

NATIONAL JUNIOR COLLEGE
Mathematics Department

General Certificate of Education Advanced Level
Higher 2

COMPUTING

Written

9569/01

28 Aug 2023

3 hours

Additional Materials: Pre-printed A4 Answer Booklet

READ THESE INSTRUCTIONS FIRST

An answer booklet will be provided with the question paper. You should follow the instructions on the front cover of the answer booklet. If you need additional answer paper ask the invigilator for a continuation booklet.

There are 6 questions totalling 100 marks.

Answer **all** questions.

Approved calculators are allowed.

The number of marks is given in the brackets [] at the end of each question or part question.

This document consists of 10 printed pages and 2 blank page.

1 An Infrastructure as a Service (IaaS) provider, CloudCompute, is providing server and networking infrastructure resources on the Internet by offering the following services:

- Computing resources as Virtual Machines (VMs). They are offered with different configurations as follows:

Type	Resources	Price (USD)
Economy VM	1 virtual CPU and 8 GB of RAM	\$0.05/hour
Standard VM	2 virtual CPU and 16 GB of RAM	\$0.10/hour
Performance VM	4 virtual CPU and 32 GB RAM	\$0.40/hour

- Storage resources as Virtual Disks (VDs). They are offered with the following configurations:

Type	Size	Price(USD) Per Disk
Small	256 GB	\$10/month
Medium	512 GB	\$20/month
Large	1TB	\$40/month

- Internet access as Virtual Networks (VNETs). They are offered with different types of security implementations as follows:

Type	Description	Price(USD)
PRIVATE	One Private IP Address with a NAT	\$10/month
PUBLIC	One Public IP Address	\$ 50/month
FW	One Public IP Address with firewall.	\$100/month

Customers can purchase and deploy these resources via the CloudCompute web portal.

The portal requires customers to register for an account with the following information:

- Customer full name.
- Email address.

- Contact Number.
- Billing Address

A unique Customer Reference ID is generated for each registered customer.

The web portal requires a customer to purchase a VM first before he/she is given the option to purchase one or more VD's and VNet's to attach to the VM purchased. (i.e., VD and VNet cannot be purchased as standalone services). A VM can be purchased and deployed without attaching to any VD or VNet. Customers are billed at the end of the month based on the number of hours (rounded up) run by the VM and the additional resources purchased. A relational database system will be used to implement the billing system such that an invoice can be billed to a customer as follows:

CloudCompute

123 Hillcrest Road
Singapore 780901

888-888-8888
con@cc.com



Billed To
Ref 876542
Choy Boon An, Andy
789 Linden Drive
Singapore 780902

Invoice

Invoice Number
00231

Billing Month
March 2020

Item Description	Unit Cost/Hours used	HR RATE	Amount
(1) Virtual Machine Instance SGVM876 (STD)	100 hours	\$0.10	\$10.00
(2) Virtual Machine Instance SGVM004 (PER)	50 hours	\$0.40	\$20.00
(3) Virtual Disk SGVD981(S)	\$10	-	\$10.00
(4) Virtual Disk SGVD988(S)	\$10	-	\$10.00
(5) Virtual Network SGVNet092 (FW)	\$100	-	\$100.00

Subtotal \$150.00

Discount \$0

(Tax Rate) 8%

Tax \$12.00

Invoice Total
\$162.00

(a) Design and draw an Entity Relationship Diagram (ERD) to describe the data model in third normal form (3NF) for the system to be build. [4]

(b) Describe the tables for the ERD that you have drawn in **(a)**, in the form of [4]

`TableName(Attribute1, Attribute2, ...)`

The primary key is indicated by underlying one or more attributes. Foreign keys are indicated by an asterisk(*).

- (c)** What is an unnormalised database ?

What are the potential errors that may arise when you attempt to build an application to access an unnormalised database? [3]

- (d)** Write the SQL query to retrieve the required data from the relational database so that the monthly cost for all the Virtual Machines (VMs) purchased by a customer with reference id = 876542 can be itemised and calculated. You do not need to show how the monthly cost is calculated. [3]

- (e)** Write the SQL query to retrieve the required data from the relational database so that the monthly cost for all the Virtual Disks (VDs) and Virtual Networks (VNETs) purchased by a customer with reference id = 876542 can be itemised and calculated. You do not need to show how the monthly cost is calculated. [4]

- (f)** Due to the increase in utility cost, the price for all the different types of VM will be increase by 10%. Describe how you intend to make the changes in your database to avoid anomalies in the monthly billing process. [2]

- (g)** What are the data privacy issues that CloudCompute needs to address and implement when customers create and store their data on virtual disks provisioned on CloudComputer platform. [3]

Instead of using a relational database, CloudCompute is considering migrating its data to a NoSQL database.

- (h)** What is the difference between a NoSQL database and a relational database? [2]
- (i)** Give a potential competitive advantage that CloudCompute has over its business competitors if it migrates its data to a NoSQL database. [1]

- 2** In a typical binary search algorithm to search for the index of an integer stored in an Array that has been sorted in ascending order of the value of the integers, the approach is to divide the Array into two parts, partitioned by an index that divides the array roughly into two halves. The search is performed by repeatedly dividing the search space in half until the target integer value is found or it is determined that the value does not exist in the Array. An iterative algorithm can be described as follow where the function returns the index of the target in the Array or the value -1 when target is not found:

```

01  DEFINE FUNCTION bin_search(A:ARRAY[0:N-1] OF INTEGERS,
    target: INTEGER) RETURNS INTEGER
02      lb  $\leftarrow$  0
03      ub  $\leftarrow$  N-1
04      WHILE lb <= ub DO
05          mid  $\leftarrow$  (ub-lb) DIV 2 //INTEGER DIVISION
06          index  $\leftarrow$  lb + mid
07          IF target = A[index] THEN
08              RETURN index
09          ELIF target < A[index] THEN
10              ub  $\leftarrow$  index - 1
11          ELSE
12              lb  $\leftarrow$  index + 1
13      ENDWHILE
14      RETURN -1
END FUNCTION

```

A ternary search algorithm can be implemented by modifying the binary search algorithm shown above by dividing the Array into three parts instead of two and using two indexes instead of one. The search is performed by repeatedly dividing the search space into three parts until the target integer value is found or it is determined that the value does not exist in the Array.

- (a)** Using pseudo-code, describe this ternary search algorithm as a function:

```

FUNCTION ternary_search(A:ARRAY[0:N] OF INTEGERS, target)
    RETURNS INTEGER

```

[6]

- (b)** Use a trace table to trace the execution of your algorithm described in 2(a)

when the following function call is made:

```
ternary_search([6,10,27,57,82,83,98],10)
```

[5]

- (c)** Using run time complexity analysis, describe the efficiency of the ternary search algorithm described in 2(a). Explain the reasoning in your analysis. [2]

- (d) Compare the ternary search algorithm described in 2(a) with the binary search function, `bin_search()`, shown above. Explain whether the two algorithms have similar or different run time efficiency ? [3]

3 Two computing devices A and B need to exchange data between each other by sending and receiving messages over a packet switch network. Network software needs to be written, installed and run on the two computers.

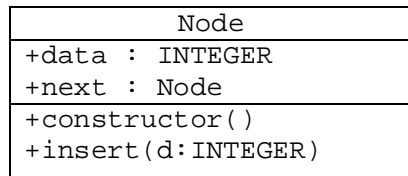
- (a) Describe two different network software architecture that can be implemented to run on the two computers for exchanging messages between each other. [2]
- (b) Explain the concept of packet switching in a network. [2]
- (c) What is the advantage of using a packet switching network over using a dedicated connection to connect device A to device B directly. [2]
- (d) Explain the difference between encoding/decoding a message and encrypting/decrypting a message. [2]
- (e) Describe and explain how two encryption/decryption techniques work. [2]
- (f) Describe a scenario where it is more appropriate to use encoding/decoding than encryption/decryption when device A needs to send a large amount of data to device B. [2]

A public key infrastructure (PKI) is used to manage the cryptography keys and certificates for devices A and B for secured network communication.

- (g) What are the keys to be generated and where should these keys be installed or deployed at ? [3]
- (h) What is the purpose of a digital certificate? [1]
- (i) Explain how a digital certificate for device A is generated? [2]

- 4 A linked list can be represented as a number of nodes each containing an item of data and a pointer to the next node. A head pointer indicates the location of the first node of the linked list. A value of `None` in a node's next pointer indicates the end of the linked list.

The UML class diagram of a `Node` abstract data type (ADT) can be described as:



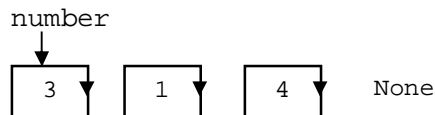
+ public accessibility

A linked list of nodes can be used to represent a positive integer value when each node in the linked list stored a single digit of the integer value.

The following pseudo-code creates a linked list and add three nodes to the linked list representing the integer value of 413_{10} :

```
number ← Node() //this creates an empty linked list
number.insert(3) // inserts a single decimal digit
number.insert(1)
number.insert(4)
```

The diagram below shows the head pointer, `number`, pointing to the nodes in the linked list.



Procedure `Z` is written to operate on a linked list described above.

```

01  PROCEDURE Z ( current: Node )
02      IF current.data = None THEN
03          OUTPUT("EMPTY LIST")
04          RETURN
05      ENDIF
06      IF current.next = None THEN
07          OUTPUT(current.data)
08      ELSE
09          CALL Z(current.next)
10          OUTPUT(current.data)
11      END IF
12  END PROCEDURE
```

- (a) State the purpose of procedure `z`. [1]
- (b) What are the line numbers that indicate that procedure `z` is a properly written recursive function? [2]
- (c) Two linked list, represented by the head pointers, `number_1` and `number_2` respectively, stored the values of two decimal integers. Using pseudo-code write a function:
- ```
FUNCTION add(number_1:Node, number_2:Node) RETURNS Node
```
- to return a link list representing the sum of the two linked list, `number_1` and `number_2`. [7]
- (d) An embedded computer system is a computer that is part of a larger system or machine. It's designed to perform a specific task and is often implemented with a very small memory footprint for compactness and efficiency. Nonnegative integer values are often stored in binary format on a fixed size 8 bits memory registers. On an embedded computer system, explain the advantages and disadvantages of using a linked list to represent a positive integer as a linked list of binary digits. [4]
- (e) State the three principles of Object-Oriented Programming (OOP). [3]
- (f) Based on the Node ADT shown above, explain how the code in procedure `z` violates the principle/s of OOP. [2]



- 5** On a computer system, characters are represented by an integer value. The ASCII and Unicode systems are two systems that can be used to represent characters.

**(a)** Explain how the ASCII system is used to represent characters. [1]

**(b)** Explain how the Unicode system is used to represent characters. [2]

Alice and Bob are working on a coding project together. Alice used a word processing software (which only supports the Unicode system) to write some Python code and saved it as a file in Unicode UTF-16 format. Alice passed the file to Bob for editing. Bob used a different software, a code editor (which only supports the ASCII system), to open the file. The code editor failed to open the file. Bob, then used his code editor to create a new file and re-write the Python code and saved it in a new file. Bob passed the new file to Alice. Alice is able to open the new file, edit and save the file.

**(c)** Explain why the file cannot be open by the code editor software used by Bob whereas Alice can use her word processing software to open and edit the new file created by Bob. [3]

**(d)** Explain how Alice can use her word processing software to create a file so that Bob can open and add his code to the file. [1]

- 6** A hash table can be implemented as a fixed size array for storing data. A hash function is often used in a hash table to locate storage space for a new record and searching for a specific record within the hash table.

**(a)** Describe three features of an effective hash function algorithm when it is used in a hash table described above ? [3]

**(b)** When new data needs to be added into a hash table, explain what happens when the hash function locate a storage space that has already being used to store existing data and what techniques can be used to resolve this situation. [4]

- (c) In cryptography, a hash function is also used to transform an input value into an output value in a process known as hashing. What are the two main features of the algorithm used in a cryptographic hash function ? [2]
- (d) A cryptographic hash function can be used to generate a digital signature. What is the purpose of a digital signature and explain how a digital signature is generated. [3]
- (e) In most web application, a user is often requested to enter a user id and password for authentication. Explain how a cryptographic hash function can be used to authenticate a user's password in a web application. [2]

**END OF PAPER**