NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF COMPUTER SCIENCE

Data Structures and Algorithms SCS 1217

Final Examination Paper **October 2024**

This examination paper consists of five (5) pages

Time Allowed : 3 hours

Total Marks : 100

Scientific Calculators are permitted

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INSTRUCTIONS

1. Answer **Question 1** and three (3) other questions
2. Use C, C++, Java or Python to write program codes

MARK ALLOCATION

QUESTION	MARKS
1	25
2	25
3	25
4	25
5	25
TOTAL	**100**

Question One

a) Define the following terms as they are used in Data Structures and Algorithms

i. Breadth First Search

ii. Minimum Spanning Tree (MST)

iii. NP hard

iv. Optimisation Algorithms

v. Backtracking [10]

b) Construct a binary tree that satisfies the following pre-order and in order traversals

In order [E X M B S A P T N W H C]

Pre-order [A B X E M S W T P N C H] [5]

c) The management of LifeCare Medical Centre has approached you as a Data Structures and Algorithms consult to develop software for its Emergency Room (ER) Patient Assessment System whose basic operations are described as follows.

Scenario: Emergency Room Patient Assessment System

Patients arrive at the ER with different medical issues, and each patient is assessed and assigned a priority based on the severity of their condition. The priority levels can be categorised as follows:

- **Critical:** Patients who are in life-threatening situations (e.g., severe trauma, cardiac arrest).
- **Urgent:** Patients needing prompt care but not in immediate danger (e.g., fractures, severe pain).
- **Non-Urgent:** Patients with minor issues that can wait (e.g., minor cuts, colds).

Which data structure would you recommend to LifeCare Medical Centre? Give reasons to justify your answer. [4]

d) Write a function to implement the pop operation on a stack. The function should take a stack as input and return the popped element. If the stack is empty it displays an underflow error and returns a "-1" value [6]

Question Two

a) Given the following expression (x * a) - y / b * (c + d)

i. Construct a binary tree from the expression [2]

ii. Use the binary tree to convert the expression to a postfix expression [2]

iii. Using a binary tree, evaluate the expression given that a=2, b=3, c=5, d=7, x=4, y=12. Show your working and compute the final result. [3]

b) Describe how Dijkstra's algorithm determines the shortest path from a source vertex to all other vertices. Use the following graph to illustrate your answer:

Vertices: A, B, C, D, E, F, G

Edges: [A – B, 5], [A - C: 2], [B – C: 1], [B – E: 2], [B – D: 4], [C-E, 7], [D – E: 6], [D – F, 3], [E - F: 1],

Source Vertex: A [10]

c) Write the pseudocode to perform the Enqueue() operation. Assume that the queue is implemented as an array, with FRONT and REAR indices pointing to the first and last elements respectively

[8]

Question Three

a) Explain the following concepts as they are used in Data Structures and Algorithms

i. Time Complexity [2]

ii. Space Complexity [2]

b) With the aid of an example, explain the following algorithm design strategies.

i. Branch and Bound [3]

ii. Divide and Conquer [4]

c) Consider the following list of integers:

List: [45, 23, 78, 34, 12, 67, 89, 21]

Illustrate how the Shell Sort works on the given list, showing the state of the list after each pass. Use 4 as your initial gap [8]

d) Write a function to reverse an array of integers in place (without creating a new array). The function should take an array and its size as input and reverse the array [6]

Question Four

a) Differentiate between internal sorting and external sorting by stating their definitions, and key characteristics. Include one example of algorithms used in each type of sorting and explain a scenario where one would be preferred over the other. [8]

b) A network has 500 Mbps of bandwidth available to allocate to five applications:

Application	Bandwidth Required (Mbps)	Priority
A	150	High
B	100	Medium
C	200	Low
D	50	High
E	80	Medium

Allocate bandwidth to the applications using the most suitable knapsack algorithm to maximise priority while staying within the available bandwidth capacity. Identify the knapsack algorithm used, show your working and provide the optimal bandwidth allocation. [6]

c) Describe the significance of choosing the gap in Shell Sort and how it impacts the algorithm's performance. Be sure to include the following points in your answer:

- The role of the gap sequence in dividing the array into subarrays
- How the gap sequence affects the number of passes required to sort the array
- The impact of different gap sequences on execution time [6]

d) Write a function to implement a sequential search algorithm that finds an element in an array. The function should take three inputs:

- arr[]: an array of integers
- n: the size of the array
- target: the element to search for

The function should return the index of the `target` element in the arr[] if it exists, and `-1` otherwise. [5]

Question Five

a) Construct a Binary Search Tree representation from the following dataset:

{8, 3, 10, 1, 6, 14, 4, 7, 13} [2]

b) Explain how a binary search tree can be used to solve the min-max problem [4]

c) Outline any 2 key differences between Dijkstra's algorithm and the Bellman-Ford Algorithm [4]

d) Using Kruskal's algorithm, find the minimum spanning tree of the graph with nodes A, B, C, D, E, F, and G, and the following edges. Show the steps and provide the final answer, including the minimum spanning tree and its total weight. [7]

Vertices: A, B, C, D, E, F, G

Edges: [A-B: 5], [A-C: 3], [A-D: 2], [B-C: 1], [B-E: 4], [C-D: 2], [C-F: 6], [D-E: 3], [D-G: 7], [E-F: 5], [F-G: 3]

Source vertex: A

e) Consider a travelling salesperson who needs to visit 5 cities: A, B, C, D, and E. The salesperson starts at city A and must visit each city exactly once before returning to city A. The distances in kilometres between the cities are as follows:

[A to B: 10], [A to C: 15], [A to D: 20], [A to E: 25], [B to C: 30], [B to D: 35], [B to E: 40], [C to D: 45], [C to E: 50], [D to E: 55]

Required:

i. Use the Travelling Sales Person's Algorithm (Branch and Bound or Brute Force method) to find the shortest possible tour that the salesperson can take to visit all 5 cities exactly once and return to city A? [6]

ii. Outline any one application of the Travelling Sales Person's Algorithm [2]

END OF QUESTION PAPER