NAME:

ALGORITHMICS UNIT 3 & 4

CHES Trial Exam 1: 2023

Seminar 4 – Thursday 28th September 2023

Reading Time: 15 minutes
Writing time: 120 minutes (2 hours)

QUESTION AND ANSWER BOOK

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	8	8	80

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape

Materials supplied

- Question and answer book of ?? pages
- Answer sheet for multiple-choice questions

Instructions

- Write your student number in the space provided above on this page.
- Check that your name and student number as printed on your answer sheet for multiple-choice questions are correct, and sign you name in the space provided to verify this.

- All written responses must be in English, point form is preferred.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the test room.

IMPORTANT NOTE: The VCAA Exam will include the Master Theorem in this form.

the Master Theorem for solving recurrence relations of the form:

$$T(n) = \begin{cases} a \cdot T\left(\frac{n}{b}\right) + kn^c & \text{if } n > 1 \\ d & \text{if } n = 1 \end{cases}$$

where $a > 0, b > 1, c \geq 0, d \geq 0, k > 0$

and its solution: $T(n) = \begin{cases} O(n^c) & \text{if } a < b^c \\ O(n^c \log(n)) & \text{if } a = b^c \\ O\left(n^{\log_b(a)}\right) & \text{if } a > b^c \end{cases}$

The VCAA form of Master Theorem is equivalent to the form of Master Theorem taught in our class:

$$a = b^c \Leftrightarrow \frac{a}{b^c} = 1$$

$$a < b^c \Leftrightarrow \frac{a}{b^c} < 1$$

$$a > b^c \Leftrightarrow \frac{a}{b^c} > 1$$

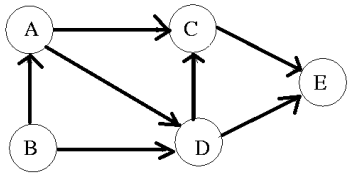
$T(n) = aT\left(\frac{n}{b}\right) + f(n^k)$

- $\frac{a}{b^k} < 1$ then $O(n^k)$
- $\frac{a}{b^k} = 1$ then $O(n^k \log_b n)$
- $\frac{a}{b^k} > 1$ then $O(n^{\log_b a})$

SECTION A – Multiple Choice – select one option only

Question 1

Consider the following Digraph:



A topological sort can be found because:

A. The directed graph is connected and only has directed acyclic components.

B. The directed graph is complete and has a cycle.

C. The directed graph is connected and has a cycle.

D. The directed graph is complete and has does not contain a cycle.

Question 2

The diameter or width of a graph G is:

A. the length of the shortest path between any two nodes

B. the largest distance between any pair of vertices. If G is disconnected, then its diameter is infinite.

C. the number of edges in a circuit, or cycle in the graph

D. a tour of a graph G which contains every edge of G.

Question 3

Which of the following is not a transparency issue in AI?

A. The ability to explain how an AI system makes decisions

B. The ability to access the data that an AI system is trained on

C. The ability to audit an AI system for bias

D. The ability to control the use of an AI system

Question 4

Q.enqueue(6)
Q.enqueue(3)
Q.dequeue( )
Q.enqueue(2)
Q.dequeue( )

Given an empty queue Q, what does Q look like after the operations above?

A. 6

B. 3

C. 2

D. It is empty

Question 5

What is the result of the following ABC recursive algorithm?

```
Function ABC(input number)
   If (number < 2) then
       Report number
   Else
       Report number + ABC(round(0.5*number))
   End if
End function
```

When called with **ABC(32):**

A. 32+16+8+4+2+1

B. 32+32+32+32+32+32

C. 32+18+9+5+3+1

D. 1+2+4+6+16+32

Question 6

Here are the steps involved in training a neural network using stochastic gradient descent:

1. Initialize the weights of the neural network to random values.
2. Randomly sample a batch of data from the training set.
3. Calculate the gradient of the loss function with respect to the weights of the neural network.
4. _____
5. Repeat steps 2-4 until the loss function converges to a minimum value.

What is the missing step 4. ?

A. Calibrate the weights of the neural network to previous values.

B. Randomly adjust the weights of the neural network to a cooling temperature schedule.

C. Backtrack to the global minimum of the loss function.

D. Update the weights of the neural network in the direction of the gradient.

Question 7

When considering different types of algorithms, which one of the following statements is **true**?

A. Divide and conquer algorithms are always faster than greedy algorithms for the same problem.

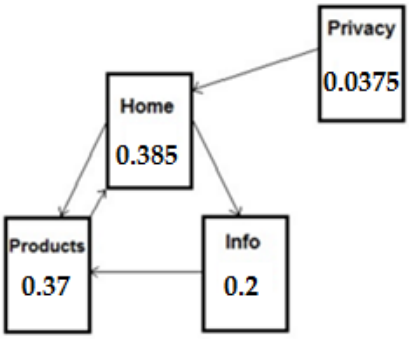
B. Greedy algorithms are always faster than divide and conquer algorithms for the same problem.

C. Greedy algorithms give good approximate answers to problems, but never the best possible answer.

D. Brute-force algorithms can never be faster than a well-designed greedy algorithm for the same problem.

Question 8

Consider the following web page system with an associated page rank value shown on each page. These values add up to 1 approximately.



The page rank for the **Products** page would be determined by which of the following recurrence formulas?

A. $\Pr(\text{Products}_{i+1}) = \frac{0.15}{4} + 0.85(\Pr(\text{Info}_i) + \Pr(\text{Home}_i))$, *where* $\Pr(\text{Info}_0) = \Pr(\text{Home}_0) = \frac{1}{4}$

B. $\Pr(\text{Products}_{i+1}) = \frac{0.15}{4} + 0.85\left(\Pr(\text{Info}_i) + \frac{1}{2}\Pr(\text{Home}_i) + \frac{1}{4}\Pr(\text{Product}_i)\right)$, *where* $\Pr(\text{Info}_0) = \Pr(\text{Home}_0) = \Pr(\text{Product}_0) = \frac{1}{4}$

C. $\Pr(\text{Products}_{i+1}) = \frac{0.15}{4} + 0.85\left(\Pr(\text{Info}_i) + \frac{1}{3}\Pr(\text{Home}_i)\right)$, *where* $\Pr(\text{Info}_0) = \Pr(\text{Home}_0) = \frac{1}{3}$

D. $\Pr(\text{Products}_{i+1}) = \frac{0.15}{4} + 0.85\left(\Pr(\text{Info}_i) + \frac{1}{2}\Pr(\text{Home}_i)\right)$, *where* $\Pr(\text{Info}_0) = \Pr(\text{Home}_0) = \frac{1}{4}$

Question 9

Algorithm XYZ has the following worst time complexity $O(2^n)$. According to Cobham's thesis this algorithm is:

A. Tractable

B. Feasible

C. Non-computable

D. Intractable

Question 10

Uncomputable functions correspond to problems that are called:

A. Undecidable

B. Intractable

C. Polynomial time

D. none of these

Question 11

Dijkstra's single-source shortest path algorithm in an undirected graph reports distances from the source to each node. These distances ……

A. are the shortest possible distances to every destination node.

B. are never the shortest possible distances when negative edge weights are present.

C. may be the shortest possible distances when negative edge weights are present.

D. may not always be the shortest possible distances when all edge weights are positive.

Question 12

What does it mean when we say that an algorithm X is asymptotically more efficient than Y?

A. X will be a better choice for all inputs

B. X will be a better choice for all inputs except small inputs

C. X will be a better choice for all inputs except large inputs

D. Y will be a better choice for small inputs

Question 13

The following data shows running times (in microseconds) for a new algorithm compared with a standard baseline algorithm, where n is a measure of the size of the input to the problem.

n	Baseline	New algorithm
1	5	3
10	105	53
100	1998	103
1000	29 902	152
10 000	398 636	202

Which Big-O expression most closely describes the running time of the baseline algorithm?

A. $O(n)$

B. $O(n^2)$

C. $O(\log n)$

D. $O(n \log n)$

Question 14

For Graph Colouring, we wish to assign the minimum number of colours, to the nodes, where neigbouring nodes cannot have the same colour, the following algorithm is using the Greedy strategy.

1. *Create a list of nodes in order of degree descending*
2. *Pick a new colour C*
3. *Go through the list, colouring each node not connected to coloured nodes with [……..]*
4. *Remove the coloured nodes from the list and repeat from step 2 until all the list is empty*

The missing action in the pseudocode is:

A. A different colour

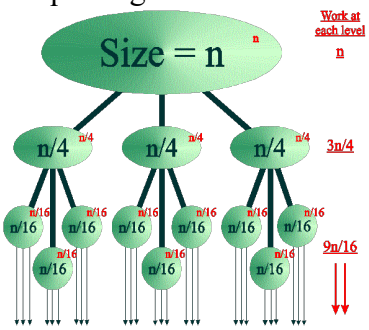
B. The same colour

C. A random colour

D. The colour C

Question 15

The call tree for a recursive divide & conquer algorithm is shown below:



The time complexity recurrence relation and the time complexity for this algorithm respectively are:

A. $T(n) = 4T(n/3) + f(n^1), O(n^{log(4)})$

B. $T(n) = 3T(n/4) + f(n^0), O(n^{log(3)})$

C. $T(n) = 3T(n/4) + f(n^1), O(n)$

D. $T(n) = 3T(n-1) + f(n^1), O(3^n)$

Question 16

Which of the following statements ***is not true***?

A. Every recursive method must have a base case or a stopping condition.

B. Every recursive call reduces the original problem, bringing it increasingly closer to a base case until it becomes that case.

C. Infinite recursion can occur if recursion does not reduce the problem in a manner that allows it to eventually converge into the base case.

D. Every recursive method must have a return value.

Question 17

What is the missing pseudocode to complete the following function for computing factorials?

```
Function factorial(Input n)
   if (n is equal to 0) then
     return 1
   else
     return _____________
   end if
End function
```

A. n * (n - 1)

B. n

C. n * factorial(n - 1)

D. n + factorial(n - 1)

Question 18

Consider the following algorithms X and Y that have triple nested loops, what would the algorithm complexity be for each algorithm?

Algorithm X (input n)	**Algorithm Y (input n)**

`Sum:=0`
`For i=1 to n do`
`  For j=1 to n do`
`  For k=1 to n do`
`  Sum:=Sum + 1`
`  End do`
`  End do`
`End do`
`End Algorithm`
	`Sum:=0`
	`For i=1 to n do`
	`  For j=1 to n do`
	`  For k=1 to n do`
	`  Mergesort(an Array of size n)`
	`  End do`
	`  End do`
	`End do`
	`End Algorithm`

A. Algorithm X has time complexity $O(n^3)$, Algorithm Y has time complexity $O(n^3)$

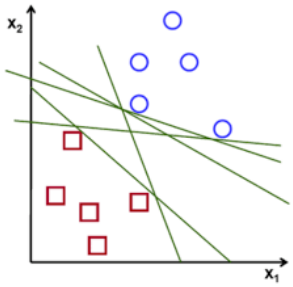
B. Algorithm X has time complexity $O(n^3)$, Algorithm Y has time complexity $O(n^4 \log n)$

C. Algorithm X has time complexity $O(n^3)$, Algorithm Y has time complexity $O(n^4)$

D. Algorithm X has time complexity $O(n^3)$, Algorithm Y has time complexity $O(n^3 \log n)$

Question 19

Where does a SVM draw its classification line using a linear kernel?



A. A best fit regression line through the data points

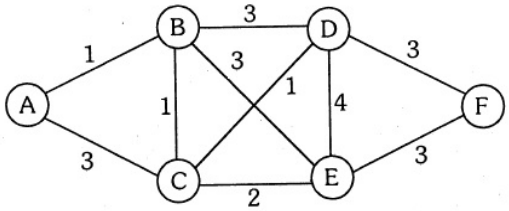
B. Equidistant between the support vectors identifying the cluster boundaries

C. Across the margin classifier of separation of the clusters

D. Through the maximum kernel function applied to the data points

Question 20

Dijkstra's algorithm on the following graph from node A explores the nodes in order:



A. A,B,C,D,E,F

B. A,C,B,E,D,F

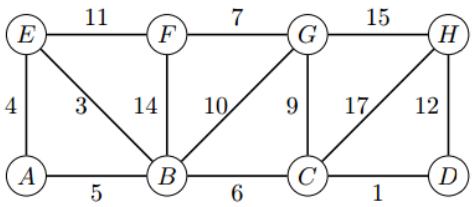
C. A,B,C,E,D,F

D. A,C,B,D,E,F

SECTION B – Extended Response Questions Answer all questions in the space provided.

Question 1 (9 marks)

a) Explain the main difference between DFS, BFS and Best-First Search graph traversal algorithms, in particular discuss the difference in each algorithm structure and abstract data types used by each algorithm. (3 marks)



b) Starting at node A, run the Depth First Search algorithm to node G on the graph shown, listing the order of nodes visited in alphabetic order where possible. (1 mark)

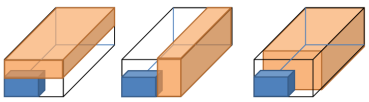
c) Starting at node A, run the Breadth First Search algorithm to node G on the graph shown, listing the order of nodes visited in alphabetic order where possible. (1 mark)

d) Starting at node A, run the Best First Search algorithm using the edge weights as rankings to node G on the graph shown, listing the order of nodes visited in alphabetic order where possible. (1 mark)

e) Describe how the A* Search algorithm would work to find a path from node A to node D using a heuristic cost stored on each node such as h(A), h(B), h(C)…etc, outlining any assumptions about the heuristic cost. (3 marks)

Question 2 (9 marks)

In the bin packing decision problem, objects of different volumes must be packed into a fixed number of bins each of given volume V1, V2, Vn.



a) In computational complexity theory this bin packing problem is classified as NP-Hard or NP-complete. Explain why this problem has two classifications and describe the circumstances for each of the classifications. (4 marks)

b) Describe in structured pseudocode how a Simulated Annealing Heuristic algorithm could be set up to solve the Bin packing problem described above. (5 marks)

Question 3 (9 marks)

While clearly identifying the base case(s) and recurring case(s), define in structured pseudocode Decrease & Conquer recursive algorithms to calculate:

a) The sum of two integers m,n, here is the hybrid function defined in mathematical notation: (2 marks)

$$s(m,n) = \begin{cases} m & ,where\ n = 0 \\ 1 + s(m, n-1) & ,where\ n > 0 \end{cases}$$

b) The power of m to n, where m is an integer m and n is a positive integer n. (3 marks)

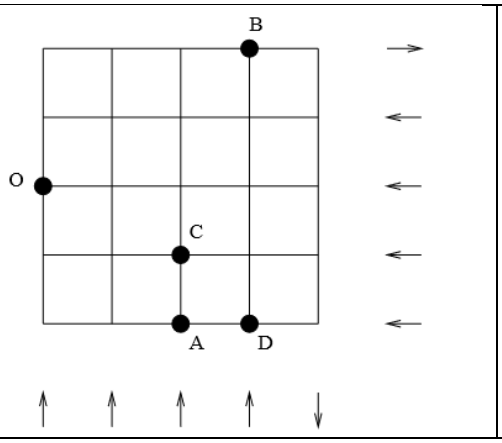
$$power(m,n) = \begin{cases} 1 & ,where\ n = 0 \\ m & ,where\ n = 1 \\ m \times power(m, n-1), & where\ n > 0 \end{cases}$$

c) Create a clear proof by Induction showing the correctness of the recursive Topological Sort algorithm for input from directed graphs depicting dependant tasks. (4 marks)


```
Algorithm topologicalSort(G, sourceNodes)
// G input acyclic, directed graph
// sourceNodes a list that was initially empty
// Assumption: at least one source node in G
  if (|V|> 0) then
      foreach node n in G.V do
          if (in_degree(n) == 0) then
              print('Source Node ‘, n)
              append node n to sourceNodes
          end if
      end do
      Append SourceNodes to TopoList
      Remove nodes in sourceNodes from G // Layers
      topologicalSort(G, sourceNodes)    // recur on graph
  else
    print('Base Case Stop Recursion’)
  end if
End Algorithm
```

Question 4 (7 marks)

a) Below is a map of Oneway City, a poorly planned town with one-way streets as indicated. Represent the information for Oneway City using fit for purpose abstract data type. (2 marks)



b) Draw the complete directed graph with vertices corresponding to O, A, B, and C (ignore D for now) and two edges between each pair of vertices, one in each direction. Label each with the distance (number of blocks) one must travel to get from one location to the other. For example, the distance from A to C is 1 block and from C to A is 11 blocks. (2 marks)

c) Suppose a delivery van leaving from O visits locations A, B, C, and D. Use Dijkstra's algorithm to find the shortest route from O to any of A, B, C and D. Show the workings that you calculated together with predecessor nodes in finding this route. (3 marks)

Question 5 (12 marks)

a) What are the main differences between solving a problem using a traditional algorithm and using a neural network? (2 marks)

b) What are the main components of designing neural networks? (3 marks)

c) What type of Machine Learning is a Neural Network? Justify your response. (2 marks)

d) Describe how a neural network is trained and what methods are used to minimise errors and then how are they used to solve problems (2 marks)

e) A neural network has been trained to understand written Chinese and respond to questions using written Chinese? Discuss if there would be any implications for Searle's views on Artificial intelligence by referencing the neural network model. (3 marks)

Question 6 (8 marks)

a. The following Quicksort algorithm calls the partition module to sort data. Complete the missing lines of the algorithms. (2 marks)

```
Algorithm Quicksort(A, low, high)
// Input A, array of numbers
// Input low, an index into the array A
// Input high, an index into the array A
   if (low < high) then
      p := Partition(A, low, high)
      Quicksort(A, low, p – 1)
      [redacted]
   end if
End Algorithm
```

```
Algorithm Partition(A, low, high)
// Input A, array of numbers
// Input low, an index into the array A
// Input high, an index into the array A
   pivot := A[high]
   i := lo - 1
   for j := low to high - 1 do
      if A[j] < pivot then
         i := i + 1
         [redacted]
      end if
   end do
// move the pivot to the correct position
   i := i + 1
   swap A[high] with A[i]
   return i  // pivot index
End Algorithm
```

b. What design pattern is used by the Quicksort algorithm? Justify and describe which parts of the algorithm inform about the design pattern used. (2 marks)

c. What is the time complexity of the helper Partition function? Justify your response. (2 marks)

d. What is the best case and worst case time and space complexity for the algorithm shown? Justify your responses using appropriate time complexity recurrence relations. (2 marks)

Question 7 (10 marks)

A Latin square is an array of k elements by k elements with some values already set.

For some Latin squares the goal is to have the integers 1 to k appear once in each row and once in each column.

Two examples of a completed k=5 numeric Latin Square is shown at right.

$$\begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 2 & 3 & 5 & 1 & 4 \\ 3 & 5 & 4 & 2 & 1 \\ 4 & 1 & 2 & 5 & 3 \\ 5 & 4 & 1 & 3 & 2 \end{bmatrix} \quad \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 2 & 4 & 1 & 5 & 3 \\ 3 & 5 & 4 & 2 & 1 \\ 4 & 1 & 5 & 3 & 2 \\ 5 & 3 & 2 & 1 & 4 \end{bmatrix}$$

a) Write a clearly defined modular algorithm using **structured pseudocode with one or more helper function(s)** to validate and check that a completed Latin square provided as input of dimension k by k has been completed correctly and has the digits 1..k in each row and also in each column once only.

(4 marks)

b) What is the time complexity of the algorithm that you have defined in part a)? Justify your answer with reference to part a).

(2 marks)

Question 7 (continued)

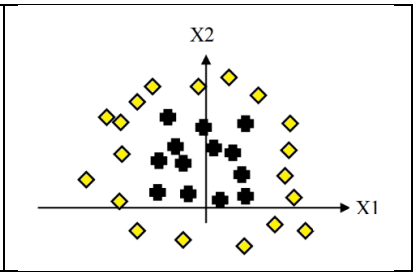
c) Describe and demonstrate how solving a 3 x 3 Latin square problem can be set up and completed by filling in the digits 1,2,3 as a minimum colour graph colouring problem.

(2 marks)

d) What is the complexity class of completing a Latin Square puzzle problem with digits 1..k? Justify your response. (2 marks)

Question 8 (8 marks)

Suppose that we want to classify two dimensional data (i.e., X = [x1, x2]) into two classes: diamonds and crosses. We have a set of training data that is plotted as follows:



a) Can a single perceptron separate the data for the diamonds and the crosses? Explain why or why not and justify your response. (2 marks)

b) Describe the Support Vector Machine algorithm used in Artificial Intelligence. (2 marks)

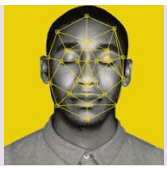
Question 8 (continued)

c) Draw a labelled diagram representing the components of the Support Vector Machine. (2 marks)

d) Can a Support Vector Machine (SVM) machine learning algorithm classify this data from part a)? Explain why or why not and justify your response (diagrams accepted). (2 marks)

Question 9 (8 marks)

Scenario 1: A company is behind schedule and over budget in building an AI application.
The AI uses facial recognition to unlock a smartphone.
Through testing the company found that the AI worked on **most** people's faces.



a) What ethical issues can arise if the company in Scenario 1 goes ahead and decides to sell the phone and fix the AI problems in the next version of the phone? (2 marks)

Question 9 (continued)

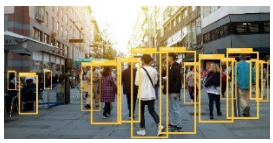
Scenario 2: An employee working for a company on an AI project finds out that the AI application could be hacked and used for criminal purposes.
The manager of the project instructs the employee to ignore it, saying 'Don't worry, that won't happen!'

b) What ethical issues that can arise in Scenario 2? What are the potential negative impacts that can arise?
(2 marks)

Scenario 3: The artwork has been generated using AI and is called "Melbourne skyline in the style of Picasso and Van Gogh" it is being printed on tourist merchandise and sold for commercial gain. Van Gogh work is in the public domain. To reproduce and/or depict works by Picasso, you will need the prior written consent of the Picasso Administration, the company representing the artist's rights holders.

c) What are the ethical issues that can arise in Scenario 3? What are the negative impacts that can arise?
(2 marks)

Scenario 4: A university campus has installed a AI surveillance system that monitors activities in various public areas of the campus to detect intruders, unauthorised visitors and combat petty crime and graffiti.



d) What are the ethical issues that can arise in Scenario 4? What are the benefits and drawbacks potentially arising from the use of AI in Scenario 4? (2 marks)

END OF TRIAL EXAM 1