| 2.1 Data structures, <br> abstract data types part $\mathbf{2}$ | Name: |  |
| :--- | :--- | :--- |
|  | Class: |  |
|  | Date: |  |

Time: 271 minutes

Marks: 178 marks

Comments:

Q1.
(a) In the context of data structures what is meant by the terms:
(i) FIFO; $\qquad$
(ii) LIFO?
(b) Queue and stack are examples of data structures. Tick in the following table to indicate whether they are FIFO or LIFO data structures.

(d) Describe one example of the use of a Binary Search Tree.
$\qquad$
$\qquad$

## Q2.

The following algorithm uses an array Values that contains the integers 4,7,9.
(a) Dry run this algorithm by using the trace table below.

```
Last \longleftarrow 
New }\longleftarrow
Ptr }\longleftarrow
```

```
WHILE (New > Values[Ptr])
    Ptr \longleftarrow Ptr + 1
ENDWHILE
WHILE (Last >= Ptr)
    Values[Last+1] \longleftarrow Values[Last]
    Last \longleftarrow Last - 1
ENDWHILE
Values[Ptr] \longleftarrow New
```

| New | Last | Ptr | Values |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $[1]$ | $[2]$ | $[3]$ | $[4]$ | $[5]$ |  |  |
| 6 | 3 | 1 | 4 | 7 | 9 |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

(b) What is the purpose of this algorithm?

(Total 7 marks)

## Q3.

Processes are rated in priority according to their expected running times. Processes with the shortest running times are given top priority. A process joining the list will be placed immediately after all other processes of equal or higher priority. The name of the process indicates the order in which it joined the list. Process6 joined the list before Process7.

The table below contains for each process its name, the memory address of its process control block, its expected running time and a pointer to the position in the table of the next process to be executed.

Processes are entered in the table wherever there is a free slot.
(i) Complete the pointer column after the following processes have been placed in the table:

HeadPointer $=6$

| Position | Name | Running Time | Address | Pointer |
| :---: | :---: | :---: | :---: | :---: |
| 1 | Process6 | 7 | 01400 |  |
| 2 |  |  |  |  |
| 3 | Process7 | 17 | 01700 |  |
| 4 | Process2 | 17 | 02300 |  |
| 5 | Process9 | 45 | 04100 |  |
| 6 | Process5 | 2 | 01200 |  |
| 7 |  |  |  |  |
| 8 | Process19 | 5 | 01900 |  |

(ii) The scheduler program is written in a high level language. Name and describe a suitable data structure for this table. $\square$

$\qquad$
$\qquad$

(iii) The Computer System Manager may wish to view the current order in which the runnable processes are predicted to run. Write an algorithm that will print the process names in runnable order.


Explain why the processes are in this list.
$\qquad$
$\qquad$
$\qquad$
$\qquad$

## Q4.

A multi-storey car park is controlled by a computer system as follows.
For a vehicle arriving at the barrier-controlled entrance:

- the computer system generates an integer number at random from a set of unused numbers which identifies the vehicle to the system
- the vehicle's driver collects a ticket containing this number from a machine at the barrier
- after a short interval a barrier is raised to enable the car to enter the car park
- the computer system remembers the current date, the arrival time and the randomly generated number.

If the car park is full a sign is lit to indicate the situation and no vehicle is allowed to enter the car park.

For a vehicle arriving at the barrier-controlled exit:

- the ticket is presented to a machine which reads the number on the ticket
- the computer system determines the length of time the vehicle has been parked in the car park and calculates the amount to pay
- the amount to pay is displayed on the machine
- the driver inserts the correct money into the machine
- the computer system records the length of time in minutes and the amount to pay in pence
- after a short interval the barrier is raised to enable the vehicle to exit.
(a) Taking account of the technology that could be used for ticket production at the entrance barrier, describe two different ways for the number assigned to the ticket to be submitted to the computer system at the exit barrier. Your answer should include a reference to the relevant input/output hardware used.

1. $\qquad$
$\qquad$
$\qquad$
2. $\qquad$
$\qquad$
$\qquad$
$\qquad$
(b) Using the table below, construct an appropriate record structure for the computer system to use to record the relevant car parking details for one vehicle. Data types should be given that would be available in a third generation programming language.

| Field Name |  | Data Type |
| :--- | :--- | :--- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Q5.
Describe how the elements in a non-empty queue are reversed with the aid of a stack
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(Total 4 marks)

## Q6.

The list Days contains the following representation of the days of the week.
[Sun, Mon, Tue, Wed, Thu, Fri, Sat]
The table below shows some functions which take a list as their single argument and
return a result which is either an element of a list, another list, or a Boolean value.

Head(list) - returns the element at the head of list (e.g. Head(Days) $\rightarrow$ Sun) if list is non empty otherwise it reports an error.

Tail(list) - returns a new list containing all but the first element of the original list (e.g. Tail(Days) $\rightarrow$ [Mon, Tue, Wed, Thu, Fri, Sat]) if list is non-empty otherwise it reports an error.

Empty(list) - returns True if list is the empty list or False otherwise. The empty list is denoted by[]
(a) What result is returned when the following function calls are made?
(i) Head (Tail(Days)) $\qquad$
(ii) Tail ([(Head(Days)]


(b) Explain why it is faster to access these elements if the above data is stored as a one dimensional array.


## Q7.

The algorithm below re-arranges numbers stored in a one-dimensional array called List.
Ptr is an integer variable used as an index (subscript) which identifies elements within
List. Temp is a variable, which is used as a temporary store for numbers from List.

```
    Ptr \longleftarrow I
While Ptr < 10 Do
    If List [Ptr] > List [Ptr+ 1] Then
        Temp \longleftarrow List [Ptr]
        List [Ptr] \longleftarrow List [Ptr+l]
        List [Ptr+l] \longleftarrow Temp
    Endif
    Ptr \longleftarrow Ptr+ 1
Endwhile
```

(a) Dry-run the algorithm by completing the table below,

It is only necessary to show those numbers which change at a particular step.

(b) What will happen when $\operatorname{Ptr}=10$ ?
(c) If the whole algorithm is now applied to this rearranged list, what will be the values of:
(i) List[1] $\qquad$
(ii) List[9] $\qquad$
(iii) List[10]? $\qquad$

Q8.
(a) (i) The birds Pheasant, Teal, Widgeon, Partridge, Woodpigeon are entered, in the order given, into a linked list so that they may be processed alphabetically. Draw this linked list.

(b) This linked list is said to be a dynamic structure. What is meant by the term dynamic structure?
$\qquad$
$\qquad$
(2)
(c) Explain how memory was allocated for the two additional data items.

## Q9.

The following data is input to a program, in alphabetical order, and is stored.
Anne
Bob
Claire
Dean
(a) Draw a diagram to show how this data is stored for:
(i) a stack;
(ii) a queue.

(b) One item is retrieved from these data structures for processing, and Eden is input.

Draw the diagrams of this new situation for:
(i) the stack;
(ii) the queue.
(c) Why are queues in computer systems usually implemented as circular queues?
$\qquad$
$\qquad$
 borrower code. This code is encoded magnetically on to an identity card issued to each borrower when they join the library. The code is read from the identity card by swiping it through a machine connected to the library's computer system. The code is also printed on the card in human-readable form.
EXAM PAPERS PRACTICE

## 


(a) Name the type of machine used to read the borrower code from the card.
(1)
(b) Each borrower code includes a check digit. What is a check digit and why is it used?
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(c) State one reason for having the human-readable form of the borrower code printed on the card.

Reason: $\qquad$
$\qquad$

Each book is allocated a unique book code. The book code together with other details as shown in Figure 2 are pasted on to the inside cover of the book. When a borrower borrows a book the book code is scanned into the computer system so that the loan can be recorded.

## Dingley Dell Town Lending Library

You may renew a book that you have borrowed by telephone.
The telephone number to use is 0129684545 .
$\qquad$
The art of Passing Computing Examinations by A. Studious

ISBN No 1-56592-488-3
Copy No 4


Book Code: 198-11926167-2420-4

Figure 2
(d) Name the device used to scan the book code into the computer system.
(e) Each loan is recorded in a separate record. All loan records are stored in a Loans file.

The loan record includes the following fields:
BookCode
BorrowerCode
DateBookToBeReturnedBy
(i) What is meant by primary key?

(f) At the end of each day the information stored in the Loans file is transferred to the Books file using sequential file access. The Books file contains a separate record for each copy of a book that the library stocks.

The book record includes the following fields:

## BookCode

BorrowerCode
LoanStatus
DateBookToBeReturnedBy
The Books file is organised sequentially. The field LoanStatus is used to record whether or not a book is currently on loan.
(i) Suggest a suitable field on which the Books file would be sorted.
(ii) Why should the Loans file be sorted and in what order, before the Books file is updated?

Reason: $\qquad$
$\qquad$
$\qquad$
Order: $\qquad$
(g) At the end of each day overdue books are identified. State the processing steps that need to be executed in the library's computer system to extract the loan details of books that have not been returned by the date recorded in the Books file and to record these details in a separate OverDueBooks file. State clearly the data that will be extracted.

Steps: $\qquad$
$\qquad$


Data: $\qquad$
$\qquad$
$\qquad$

## Q11.

The list Ports contains the following names:
[Southampton, Barcelona, Athens, Alexandria, Tunis, Lisbon]
The table below shows some functions which take a list as their single argument and return a result which is either an element of a list or a boolean value.

Head(list) - If the list is non-empty, it returns the element at the head of the list (e.g. Head (Ports) $\rightarrow$ Southampton) otherwise it reports an error

Tail(list) - If the list is non-empty it returns a new list containing all but the first element of the original list, otherwise it reports an error

Empty(list) - if the list is the empty list it returns True otherwise it returns False. The empty list is donated by [ ]
(a) What result is returned when the following function calls are made?
(i) Tail(Ports) $\qquad$
$\qquad$
(ii) $\quad \operatorname{Head}($ Tail(Tail(Ports)))


A recursively defined procedure P , which takes a list as its single parameter, is defined below.

```
    Define Procedure P(list)
    EXAMMPAPERS PRACTICE
        Print Head(list)
    EndIf
EndDefine
```

(b) What is meant by recursively defined?
$\qquad$
$\qquad$
(c) Explain why a stack is needed to execute procedure P recursively.
$\qquad$
$\qquad$
$\qquad$
(d) For the procedure call P (Ports) give the PRINTed output in the order in which it is produced.
$\qquad$
$\qquad$
(e) Complete the table to show the list Ports as a linked list so that the ports can be accessed in alphabetical order.


Q12.
(a) An example of an iteration in Pascal is:

FOR $x$ : = 1 TO 10 DO writeln ('Hello');
In a high level programming language you are familiar with, using the correct syntax, give an example of:
(i) declaration; $\qquad$
(ii) assignment; $\qquad$
(iii) selection. $\qquad$
(b) A one-dimensional array q contains the following characters:

| $q$ |
| :---: |
| $D$ |
| K |
| C |
| T |
| M |

[5]
(i) Dry run the following algorithm, recording your results in the diagram.


UNTIL pointer2 $=0$

| q |  |
| :---: | :---: |
| D | $[5]$ |
| K | $[4]$ |
|  | $[3]$ |
| $[2]$ |  |
|  | $[1]$ |


(ii) What is the purpose of the above algorithm?

## Q13.

Players, in a national lottery, show their selection of different numbers by placing marks on an entry form similar to the one shown in Figure 1. The entry form is then inserted into a machine at the point of sale and the numbers are read.


Figure 1
(a) Name the method being used to read the data.

The data are transmitted to a central computer which allocates a unique transaction code. This code is relayed back to the point of sale where a machine prints the chosen numbers and a transaction code onto the ticket similar to the one shown in Figure 2.

## National Lottery Ticket

Transaction code 198-11926167-2420-4
 $\begin{array}{llllllll}\text { Chosen Numbers } & 06 & 14 & 21 & 32 & 43 & 44\end{array}$

Wed 16 Aug 00
£ 1.00

Point of Sale No. 106320


198-11926167-2420-4

Figure 2
(b) Each transaction code includes a check digit. What is a check digit and why is it used?
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(c) Each transaction is recorded in a separate record. All transaction records for a particular lottery draw are stored in a single transaction file.

The transaction record includes the following fields:
Date of Purchase
Date of Draw
Point of Sale Identification Code
Transaction Code
Chosen Numbers
(i) What is meant by primary key?
(ii) Which of the above fields should be chosen as the primary key?

(iii) What would be a suitable file organisation for the transaction file if it is required that the ticket(s) with the winning numbers is to be found? Justify your choice.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(iv) If individual records need to be accessed quickly what file organisation should be used? Justify your choice.
(d) After a draw, some lottery prize-winners can check their tickets at any lottery point of sale machine. State the processing steps required by the lottery's computer system to check if the ticket is a winning ticket.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$

Q14.


The memory of a computer holds an array of records, each of which includes name, address and other information.
(a) What condition is necessary for the binary search (binary chop) process to work correctly?
$\qquad$
$\qquad$
(b) Describe this process to find the position in the array of the record containing a given name.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(c) Why is this search method normally faster than a linear search?
$\qquad$
$\qquad$
$\qquad$
$\qquad$

## Q15.



The plan below shows the layout of the Mass Transit Railway (MTR) in Hong Kong. The maintenance depot is at Mong Kok.


All the trains operate the same cycle (sequence) of journeys, given by the algorithm below. The algorithm is intended to ensure that:

1. trains are serviced as soon as possible after covering 135 km , and
2. each train will have travelled in both directions along each track at least once in the cycle.

The algorithm relates to three arrays called station, journey and km . The contents of these arrays are shown below.


The $6 \times 6$ two-dimensional array $\mathbf{k m}$, representing the distance between stations (in kilometres), contains

| Second Subscript | First subscript |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | km | 0 | 1 | 2 | 3 | 4 | 5 |
|  | 0 | 0 | 22 | 28 | 15 | 36 | 12 |
|  | 1 | 22 | 0 | 50 | 37 | 58 | 34 |
|  | 2 | 28 | 50 | 0 | 43 | 64 | 40 |
|  | 3 | 15 | 37 | 43 | 0 | 27 | 3 |
|  | 4 | 36 | 58 | 64 | 27 | 0 | 24 |
|  | 5 | 12 | 34 | 40 | 3 | 24 | 0 |

The proposed algorithm is:

```
    org:=0
last := 1
dest:= 3
maintain := FALSE
start := station[org]
finish := station[dest]
totalkm := km [org, dest]
org := dest
while(TRUE)
n := 0
repeat
\begin{array} { l } { n : = n + 1 } \\ { \text { if (maintain = TRUE) then } } \end{array}
        endif
        dest := journey [n]
if (totalkm > 135) then
            dest := 0
last := n
maintain := TRUE
endif
    start := station[org]
finish := station[dest]
totalkm := totalkm + km[org, dest]
org := dest
until n >= 6
```

endwhile
(a) What is the effect of the instructions while(TRUE) and endwhile?
$\qquad$
$\qquad$
(b) For each of the variables maintain and $n$, state with a reason what data type it should be.
$\qquad$
$\qquad$
$\qquad$

(c) Copy and complete the trace table below, for one iteration of the outer (while .... endwhile) loop.

| n | org | dest | last | Start | Finish | Totalkm | maintain | comments |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0 |  |  |  |  |  |  |  |
|  |  |  | 1 |  |  |  |  |  |
|  |  | 3 |  |  |  |  | FALSE |  |
|  |  |  |  | MK |  |  |  |  |
|  |  |  |  |  | SW |  |  |  |
|  |  |  |  |  |  | 15 |  |  |
|  |  |  |  |  |  |  |  |  |

(d) An objective of the algorithm is that each train has travelled in both directions along every track at least once in the cycle. Using your trace table, state, with reasons, whether this objective has been achieved.


Data is held in a linked list. The array animals contain records with the content shown.

2.A.M| | Subscript | Data | Pointer |
| :---: | :---: | :---: |
| 1 | Elephant |  |
| 2 | Deer |  |
| 3 | Bear |  |
| 4 | Rabbit |  |
| 5 | Cow |  |
| 6 |  |  |

(a) Give the values that would be needed in the pointer field of each non-empty record to produce a list in alphabetical order. A pointer value of zero indicates the end of the list.
(b) The variables Start and Freestorage are used to point to the start of the list and the next free space, respectively. What values should they contain?
$\qquad$
$\qquad$
(c) Describe the steps needed to add "Monkey" to the list.
$\qquad$
$\qquad$


## Q17.

(a) Draw a diagram to show the structure of a queue.

PRACTICE
(b) Write an algorithm to show how a data item is added to a queue. Take into account the possibility that the queue is full.

$\qquad$
$\qquad$
(Total 4 marks)

