



UNIVERSITY OF MORATUWA

FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

BSc Engineering Honours Degree

2017 Intake Semester 2 Examination & 2016 Intake Semester 4 Examination

CS2022: DATA STRUCTURES & ALGORITHMS

Time allowed: 2 Hours

December 2018

ADDITIONAL MATERIAL: *None*

INSTRUCTIONS TO CANDIDATES:

1. This paper consists of **two (3) Sections** in **14** pages.
2. Answer **all** questions in the question paper itself **in the space provided**. If you make a mistake or need additional space you may attach additional sheets.
3. Section A contains **fifteen (15) MCQ and short answer questions**. Answer these questions in the space provided in the paper.
4. **For each MCQ question** in section A, there is **only one correct answer** and you are expected to **clearly mark only one choice**.
5. Each question in section A carries 2 marks.
6. Each question in section B carries 4 marks.
7. Section C contains **two (2)** essay type questions.
8. The maximum attainable mark for each question in section B is given in brackets.
9. The maximum attainable mark for this paper is 100. This examination accounts for 60% of the module assessment.
10. This is a an open for limited content examination. You are authorized to bring 3 (three) A4 page (both side) to the examination and refer to it during the examination if required.
NB: It is an offence to be in possession of unauthorized material during the examination.
11. Only calculators approved and labelled by the Faculty of Engineering are permitted.
12. Assume reasonable values for any data not given in or with the examination paper. Clearly state such assumptions made on the script.
13. In case of any doubt as to the interpretation of the wording of a question, make suitable assumptions and clearly state them on the script.
14. This paper should be answered only in English.

SECTION A

For multiple choice questions underline the appropriate answer.

- (1) Two main measures for the efficiency of an algorithm are
 A. Processor and memory. B. Complexity and capacity
C. Time and space D. Data and space
- (2) The Worst case occur in linear search algorithm **only** when
 A. item is somewhere in the middle of the array
 B. Item is not in the array at all
 C. Item is the last element in the array
D. Item is the last element in the array or is not there at all

Consider the following graph in answering questions 3 to 5.

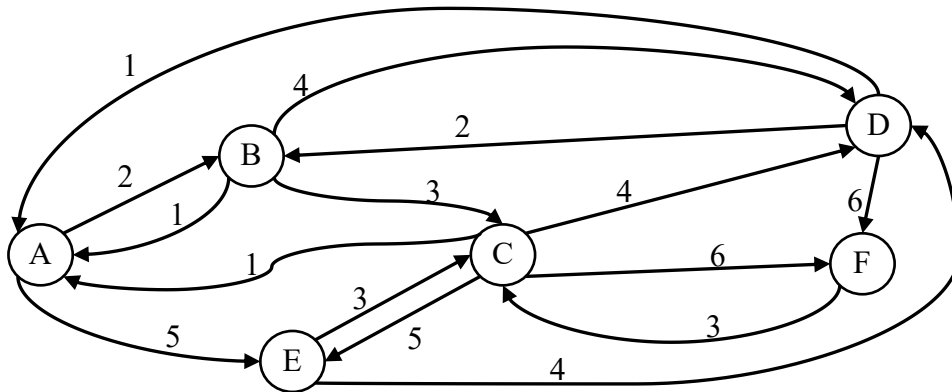


Figure 1

- (3) Which of the following statements are correct regarding the graph in figure 1?
- I. In-degree of the vertex D is three. ✓
 - II. The degree of the vertex E is two. ✗
 - III. The graph is a strongly connected graph. ✓
 - IV. The graph is a directed acyclic graph ✗
- a) Only I and II d) All four are correct
 b) Only II and III e) None of the above answers
c) Only I and III
- (4) The breadth first search (BFS) starts at Node A of graph in figure 1 resulted in the sequence A, (B, E), (C, D, F). Brackets indicate sub-sequences that could be in any order. Write a resulting sequence if the BFS starts at Node B.

B, (A, C, D), (E, F)

- (5) Which of the following sequences are possible if we perform depth first search for the graph provided in figure 1 starting from Node E.

- I. E, D, F, C, A, B ✓
- II. E, C, D, A, B, F ✓
- III. E, C, A, B, D, F ✓

- a) Only I
- b) Only II
- c) Only II
- d) All three
- e) None of the above

- (6) Show a minimum spanning tree generated by Prim's algorithm of the graph shown in figure 2, assuming the initial vertex selected is A. (You are only required to highlight the selected edges in order.)

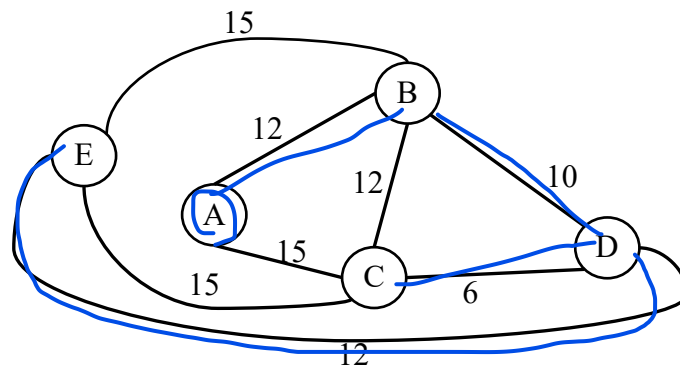


Figure 2

A-B, B-D, C-D, D-E

- (7) Given $f(x) = 5x^3 + 25x$ and $g(x) = 350x^3 + 4234x^2 + 51x + 6$ and $h(x) = x^4 + 5x^2 + 24$, which of the following statements are true?

- I. Functions $g(x)$ and $h(x)$ are in the set $O(x^5)$. ✓
- II. Functions $g(x)$ and $h(x)$ are in the set $\omega(f(x))$. ✗
- III. Functions $f(x)$ and $g(x)$ are in the set $o(h(x))$. ✓

- a) Only I and II
- b) Only II and III
- c) Only I and III
- d) All three are correct
- e) None of the above answers

(8) If the pre-order traversal of a complete binary tree resulted in **A, B, D, E, C, F, G** the post-order traversal will definitely result in

- a) ~~D, E, B, F, G, C, A.~~
- b) ~~A, B, C, D, E, F, G.~~
- c) G, F, C, E, D, B, A.
- d) Cannot say for sure.

(9) Consider an implementation of unsorted singly linked list. Suppose it has its representation with a head pointer only. Given the representation, which of the following operation can be implemented in $O(1)$ time?

- I. Insertion at the front of the linked list ✓
 - II. Insertion at the end of the linked list $\times O(n)$
 - III. Deletion of the front node of the linked list ✓
 - IV. Deletion of the last node of the linked list $O(n)$
- a) I and II
 - b) I and III
 - c) I, II and III
 - d) I, II and IV

(10) Which of the following is/are property/properties of a dynamic programming problem?

- I. Optimal substructure
 - II. Overlapping subproblems
 - III. Greedy property
- a) Only I
 - b) I and II
 - c) I, II and III
 - d) None of the above

(11) Following array is to be sorted using insertion sort.

25	12	48	8	22	16	3	107
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The array after first and second iteration of insertion sort are shown below.

After First Iteration:

12	25	48	8	22	16	3	107
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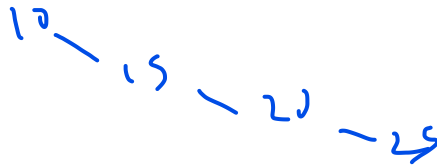
After Second Iteration:

12	25	48	8	22	16	3	107
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What will be the array after the **fourth** Iteration of the Insertion sort?

8	12	22	25	48	16	3	107
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- (12) A binary search tree has the values 10,15,20,25. The search algorithm took 5 comparisons to figure out that 30 is not present. Draw this binary search tree.



- (13) To measure Time complexity of an algorithm Big O notation is used which:

- a) Describes limiting behaviour of the function
- b) Characterises a function based on growth of function
- c) Upper bound on growth rate of the function
- d) all of the mentioned

- (14) If $f(x) = 4x^4 + 4x + 5$ and $g(x) = 12x^4 + 22x^2 + 7$ and $h(x) = 5x^2 + 58$ which of the following statements is **correct**?

- a) $f(x) \in \Theta(g(x))$ and $g(x) \in \omega(h(x))$ and $h(x) \in o(f(x))$ ✓
- ~~x~~ b) $f(x) \in o(g(x))$ and $f(x) \in \Omega(g(x))$ and $f(x) \in \omega(h(x))$
- c) $g(x) \in O(h(x))$ and $g(x) \in \omega(h(x))$ and $g(x) \in \Omega(f(x))$
- d) $h(x) \in \Theta(f(x))$ and $g(x) \in \Omega(f(x))$ and $f(x) \in O(g(x))$

- (15) What can be the applications of Depth First Search?

- a) For generating topological sort of a graph
- b) For generating Strongly Connected Components of a directed graph
- c) Detecting cycles in the graph
- d) All of the mentioned

SECTION B

1. Why we need Abstract Data Types (ADT)? Briefly explain. [4 marks]

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2. What is optimal substructure property? Briefly explain using Knapsack problem. [4 marks]

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3. What is the most efficient data structure to build a keyword index for an e-book. You should be able to search for the list of pages corresponding to a keyword should happen in nearly $O(1)$ time. Justify your answer briefly. [4 marks]

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4. Draw a flowchart to express the algorithm to find the maximum of the elements in an integer array. [4 marks]

5. Minimizing data clustering is a major challenge in Hash Table implementations. Explain what is primary clustering? [4 marks]

SECTION C

Q1.

[25 marks]

(a) Show that for any real constants a and b , where $b > 0$, $(n + a)^b = \theta(n^b)$.

[4 marks]

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(b) Insertion sort can be expressed as a recursive procedure as follows. In order to sort an array $A[1 \dots n]$, we recursively sort the array $A[1 \dots (n-1)]$ and then insert the element $A[n]$ into the sorted array.

i) What will be the terminating condition for the recursion?

[2 marks]

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- ii) What will be the worst case time complexity of non-recursive part of the algorithm (inserting the element $A[n]$ into the sorted array)? Explain your answer. [3 marks]

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- iii) Derive the recurrence formula to express the running time of the recursive insertion sort algorithm. [3 marks]

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- iv) Solve the recurrence formula in part (iii) using a suitable method and express the worst case running time of the recursive insertion sort algorithm. [3 marks]

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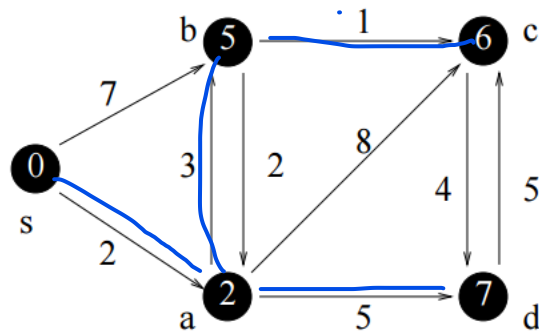
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- (c) The Dijkstra's algorithm runs a while loop for the $|V|$ number of iterations. In the given tables below, fill the Q, adjacency vector (π) and the distance vector (d) after each iteration of the while loop in Dijkstra's algorithm for the following graph starting from S. [10 marks]



v	s	a	b	c	d
Initialize : Q = {s,a,b,c,d}					
d[v]	0	∞	∞	∞	∞
$\Pi[v]$	nil	nil	nil	nil	nil
Iteration 1 : Q =					
d[v]	0	2	7	∞	∞
$\Pi[v]$	nil	s	s	nil	nil
Iteration 2 : Q = a b c d					
d[v]	0	2	5	10	7
$\Pi[v]$	nil	s	a	a	a
Iteration 3 : Q = b c d					
d[v]	0	2	5	6	7
$\Pi[v]$	nil	s	a	b	a
Iteration 4 : Q = c d					
d[v]	0	2	5	6	7
$\Pi[v]$	nil				
Iteration 5 : Q = \emptyset					
d[v]	0	2	5	6	7
$\Pi[v]$	nil				

Q2.

[25 marks]

- (a) An application is designed to store the medical records of the patients who are taking medication from the government hospitals. The national identity card number (NIC) of each patient is used to uniquely identify the patient and for each patient the details such as name, contact number and address are stored in the database. When the patient visits the hospital first time, he will be asked to register in the system and after that his record will be retrieved using the NIC number. In addition to this main information, for each hospital visit of a patient a separate record, which contain the date of visit, reason for visit, the hospital visited and the treatment prescribed, will be created. These hospital visit records for one patient should be kept sorted according to the date of visit (most recent one first). Propose a suitable structure to organize the data for this application. The data structure you propose should support fast access to the patient records when the number of patients is very large. Justify your suggestion.

[8 marks]

(b) A binary search tree (BST) is a node based binary tree data structure which has the following properties.

- The left subtree of a node contains only nodes with keys less than the node's key.
- The right subtree of a node contains only nodes with keys greater than the node's key.
- Both the left and right subtrees must also be binary search trees.

From the above properties it naturally follows that each node (item in the tree) has a distinct key. Write a pseudocode to check if a binary tree is BST or not. Analyze the time complexity of your algorithm.

Use this additional sheet for answering if required.

--- *End of the Paper* ---