 to 4 (**not** Task 5) work by conducting the following test:

- Select option "1. Run simulation with default settings" from the main menu.

Evidence that you need to provide

Include the following in your Electronic Answer Document.

1 1 . 1 Your PROGRAM SOURCE CODE for the whole of the `Location` class, including the constructor subroutine.

[3 marks]

1 1 . 2 Your PROGRAM SOURCE CODE for the amended `CreateLandscapeAndAnimals` subroutine from the `Simulation` class.

[3 marks]

Question 11 continues on the next page

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1 1 . 3 Your PROGRAM SOURCE CODE for the amended `DrawLandscape` subroutine from the `Simulation` class.

[2 marks]

1 1 . 4 Your PROGRAM SOURCE CODE for the amended `CreateNewWarren` and `CreateNewFox` subroutines from the `Simulation` class.

[3 marks]

1 1 . 5 SCREEN CAPTURE(S) for the described test, showing the correct type of territory in each location on the landscape.

[1 mark]

1 2 The landscape affects the foxes' ability to eat the rabbits. Foxes do not like to swim, so will not cross the rivers on the landscape to eat. If a river lies between a fox and a warren, the fox will not eat any rabbits in the warren, even if it is near enough for it to do so.

As the rivers only run horizontally and vertically, and extend from one side of the landscape to the other, a simple way to check if reaching a warren would require a fox to cross a river is to:

- Calculate the coordinates of all of the locations between the fox and the warren in a horizontal line, level with the fox.
- Calculate the coordinates of all of the locations between the fox and the warren in a vertical line, level with the fox.
- If any of the locations horizontally or vertically between the fox and the warren contain a river, then the fox will not eat any of the rabbits in the warren as the fox's path to the warren crosses a river.

Figure 15 shows the locations that would need to be checked to see if fox **F** could eat any rabbits in warren **W**. The locations that need to be checked are shown in black and the rivers are shown in grey. As location (5, 7) contains part of a river, the fox would not eat any rabbits in this warren.

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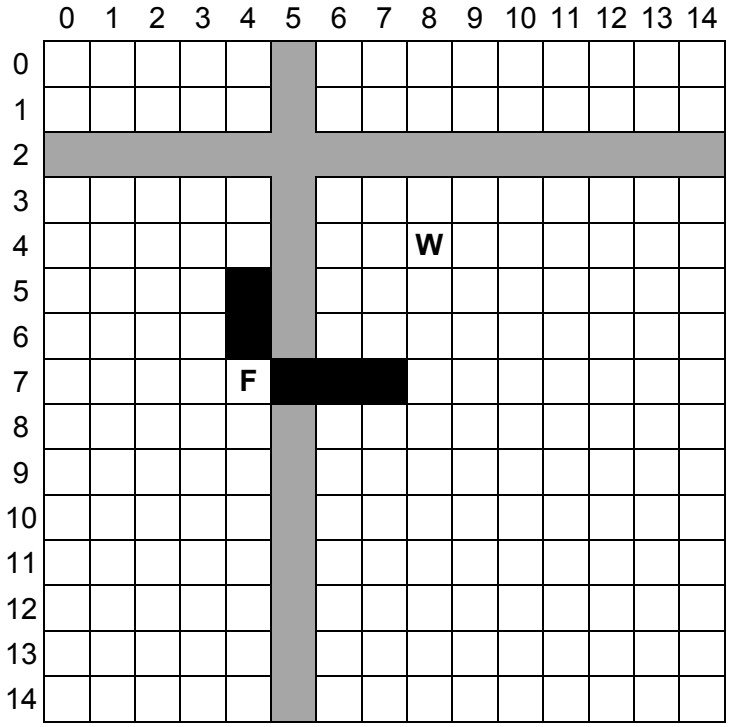
Figure 15



If you have not been able to fully complete **Question 11**, you will still be able to get most of the marks for this question if you can correctly compute the coordinates of the locations that would need to be checked to see if a river was present.

To get full marks for this question, your solution must work regardless of whether a warren is above, below, to the left or to the right of a fox.

What you need to do

Task 1
Create a new subroutine `CheckIfPathCrossesRiver`, in the `Simulation` class, that takes the coordinates of two locations in the landscape **and** checks if there is a river between them.

Task 2
Modify the `FoxesEatRabbitsInWarren` subroutine in the `Simulation` class so that it calls the `CheckIfPathCrossesRiver` subroutine, **and** ensures that if there is a river between a fox and a warren then the fox will not eat any rabbits from the warren.

Test
Check that the changes you have made work by conducting the following test:

- Select option "1. Run simulation with default settings" from the main menu.
- Then select option "1. Advance to next time period showing detail".

When the test is conducted, no rabbits in the warren at (1, 1) should be eaten as it is bounded by rivers on all sides.

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Evidence that you need to provide
Include the following in your Electronic Answer Document.

1 2 . 1 Your PROGRAM SOURCE CODE for the new subroutine `CheckIfPathCrossesRiver` from the `Simulation` class.

[9 marks]

1 2 . 2 Your PROGRAM SOURCE CODE for the amended subroutine `FoxesEatRabbitsInWarren` from the `Simulation` class.

[2 marks]

1 2 . 3 SCREEN CAPTURE(S) for the described test.

Your SCREEN CAPTURE(S) only needs to show what happens in the warren at location (1, 1) when the simulation advances to the next time period. It should contain similar information to **Figure 16** below, but the exact number of rabbits killed, dying of old age and other details may differ owing to the random nature of parts of the simulation.

[1 mark]

Figure 16

```
Warren at (1,1):
  Period Start: Periods Run 0 Size 38
  3 rabbits killed by other factors.
  0 rabbits die of old age.
  14 baby rabbits born.
  Period End: Periods Run 1 Size 49
```

END OF QUESTIONS

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