Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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11	
12	
TOTAL	

AQA

General Certificate of Education
Advanced Level Examination
June 2015

Computing COMP3

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

Tuesday 23 June 2015 9.00 am to 11.30 am

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

Time allowed
- 2 hours 30 minutes

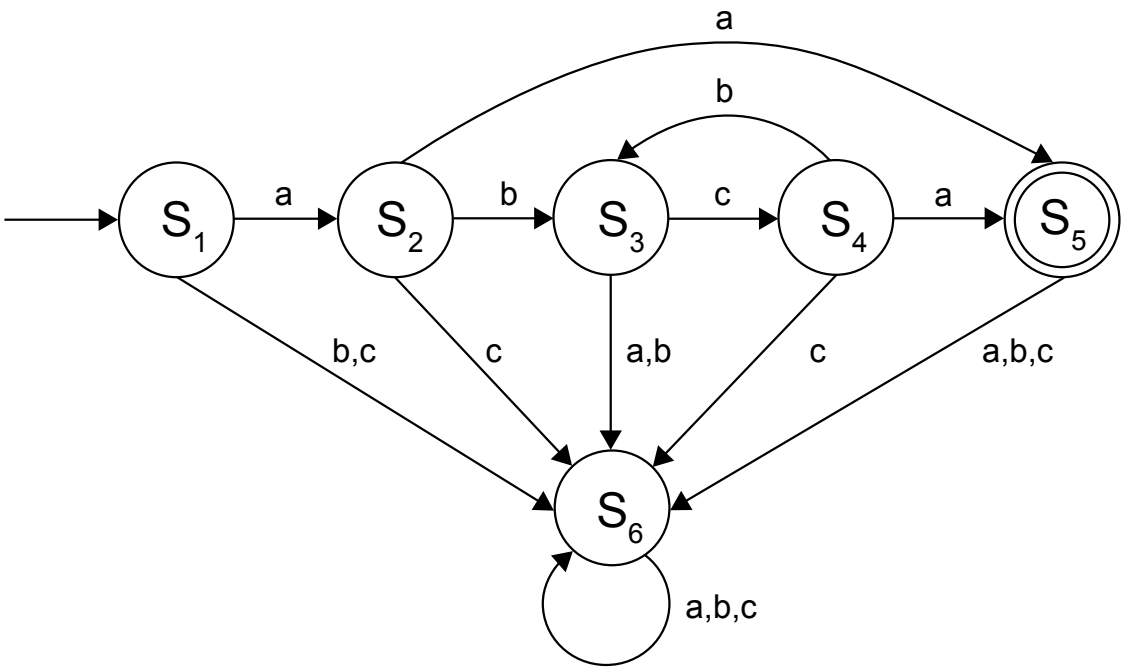
Instructions
A
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in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

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

1 **Figure 1** shows a Finite State Automaton (FSA). The FSA has input alphabet {a, b, c} and six states, S_1, S_2, S_3, S_4, S_5 and S_6.

Figure 1



1 (a) Complete the empty cells in the **part of the transition table** shown in **Table 1** for the FSA in **Figure 1**.

[1 mark]

Table 1

Current State	S_1	S_1	S_1	S_2	S_2	S_2	S_3	S_3	S_3
Input Symbol	a	b	c	a	b	c			
Next State	S_2	S_6	S_6	S_5	S_3	S_6			

1 (b) Give the name of the state that the FSA will end up in when processing the string `abcb`.

[1 mark]

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1 (c) Describe the purpose of state S_6.

[1 mark]

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1 (d) The FSA in **Figure 1** accepts strings that consist of:

- a letter `a`
- followed by zero or more occurrences of the string `bc` and
- ending with a second letter `a`.

For any FSA, it is possible to write a regular expression that will match the same language (set of strings) as the FSA.

Write a regular expression that will match the same language that is accepted by the FSA in **Figure 1**.

[2 marks]

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1 (e) The Turing Machine is a more powerful abstract model of computation than the FSA.

Explain why the Turing Machine model can be used to recognise a greater range of languages than an FSA could.

[1 mark]

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6

Turn over for the next question

2 A school enters Year 12 and Year 13 students for AS and A Level qualifications.

Each qualification is identified uniquely by a combination of a subject name and level, e.g. 'Computing' and 'A Level'. A qualification with the same name can exist at both AS Level and A Level.

Qualifications are split up into modules. Each module is identified by a code, e.g. 'COMP3'. No two modules can have the same code, even if they are in different qualifications. A module also has a name and a number of UMS points associated with it.

Each student who is being entered for modules has their Forename, Surname, Centre Number and Candidate Number recorded. Taken together, the Centre Number and Candidate Number uniquely identify a student.

When a student is entered for a module their Centre Number, Candidate Number and the Exam Session that the entry is for (e.g. 'Summer 2015') are recorded, together with the information necessary to identify which module the entry is for. A student who is unhappy with their result can re-sit a module in a later session.

2 (a) Develop a **normalised** design for a relational database to store the information described above.

List the names of **all** of the relations together with the attributes that each will contain.

Underline the attribute(s) that will form the primary key in each relation.

To help you, the Student relation has already been defined.

[5 marks]

Student (<u>CentreNumber, CandidateNumber</u>, Forename, Surname)

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2 (b) The primary key in the Student relation is made up of two attributes, as no one attribute can uniquely identify a student.

What name is given to this type of key?

[1 mark]

.....

6

Turn over for the next question

3 A student is configuring the Local Area Network (LAN) at her home.

The following five hardware devices are connected to the network:

❶ a Combined Device that includes a wireless access point, switch, firewall, router and ADSL modem for connection to the telephone network

❷ a desktop computer that is connected to the network by cable

❸ a smart TV that is connected to the network by cable

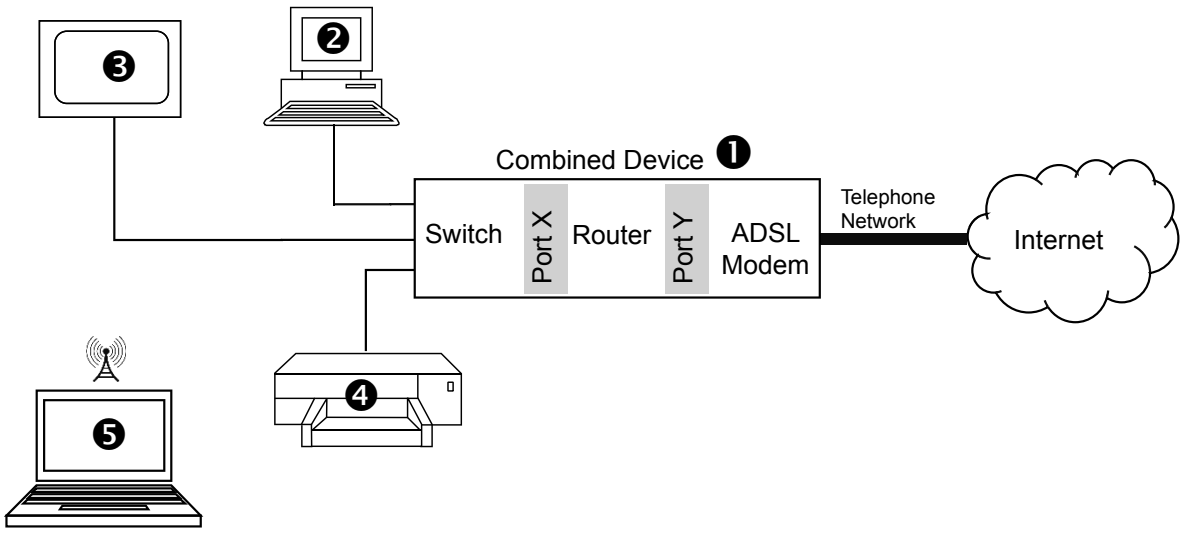
❹ a printer that is connected to the network by cable

❺ a laptop computer that can connect to the network wirelessly.

Figure 2 shows the physical topology of the LAN and its connection to the Internet.

Some, but not all, of the components of the Combined Device are shown in **Figure 2.**

Figure 2



- **Port Y** of the router in the Combined Device has the IP address 82.73.12.9.
- The network adapter card in the desktop computer has been allocated the IP address 192.168.0.2.
- The subnet mask 255.255.255.0 has been programmed into devices ❷ to ❺.

3 (a) **Port X** is the router port, within the Combined Device, that allows devices on the LAN to access the Internet. Suggest a suitable IP address that could be allocated to **Port X** of the Combined Device.

[1 mark]

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3 (b) What physical network topology has been used for the LAN?

[1 mark]

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3 (c) The IP addresses allocated to the devices on the LAN are non-routable IP addresses. The IP address allocated to **Port Y** of the combined device is a routable IP address.

Explain why the devices connected to a LAN are usually given non-routable IP addresses.

[2 marks]

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3 (d) The desktop computer is uploading a file to an FTP server on the Internet.

The FTP server has IP address 67.84.23.102

Explain how the desktop computer will use the subnet mask (255.255.255.0), that it has been programmed with, to determine that the data being sent to the FTP server must be sent to the combined device from where it will be transferred on to the Internet.

[3 marks]

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3 (e) The combined device contains a firewall.

Describe how the firewall might control the data that flow between the LAN and the Internet.

[3 marks]

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3 (f) The ADSL connection to the Internet is broadband and the cabled connections within the LAN are baseband.

Explain the difference between a broadband connection and a baseband connection.

[1 mark]

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3 (g) The smart TV is capable of being connected to the network wirelessly or using a cabled connection.

Explain why a cabled connection has been used.

[1 mark]

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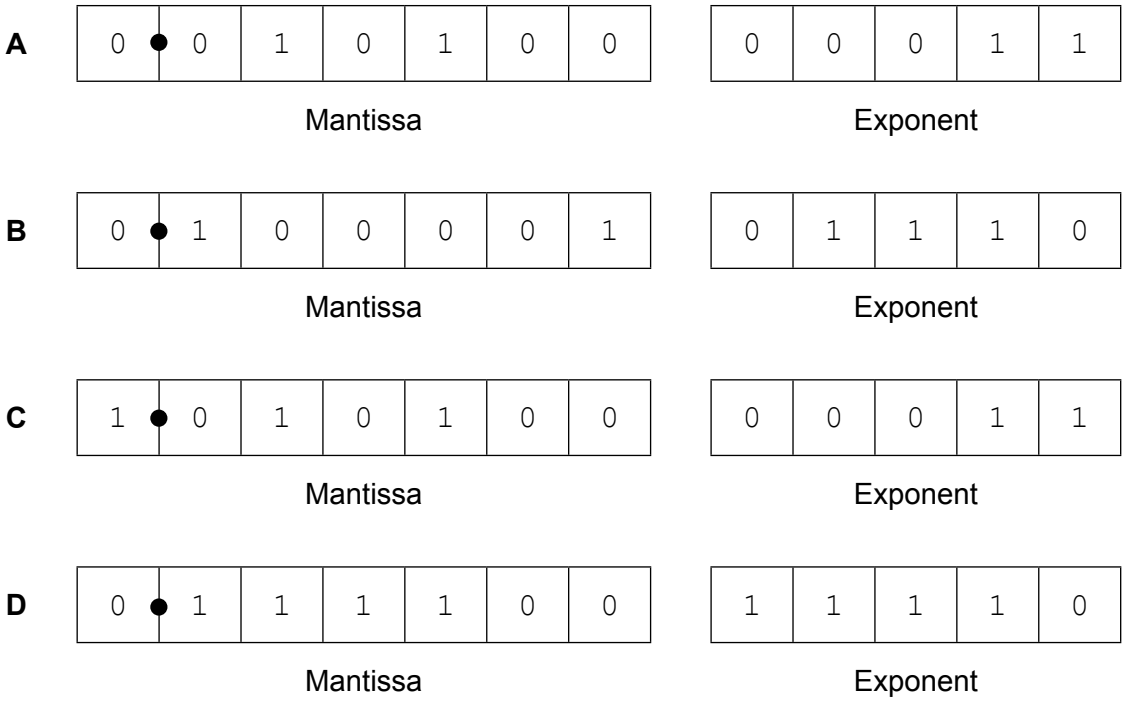
12

4 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**.

4 (a) Four bit patterns that are stored in this computer's memory are listed in **Figure 3** and labelled with the letters **A** to **D**. Three of the bit patterns are valid floating point numbers and one is not.

Figure 3



Complete **Table 2** below. In the **Correct letter (A-D)** column write the appropriate letter from **A** to **D** to indicate which bit pattern in **Figure 3** matches the description in the **Value description** column.

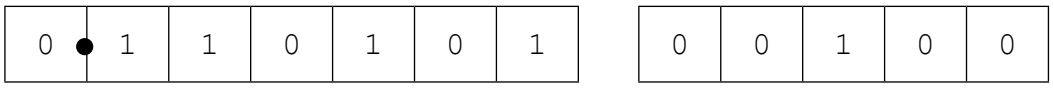
Do **not** use the same letter more than once.

[3 marks]

Table 2

Value description	**Correct letter (A-D)**
A negative value	
The largest positive number of the four values	
A value that is not valid in the representation because it is not normalised	

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



Mantissa Exponent

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

[1 mark]

Working .....

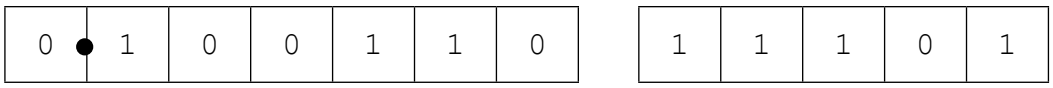
.....

.....

[1 mark]

Answer .....

4 (c) This is a floating point representation of a number:



Mantissa Exponent

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

[1 mark]

Working .....

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[1 mark]

Answer .....

4 (d) Write the normalised floating point representation of the denary value 2944 in the boxes below. Show how you have arrived at your answer.

[2 marks]

Working.....

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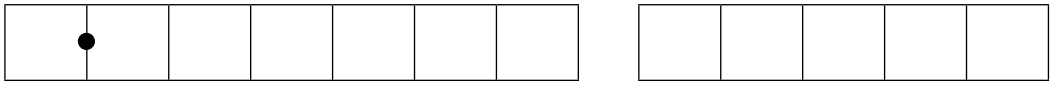
[1 mark]

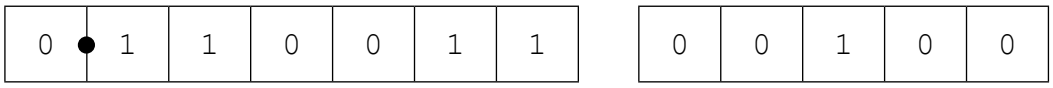
Answer



Mantissa Exponent

4 (e) There can be a loss of precision when a denary number is stored using this floating point system.

The closest possible representation of the denary number 12.87 is shown below:



Mantissa Exponent

By converting this bit pattern back into denary, it can be seen that the actual number stored is 12.75, not 12.87.

4 (e) (i) Calculate the absolute error that has occurred.

[1 mark]

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4 (e) (ii) Calculate the relative error that has occurred. Express your answer as a percentage to four decimal places.

[1 mark]

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4 (e) (iii) Sometimes a floating point calculation can produce a result that is so close to zero that the result's closest possible representation is zero.

What is the name given to this specific type of error?

[1 mark]

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13

5 A computer program is being developed for a car hire company. The program must store, in a file, details of the 600 vehicles that the company owns.

The records in the file will be stored and retrieved using hashing.

An alternative method that could be used instead of hashing would be to store the records in order of registration number, and use a search algorithm such as binary search for retrieval.

5 (a) (i) State **one** advantage of organising the data using hashing instead of organising the data in order by registration number.

[1 mark]

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5 (a) (ii) State **one** advantage of organising the data in order by registration number instead of organising the data using hashing.

[1 mark]

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Each vehicle is uniquely identified by its registration number. A registration number consists of:

- two alphabetic characters
- followed by two numeric digits
- followed by three further alphabetic characters.

An example registration number is DA18CFE.

The programmer has chosen the hash function on the next page to calculate a hash value from a registration number.

Hash value = (position in alphabet of letter at position 1 +
position in alphabet of letter at position 2 * 10 +
numeric digit at position 3 * 100 +
numeric digit at position 4 * 500) MOD 1000

For the example DA18CFE the hash value would be calculated as follows:

Hash value = (position in alphabet of 'D' (4) +
position in alphabet of 'A' (1) * 10 +
1 * 100 +
8 * 500) MOD 1000
= 4114 MOD 1000
= 114

5 (b) Calculate the hash values for the following **two** registration numbers. You may use the space provided for working, if required.

[1 mark]

AE21KWB

Working.....

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Hash value .....

KD70DAF

Working.....

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Hash value .....

5 (c) Calculating the hash values for the two registration numbers in part **5(b)** has produced a collision.

In the context of storing data in files using hashing, explain the effect of this collision and how this might be dealt with.

[2 marks]

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5

6 Explain the role of the operating system and state the important tasks which are carried out by most operating systems.

Beyond those of a standard operating system, describe the additional operational characteristics that you would expect a real time operating system to have.

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.

[7 marks]

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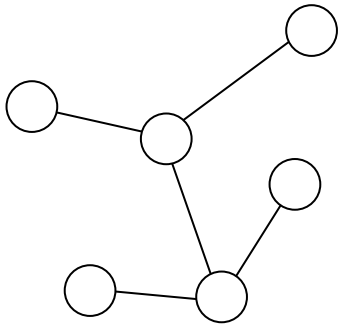
7

Turn over for the next question

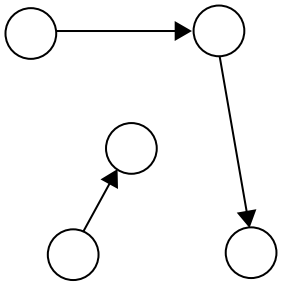
7 (a) **Figure 4** shows four graphs, labelled with the letters **A** to **D**.

Figure 4

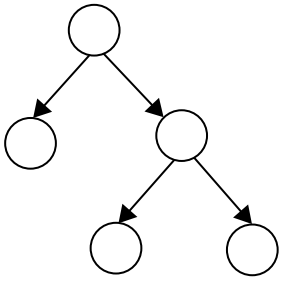
Graph **A**



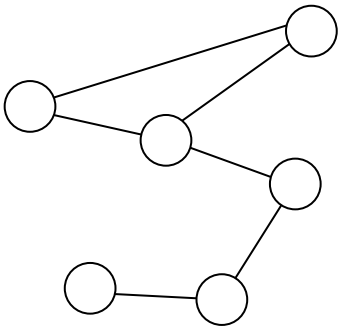
Graph **B**



Graph **C**



Graph **D**



Complete **Table 3** below. In the **Correct letter (A-D)** column write the appropriate letter from **A** to **D** to indicate which graph in **Figure 4** matches the description in the **Description** column.

Do **not** use the same letter more than once. You will not need to use all of the letters.

[2 marks]

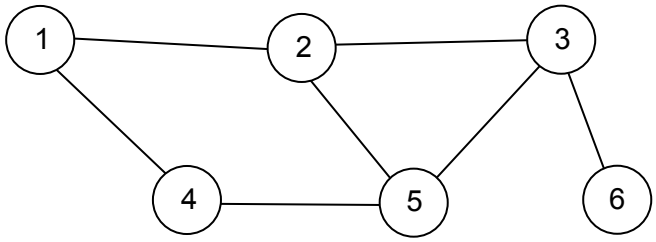
Table 3

Description	**Correct letter (A-D)**
A graph that is not connected	
A graph that is a tree	

7 (b) It is possible to represent a computer network as a graph, with each vertex representing a router and each edge representing a communications link.

Figure 5 is a graph representation of a medium-sized computer network that consists of 6 routers and 7 communications links. The routers have been numbered from 1 to 6.

Figure 5



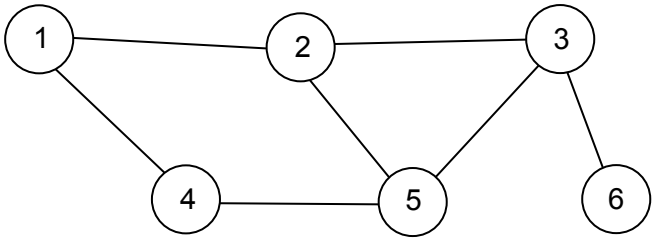
Complete **Table 4** below to show how the graph in **Figure 5** would be stored using an adjacency matrix.

[2 marks]

Table 4

7 (c) **Figure 5** from page 17 is repeated here so that you can answer **Question 7(c)** without having to turn back in the question booklet.

Figure 5 (Repeated)



A simple method of determining the shortest path through a network from one router to another is to perform a breadth first search of the graph representation of the network.

The algorithm in **Figure 6** can be used to perform a breadth first search of a graph. It makes use of two subroutines, `PutVertexIntoQueue` and `GetVertexFromQueue`, which are explained below the algorithm.

Figure 6

```
Procedure ShortestRoute(S, D)
  PutVertexIntoQueue(S)
  Discovered[S] ← True
  Found ← False
  While Queue is Not Empty And Found = False Do
    V = GetVertexFromQueue
    For each vertex U which is adjacent to V Do
      If Discovered[U] = False And Found = False Then
        PutVertexIntoQueue(U)
        Discovered[U] ← True
        Parent[U] ← V
        If U = D Then Found ← True
      EndIf
    EndFor
  EndWhile
  If Found = True Then
    C ← D
    Output D
    Repeat
      C ← Parent[C]
      Output C
    Until C = S
  EndIf
EndProcedure
```

- `PutVertexIntoQueue` is a subroutine that adds a vertex to the rear of a queue.
- `GetVertexFromQueue` is a subroutine that returns the name of the vertex at the front of the queue and removes it from the queue.

Complete the trace table below to show how the `Discovered` and `Parent` arrays, the variable `Found` and the queue contents are updated, together with what output is produced by the algorithm when it is called using `ShortestRoute(1, 6)`.

Before the algorithm is carried out, all cells in the `Discovered` array are set to the value `False` and the queue is empty.

The values of the variables `S`, `D`, `V`, `U` and `C` have already been entered into the table for you.

The letter `F` has been used as an abbreviation for `False`. You should use `T` as an abbreviation for `True`.

[6 marks]

						Discovered						Parent							
S	**D**	**V**	**U**	**C**	**Queue** Front Rear	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**	**Found**	**Output**
						F	F	F	F	F	F								
1	6																		
		1	2																
			4																
		2	1																
			3																
			5																
		4	1																
			5																
		3	2																
			5																
			6																
				6															
				3															
				2															
				1															

7 (d) Explain why it is useful to find the shortest path through the network.

[1 mark]

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11

Turn over ▶

8 A computer program is being developed that will simulate the organisation of wagons (trucks) in a railway shunting yard. The simulation will be based on a model developed by the shunting yard manager and a systems analyst.

8 (a) In the context of simulation, explain what a model is.

[1 mark]

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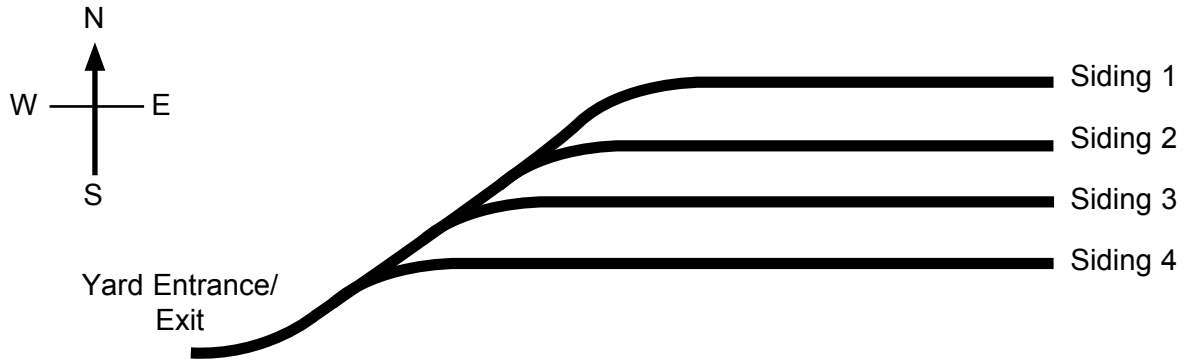
Figure 7 shows the layout of the railway yard. The wagons enter the yard and are pushed into an appropriate siding, depending upon their final destination. Each siding can hold many wagons. Wagons can **only** enter and leave a siding using the Yard Entrance/Exit at the west.

Figure 7



Wagons will be represented as objects in an object-oriented programming language.

Each of the sidings will be represented as a stack data structure.

8 (b) Explain why a stack data structure is appropriate for representing a siding.

[2 marks]

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8 (c) The computer program developer intends to implement a stack by using a fixed length array of 30 wagon objects, named `StackArray`, with indices running from `1` to `30`. An integer variable `TopOfStackPointer`, that will store the array index of the item at the top of the stack, will also be used. The first object stored in the array will be stored at index `1`, the second at index `2` and so on. `TopOfStackPointer` will be initialised to `0`.

Write a pseudo-code algorithm for the `Pop` operation to remove a value from the stack and store it in a wagon object variable named `CurrentWagon`.

Your algorithm should cope appropriately with any potential errors that might occur.

[4 marks]

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Question 8 continues on the next page

8 (d) Wagons come in two different categories: open wagons (without a roof) and closed wagons (with a roof). Closed wagons can be either refrigerated or non-refrigerated.

In an object-oriented programming language, five classes are to be created, named **Wagon**, **OpenWagon**, **ClosedWagon**, **RefrigeratedWagon** and **NonRefrigeratedWagon**.

Draw an inheritance diagram for the five classes.

[3 marks]

8 (e) The **Wagon** class has data fields **OwnerName**, **Weight** and **NumberOfWheels**.

The class definition for **Wagon** is:

```
Wagon = Class
            Public
               Procedure CreateWagon
               Function GetOwnerName
               Function GetWeight
               Function GetNumberOfWheels
            Private
               OwnerName: String
               Weight: Real
               NumberOfWheels: Integer
         End
```

The **ClosedWagon** class has the following additional data fields:

- **Height**: The height of the wagon in metres, which could be a non-integer number
- **NumberOfDoors**: The number of doors that can be used to access the wagon
- **SuitableForFoodstuffs**: A true or false value that indicates if it is safe to carry food in the wagon or not.

Write the class definition for **ClosedWagon**.

You should include the necessary data fields and any additional procedures or functions that the class would require in your definition.

[4 marks]

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14

9 A message is to be transmitted from Computer A to Computer B. For security reasons, the message will be encrypted.

9 (a) What is encryption?

[1 mark]

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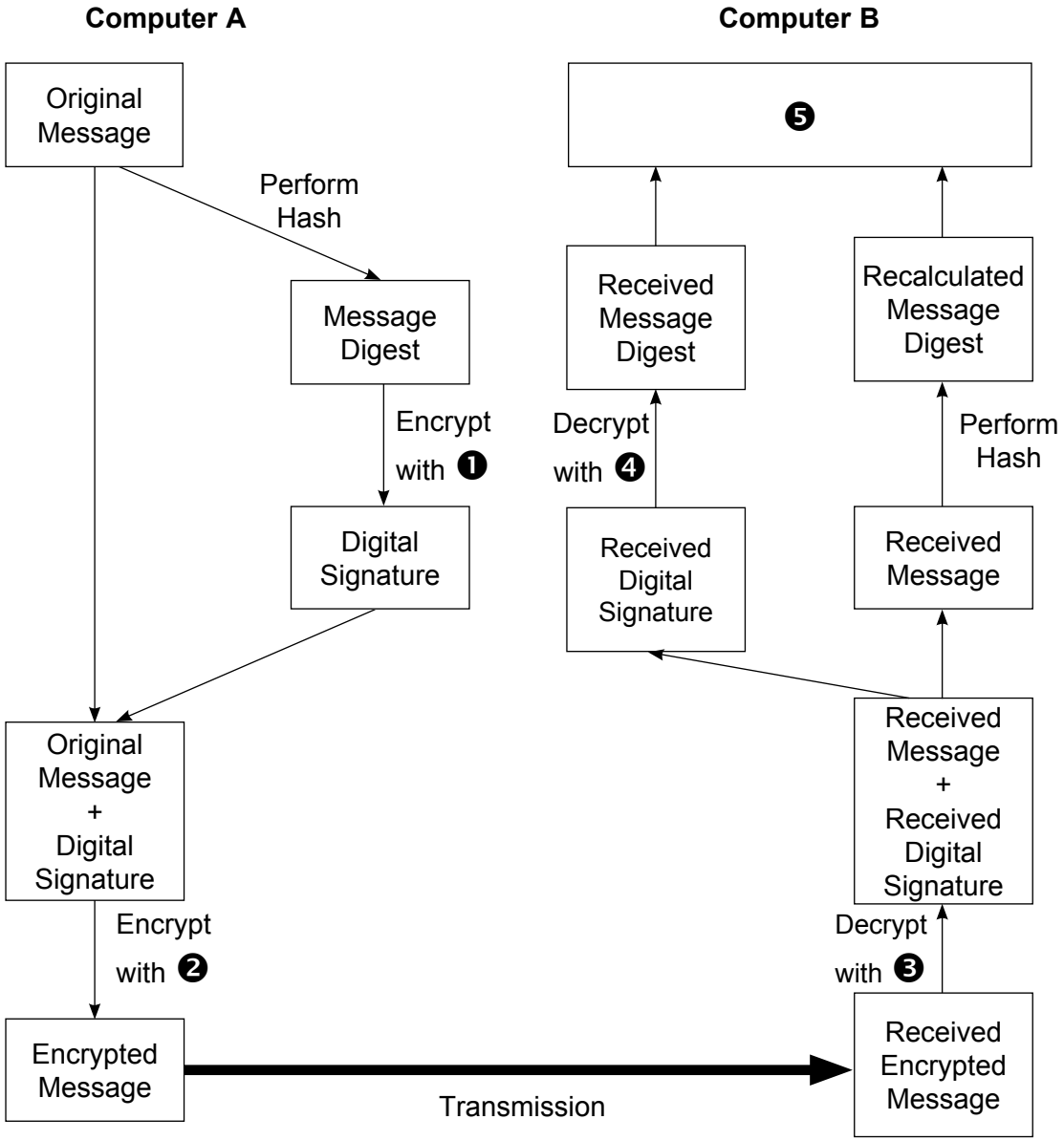
The data that are being transmitted will be encrypted and decrypted using public and private keys. **Figure 8** shows the encryption and decryption processes. The symbols ❶ to ❹ in the figure represent the names of keys.

Figure 8



9 (b) State the names of the keys that are represented by each of the symbols ❶ to ❹.

[2 marks]

Label	Key Name
❶	
❷	
❸	
❹	

9 (c) Describe the process that will take place at the position labelled ❺.

[1 mark]

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9 (d) State **two** purposes of the addition of the digital signature to the message.

[2 marks]

Purpose 1 .....

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Purpose 2 .....

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6

Turn over for the next question

10 David runs a beauty salon. He uses a database management system (DBMS) to store the information that he needs to manage his business. This information includes customer contact details, staff names, the treatments that the salon offers (for example, 'spray tan') and appointments that customers have made for treatments. A separate appointment must be made for each treatment.

The details are stored in a database using the following four relations:

Customer(CustomerID, Forename, Surname, TelephoneNumber, EmailAddress)

Staff(StaffID, Forename, Surname, IsQualified)

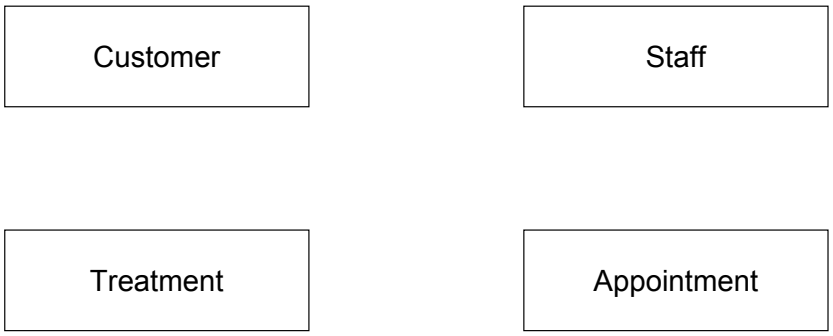
Treatment(TreatmentName, Price, TimeTaken, NeedsQualification)

Appointment(CustomerID, TreatmentName, ApDate, ApTime, StaffID)

- The IsQualified attribute for a member of staff stores one of the values True or False, to indicate if the member of staff is fully qualified or not.
- The NeedsQualification attribute for a treatment stores True or False, to indicate if the treatment can only be given by a qualified member of staff.
- The TimeTaken attribute for a treatment is the number of minutes (a whole number) that the treatment takes.

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

[2 marks]



10 (b) Complete the following Data Definition Language (DDL) statement to create the Treatment relation, including the key field.

[3 marks]

```
CREATE TABLE Treatment (
```

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.....)

10 (c) David wants to send e-mail advertisements to all his customers who had a 'Luxury Manicure' treatment in 2014.

To send the e-mail, the customers' e-mail addresses, forenames and surnames are needed.

Write an SQL query to retrieve the e-mail address, forename and surname of each customer to whom e-mails should be sent.

[6 marks]

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11

11 Problems can be classified into different categories based upon how efficiently they can be solved, or if they can be solved at all.

Three such classifications are:

- tractable
- intractable
- unsolvable.

11 (a) Explain what it means for a problem to be described as tractable.

[2 marks]

.....

.....

.....

11 (b) What approach(es) might a programmer take if asked to 'solve' an intractable problem?

[2 marks]

.....

.....

.....

.....

11 (c) Tick **one** row in **Table 5** to indicate which of the problems listed in the table is **unsolvable**.

[1 mark]

Table 5

Problem	**Unsolvable? (✓ one row)**
The problem of sorting a list into order	
The Halting problem	
The travelling salesman problem	

11 (d) Sometimes more than one algorithm exists to solve the same problem.

In such cases, a programmer may select the algorithm to use based upon the time and space complexity of the algorithm.

Table 6 below shows the order of time complexity of three different algorithms to solve a problem.

Tick **one** row in **Table 6** to indicate which of the algorithms is the **least time efficient**.

[1 mark]

Table 6

Order of Time Complexity	**Least Time Efficient? (✓ one row)**
$O(2^n)$	
$O(n)$	
$O(n^2)$	

6

Turn over for the next question

12 The Backus-Naur Form (BNF) production rules in **Figure 9** define the syntax of a number of programming language constructs.

Figure 9

```
<forloop>    ::= FOR <variable> = <integer> TO <integer>
<variable>   ::= <letter> | <letter> <string>
<string>     ::= <character> | <character> <string>
<integer>    ::= <digit> | <digit> <integer>
<character>  ::= <digit> | <letter>
<digit>      ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
```

A `<letter>` is any alphabetic character from `a` to `z` or `A` to `Z`.

12 (a) **Table 7** contains a list of variable names. Place a tick in each row if the stated variable name is a valid `<variable>` for the production rules in **Figure 9**.

You may tick **more than one** box.

[1 mark]

Table 7

<variable>	**Valid? (✓ any number of rows)**
a	
money_paid	
taxrate2	
2ndPlayerName	

12 (b) The production rule for an `<integer>` is recursive.

Explain why recursion has been used in this production rule.

[1 mark]

.....

.....

.....

12 (c) Here is an example of a valid <forloop> :

```
FOR count = 1 TO 10
```

The BNF production rules in **Figure 9** can be used to check whether or not a <forloop> is syntactically correct.

However, it is possible that a programming language statement that is a syntactically correct <forloop> may still produce an error when the program that it is part of is compiled.

Describe **one** example of why a syntactically correct <forloop> may still produce an error when a program is compiled.

[1 mark]

.....

.....

.....

.....

3

END OF QUESTIONS

There are no questions printed on this page

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