Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

A-level
COMPUTING

Unit 3 Problem Solving, Programming, Operating Systems, Databases and Networking

Wednesday 22 June 2016 Morning Time allowed: 2 hours 30 minutes

Materials
You will need no other materials.
You may use a calculator.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The use of brand names will **not** gain credit.
- Question **6** should be answered in continuous prose. In this question you will be marked on your ability to:
  - use good English
  - organise information clearly
  - use specialist vocabulary where appropriate.

Do not write outside the box

Answer **all** questions in the spaces provided.

1 (a) Three important computer security procedures are:

- authentication
- authorisation
- accounting

Table 1 lists two situations which involve the use of security procedures.

For each row in **Table 1**, place a tick in **one** column to indicate whether the **Situation and Procedure** is an example of **Authentication**, **Authorisation** or **Accounting**.

[2 marks]

Table 1

Situation and Procedure	Authentication	Authorisation	Accounting
A web server generating a log of the IP addresses of computers that have accessed it.			
Using a digital signature when sending an e-mail message.			

1 (b) Viruses and worms are both threats to computer security.

Explain what a virus is, and explain the difference between a virus and a worm.

[3 marks]

Do not write outside the box

1 (c) A message is to be sent from Computer A to Computer B.

Describe the steps that would be involved in producing a digital signature for the message before it is transmitted by Computer A.

[4 marks]

9

Turn over for the next question

2 Reverse Polish Notation is an alternative to standard infix notation for writing arithmetic expressions.

2 (a) Convert the Reverse Polish Notation expressions in **Table 2** to their equivalent infix expressions.

[2 marks]

Table 2

Reverse Polish Notation	**Equivalent Infix Expression**
18 9 −	
10 4 − 12 ×	

2 (b) State **one** advantage of Reverse Polish Notation over infix notation.

[1 mark]

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3

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

3 A particular computer uses a **normalised** floating point representation with a 7-bit mantissa and a 5-bit exponent, both stored using **two's complement**.

3 (a) In the boxes below, write the most negative value that can be stored using this representation:

[2 marks]

Mantissa

•						

Exponent

3 (b) This is a floating point representation of a number:

Mantissa

1 •	0	1	0	1	1	0

Exponent

0	1	0	1	1

Calculate the denary equivalent of the number. Show how you have arrived at your answer.

[2 marks]

Working ____

____

____

Answer ____

3 (c) Write the normalised floating point representation of the denary value 12¾ in the boxes below. Show how you have arrived at your answer.

[3 marks]

Working ____

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Answer

Mantissa

•						

Exponent

Do not write outside the box

3 (d) Floating point numbers are usually stored in normalised form.

3 (d) (i) State **two** advantages of using a normalised representation.

[2 marks]

Advantage 1 ______________________________

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Advantage 2 ______________________________

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3 (d) (ii) When a number is stored in normalised form it is always the case that the bits either side of the binary point are different from each other, ie if the bit before the binary point is 0, the bit after it will be 1 and if the bit before it is 1, the bit after it will be 0.

Using this information, explain how the 12 bits used to store a floating point number in this question could be used more efficiently, to increase the precision of the numbers which could be represented, without reducing the available range.

[2 marks]

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11

4 A bar code scanner is connected to a computerised point of sale system (till). When a product is sold, the bar code that is printed on the product is scanned by the scanner and transmitted to the point of sale system.

This transmission uses asynchronous serial communication and odd parity.

Figure 1 shows the ASCII code for the character "9", which has been read from the bar code, being transmitted to the point of sale system.

4 (a) Write the missing values of the stop bit, parity bit and start bit on **Figure 1**.

[2 marks]

Figure 1

		0	1	1	1	0	0	1	
Stop Bit	**Parity Bit**	**ASCII Code**							**Start Bit**

Direction of data transmission →

4 (b) Explain what asynchronous data transmission is and why stop and start bits are required when asynchronous data transmission is used.

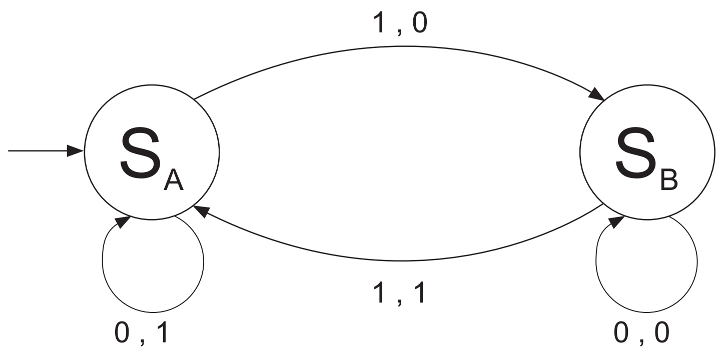
[3 marks]

As part of the process of preparing the data for transmission, the 7-bit ASCII code (0111001) is processed by a Mealy machine (a type of Finite State Machine with output).

The ASCII code is processed from left to right, ie the leftmost 0 is the first digit to be processed.

Figure 2 shows a diagram of the Mealy machine. Each transition is labelled with the input symbol that will trigger the transition, followed by a comma, followed by the output that will be produced.

Figure 2



4 (c) What output is generated by the Mealy machine in **Figure 2** for the input `0111001`?

[1 mark]

____

4 (d) The last digit output by the Mealy machine is used in the transmission.

Explain what this last digit represents.

[1 mark]

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Question 4 continues on the next page

4 (e) Serial communication has been chosen instead of parallel communication even though the scanner and point of sale system are located next to each other.

State **two** reasons why this choice is appropriate.

[2 marks]

Reason 1 ______________________________

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____

Reason 2 ______________________________

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9

Turn over for the next question

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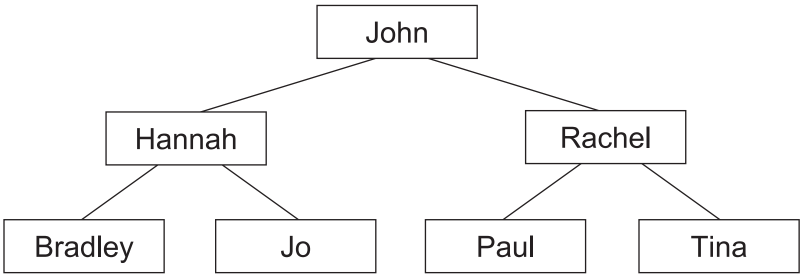
ANSWER IN THE SPACES PROVIDED**

5 A binary search tree can be used to represent a list of data so that it can be efficiently searched. **Figure 3** shows an example of a binary search tree:

Figure 3



5 (a) The tree in **Figure 3** is to be searched for data item "Lisa". The tree does not contain "Lisa".

List the data items that will be examined, in the order that they will be visited, when "Lisa" is searched for.

[1 mark]

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5 (b) Tick **one** box in **Table 3** to indicate the time complexity of the algorithm used to search for data in a binary search tree.

[1 mark]

Table 3

Time Complexity	**Tick one box**
O(n)	
O(log n)	
$O(n^2)$	

Do not write outside the box

5 (c) In **Figure 4** below, show how the tree in **Figure 3** could be represented by a **Start Index**, together with a one-dimensional array of records, each of which contains the fields **Left Pointer**, **Data** and **Right Pointer**:

[3 marks]

Figure 4

Start Index

= ....

Index	Left Pointer	Data	Right Pointer
[1]			
[2]			
[3]			
[4]			
[5]			
[6]			
[7]			

5 (d) The array shown in **Figure 4** is an example of a static data structure.

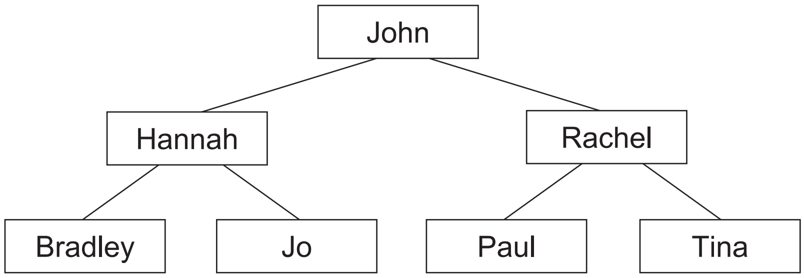
Explain the differences between a static data structure and a dynamic data structure, and what the heap is used for with a dynamic data structure.

[3 marks]

Turn over ▶

Figure 3 is repeated below so that you can answer part **5 (e)** without having to turn back in the question paper booklet.

Figure 3 (repeated)



5 (e) An in-order traversal is carried out on the binary tree in **Figure 3** to output the values stored in the nodes of the tree.

5 (e) (i) Write out the data items from the tree, in the order that they will be output during the traversal.

[1 mark]

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5 (e) (ii) What is the significance of the order that the data items have been output in?

[1 mark]

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5 (f) Graph traversal is a more complex problem than tree traversal. State **one** feature that a graph might have, which a tree cannot have, that makes graph traversal more complex.

[1 mark]

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11

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

6 Rich client (thick client), thin client and Software as a Service (SaaS) are three methods that can be used to make software applications available to the users of computers that are connected to a network.

- Explain how rich client and thin client systems work.
- Describe the different hardware requirements of rich client and thin client systems.
- Explain why Software as a Service can be considered to be a special type of thin client system, and what distinguishes it from other types of thin client systems.

In your answer you will be assessed on your ability to use good English, and to organise your answer clearly in complete sentences, using specialist vocabulary where appropriate.

[8 marks]

8

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

7 (a) Two important components of a Turing machine are the transition function and the tape.

Five components of a typical modern computer system are listed below:

1. DVD-ROM
2. Compiler
3. Main Memory
4. Processor
5. Program

Complete **Table 4** by writing into it the numbers of the modern computer system components from the list above that would fulfil the role most similar to the transition function and the tape in a Turing machine.

[2 marks]

Table 4

Turing machine component	**Number (1-5) of modern computer system component with most similar role**
Transition function	
Tape	

7 (b) Explain the relationship between the Turing machine, as a model of computation, and an algorithm.

[1 mark]

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7 (c) A Turing machine has been designed to complete a task.

The machine has states S_B, S_F, S_0, S_1, S_R, S_E, and S_H. S_B is the start state and S_H is the stop state.

The machine stores data on a single tape which is infinitely long in one direction. The machine's alphabet is 0, 1, #, □, where □ is the symbol used to indicate a blank cell on the tape.

The transition rules for this Turing machine can be expressed as a transition function δ. Rules are written in the form:

$$\delta(\text{Current State, Input Symbol}) = (\text{Next State, Output Symbol, Movement})$$

So, for example, the rule:

$$\delta\,(S_B, \square) = (S_F\,, \#, \leftarrow)$$

means:

IF the machine is currently in state S_B AND the input symbol read from the tape is a blank symbol (□)
THEN the machine should change to state S_F, write a # to the tape and move the read/write head one cell to the left

The machine's transition function, δ, is defined by:

$$\delta\,(S_B, 0) = (S_B, 0, \rightarrow)$$
$$\delta\,(S_B, 1) = (S_B, 1, \rightarrow)$$
$$\delta\,(S_B, \square) = (S_F, \#, \leftarrow)$$

$$\delta\,(S_F, \#) = (S_F, \#, \leftarrow)$$
$$\delta\,(S_F, 0) = (S_0, \#, \rightarrow)$$
$$\delta\,(S_F, 1) = (S_1, \#, \rightarrow)$$
$$\delta\,(S_F, \square) = (S_E, \square, \rightarrow)$$

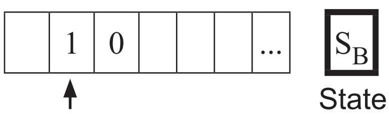
$$\delta\,(S_0, \#) = (S_0, \#, \rightarrow)$$
$$\delta\,(S_0, 0) = (S_0, 0, \rightarrow)$$
$$\delta\,(S_0, 1) = (S_0, 1, \rightarrow)$$
$$\delta\,(S_0, \square) = (S_R, 0, \leftarrow)$$

$$\delta\,(S_1, \#) = (S_1, \#, \rightarrow)$$
$$\delta\,(S_1, 0) = (S_1, 0, \rightarrow)$$
$$\delta\,(S_1, 1) = (S_1, 1, \rightarrow)$$
$$\delta\,(S_1, \square) = (S_R, 1, \leftarrow)$$

$$\delta\,(S_R, \#) = (S_F, \#, \leftarrow)$$
$$\delta\,(S_R, 0) = (S_R, 0, \leftarrow)$$
$$\delta\,(S_R, 1) = (S_R, 1, \leftarrow)$$

$$\delta\,(S_E, \#) = (S_E, \square, \rightarrow)$$
$$\delta\,(S_E, 0) = (S_H, 0, \rightarrow)$$
$$\delta\,(S_E, 1) = (S_H, 1, \rightarrow)$$
$$\delta\,(S_E, \square) = (S_H, \square, \rightarrow)$$

This Turing machine is carrying out a computation. The machine starts in state S_B with the string 10 on the tape. All other cells contain the blank symbol, □ (not shown). The read/write head is positioned at the left hand end of the string on the tape, as indicated by the arrow:



After eight steps of the computation have been completed, the tape contents, state and position of the read/write head are:

		1	#	#	0		...
Head		↑					
State	S_F						

Trace the computation of the Turing machine, from step nine onwards, using the transition function δ. Show the contents of the tape, the current position of the read/write head and the current state as the input symbols are processed. Step eight has been repeated at the start of the trace.

[6 marks]

Step								State
8.		1 ↑	#	#	0		...	S_F
9.							...	
10.							...	
11.							...	
12.							...	
13.							...	
14.							...	
15.							...	
16.							...	
17.							...	
18.							...	
19.							...	
20.							...	
21.							...	
22.							...	

7 (d) Explain the purpose of the Turing machine that you have traced the execution of.

[1 mark]

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10

Turn over ▶

8 A parcel delivery company uses a relational database to store information about the deliveries that it makes. These details include information about each customer who sends a parcel, the individual parcels being delivered and pricing details.

The company offers three different service speeds, which are "Express", "Standard" and "Economy". The price that is charged for delivering a parcel depends upon the service speed selected and the weight of the parcel (to the nearest gram). For each service speed, parcel prices are split into bands for a range of weights. For example, for the "Express" service, the price bands are as follows:

Minimum Weight (g)	**Maximum Weight (g)**	**Price**
0	249	£1.99
250	499	£2.99
500	999	£3.99
1000	4999	£4.99
5000	19999	£9.99

Similar price bands, but with different prices, exist for the "Standard" and "Economy" services.

The details are stored using the three relations in **Figure 5**.

Figure 5

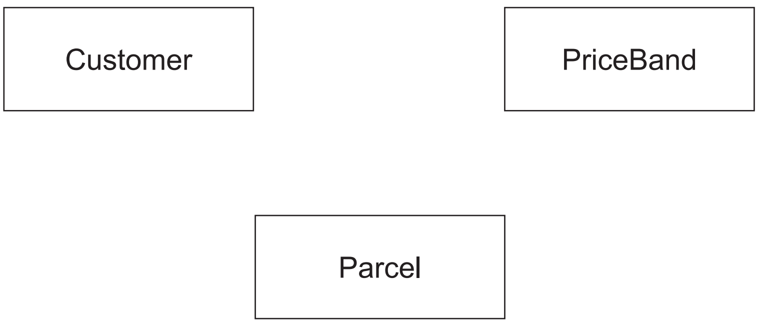
Customer(CustomerID, Title, Forename, Surname)

PriceBand(ServiceSpeed, MinWeight, MaxWeight, Price)

Parcel(ParcelID, ServiceSpeed, Weight, DateSent, CustomerID, RecipientName, HouseNumber, Street, Town, County, Postcode)

8 (a) On the incomplete Entity-Relationship diagram below, show the degree of the three relationships that exist between the entities.

[2 marks]



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8 (b) The price that is charged for an "Express" delivery, weighing between 1000 and 4999 grams is to be increased to £5.99. Complete the SQL statements below to make this update.

[4 marks]

UPDATE ______________________________

SET ______________________________

WHERE ______________________________

____

8 (c) Write a query that will list all of the parcels sent by the customer whose **CustomerID** is 109.

For each parcel, the list should include the **DateSent**, the **Postcode** that the parcel was sent to, the **ServiceSpeed** that was used and the **Price** charged, and no other details.

The list should be presented in order, with the parcel sent the longest time ago at the top of the list and the parcel sent most recently at the bottom.

[6 marks]

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Turn over ▶

Figure 5 is repeated below to help you answer question **8 (d)** without having to turn back in the question booklet.

Figure 5 (Repeated)

Customer(<u>CustomerID</u>, Title, Forename, Surname)

PriceBand(<u>ServiceSpeed, MinWeight</u>, MaxWeight, Price)

Parcel(<u>ParcelID</u>, ServiceSpeed, Weight, DateSent, CustomerID, RecipientName, HouseNumber, Street, Town, County, Postcode)

8 (d) The **Street**, **Town** and **County** parts of a recipient's address can all be identified from the **Postcode**.

This means that the Parcel relation is not normalised and contains redundant data.

Redesign the Parcel relation, and create any new relations that you think are necessary, to eliminate this redundancy from the database to produce a normalised design.

Use the same notation that has been used in **Figure 5** when answering this question part. Make sure that you underline the attribute(s) that make up the primary key in each relation.

[3 marks]

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15

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9 An operating system is designed to hide the complexities of the hardware from the user and to manage the hardware and other resources.

9 (a) State **three** different types of management of either hardware or other resources that are performed by an operating system.

[3 marks]

Type 1 ____

____

Type 2 ____

____

Type 3 ____

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9 (b) Explain what an interactive operating system is.

[1 mark]

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4

Turn over for the next question

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10 A computer games programmer is writing a game. One aspect of the game involves a character who can carry various items, such as a bag of seeds, and an axe, around with her. The list of items that the character is currently carrying will be stored as a linked list of items of the `String` data type. The list is stored in no particular order.

The game is being developed using object-oriented programming. The **LinkedList** class will be used to store that list of items.

The class definition for the **LinkedList** class is:

```
LinkedList
  = Class
      Public
        Procedure CreateList
        Procedure DestroyList
        Procedure AddItem(NewItem: String)
        Procedure DeleteItem(DelItem: String)
        Function ContainsItem(SearchItem: String): Boolean
        Function IsEmpty: Boolean
      Private
        Start: Pointer
        Current: Pointer
        Previous: Pointer
      End
```

10 (a) Creating a class such as the **LinkedList** class, that can be used by other parts of a much bigger program, is a form of abstraction.

Explain why the **LinkedList** class is a form of abstraction.

[1 mark]

10 (b) Explain why the functions and procedures, such as `AddItem` have been declared to be `Public` whilst the data items such as `Start` have been declared as `Private`.

[2 marks]

Do not write outside the box

10 (c) Write a pseudo-code algorithm for the `DeleteItem` operation.

You may assume that:

- `Start` is a pointer to the memory location of the first item in the linked list
- The variable `DelItem`, which will be passed to the `DeleteItem` operation as a parameter, is a `String` that contains the name of the item to delete, exactly as the name appears in the linked list
- The linked list is not empty, and does contain the item to be deleted
- For each item stored in the list, two fields are stored, which are called `DataValue` and `Next`. The `DataValue` is the name of the item that is stored and `Next` is a pointer to the memory location of the next item in the list. To access the values stored in these fields at a particular memory location, such as `Current`, the instructions `Current.DataValue` and `Current.Next` would be used
- An operation called `Release` is provided by the operating system that will make a specified memory location that is no longer required available for re-use
- You should make use of the data items `Current` and `Previous`, both of which are pointers, when searching the list to locate the item that is to be deleted.

[8 marks]

11

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11 A dictionary is an abstract data type that allows pairs of values to be associated with each other. For example, an English-French dictionary might associate English words with their translations into French. In such a dictionary, "Apple" would be associated with "Pomme" because "Pomme" is the French word for "Apple".

At a lower level of abstraction, a dictionary could be implemented as a data structure using a number of different methods. Two possible implementation methods are:

- **Implementation One**: As an unordered list in an array.
- **Implementation Two**: Using hashing, with the English word being passed through a hash function to calculate the position of the correct French translation in an array.

In each implementation, a record containing the English word and the equivalent French word are stored at each index in the array that is in use.

Figure 6 shows how an English-French dictionary containing five words could be implemented using these two methods.

Figure 6

Implementation One – Unordered List

Index	English Word	French Word
[1]	Apple	Pomme
[2]	Lemon	Citron
[3]	Strawberry	Fraise
[4]	Grapefruit	Pamplemousse
[5]	Pear	Poire
[6]		
[7]		
[8]		
[9]		
[10]		

New words are inserted into the array in the first available slot. The next word would be stored at position 6.

Implementation Two – Hashing

Index	English Word	French Word
[1]	Pear	Poire
[2]	Lemon	Citron
[3]		
[4]		
[5]		
[6]		
[7]	Apple	Pomme
[8]	Strawberry	Fraise
[9]		
[10]	Grapefruit	Pamplemousse

The position to store a word is calculated from the English word using a hashing function.

Do not write outside the box

11 (a) Explain why, when the French translation of an English word needs to be looked up, **Implementation Two** is more time efficient than **Implementation One**.

[2 marks]

11 (b) In **Implementation Two**, it is possible that the hash function could compute the same value for two different English words.

Explain what the effect of this would be, and how it could be dealt with.

[2 marks]

11 (c) In **Implementation Two**, both the English and French words are stored at each index in the Array. In this implementation, explain why it would not be possible to perform reliable English to French translation if only the French words were stored.

[1 mark]

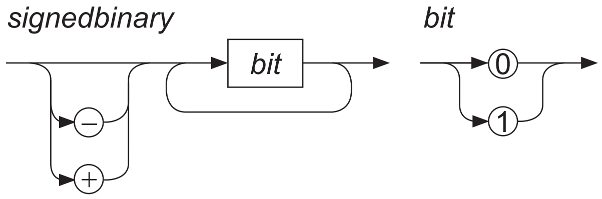
5

Turn over ▶

12 **Table 5** shows three definitions of a language for signed binary numbers, each written using a different standard notation.

All three definitions are supposed to be of the same language for signed binary numbers, but one of them contains an error which means that it defines a different language.

Table 5

<table>
<tr><td>1</td><td><signedbinary> ::= + <binary> | - <binary> | <binary>
<binary> ::= <bit> | <bit> <binary>
<bit> ::= 0 | 1</td></tr>
<tr><td>2</td><td>
</td></tr>
<tr><td>3</td><td>(+|-)(0|1)$^{+}$</td></tr>
</table>

12 (a) What is the name of the standard notation used in definition **2** in **Table 5**?

[1 mark]

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12 (b) State the number of the definition (**1** to **3**) in **Table 5** that does not define the same language as the other two definitions.

[1 mark]

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12 (c) Explain how the language defined by the definition that you have identified in part **12 (b)** would differ from the language defined by the other two definitions.

[1 mark]

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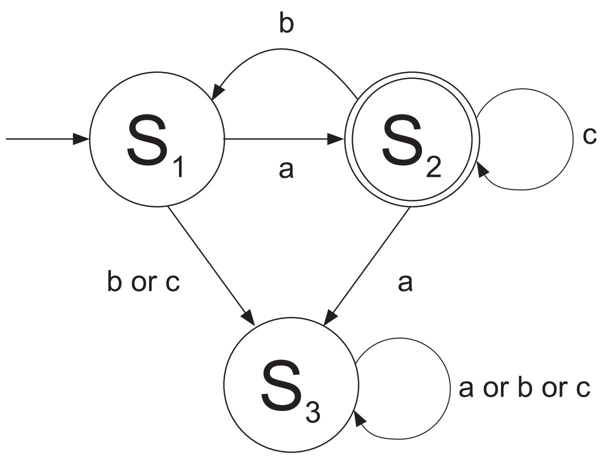
Figure 7 shows a finite state automaton that recognises a language.

Figure 7



12 (d) Write a regular expression that would recognise the same language as the finite state automaton in **Figure 7**.

[1 mark]

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4

END OF QUESTIONS

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