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Programme Code: TU856 & TU858  
Module Code: CMPU2001  
CRN: 22395 & 26458

## **TECHNOLOGICAL UNIVERSITY DUBLIN**

### **City Campus - Grangegorman**

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**TU856 - BSc. in Computer Science**

**TU858 - BSc. in Computer Science (International)**

**Year 2**

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**SEMESTER 2 EXAMINATIONS 2024/25**

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### **CMPU2001 - Algorithms & Data Structures**

#### **Internal Examiners:**

Mr. Richard Lawlor  
Dr. Paul Doyle

#### **External Examiner:**

Dr. Colm O'Riordan

#### **Exam Duration:**

2 hours

#### **Instructions To Candidates:**

Attempt three out of four questions. All questions carry equal marks. One complementary mark for paper.

**Special Instructions /Handouts/ Materials Required:** none

- 1. (a)** What are the differences, if any, between a Heap array and a sorted array?

What are the main advantages of a binary Heap compared to both an unsorted array and a sorted array from the point of view of **insert()** and **remove()** operations?

(6 marks)

- (b)** Selection sort and Heap sort are similar in that they are both examples of *hard-split easy-join*. Comment on this.

(6 marks)

- (c)** Draw the following heap array as a two-dimensional binary tree data structure:

k	0	1	2	3	4	5	6	7	8	9	10	11
a[k]		12	11	8	10	7	5	1	9			

Also, assuming another array hPos[] is used to store the position of each key in the heap, show the contents of hPos[] for this heap.

(6 marks)

- (d)** By using tree and array diagrams, illustrate the effect of inserting a node whose key is **13** into the heap in the array of part (c). You can ignore effects on hPos[].

(8 marks)

- (e)** Write in pseudocode a recursive version, maxHeapify(int k), of the siftDown(int k) Heap operation.

(7 marks)

- 2. (a)** Using diagrams, show the detailed workings for the first two passes of the outer loop of a bubble sort on the following array.

6	3	1	9	8	2	4	7	0	5
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Use your resulting array diagram to point out in your own words a significant flaw in bubble sort.

(6 marks)

- (b)** What is the basic idea behind comb sort that makes it an improvement on bubble sort.

Apply comb sort to the array in part (a) until it becomes bubble sort.

(8 marks)

- (c)** Show the first two partitionings that occur when quick sort is applied to the array in part (a).

(7 marks)

- (d)** Provide a simple example which shows quick sort at its worst. What is the complexity of quick sort at its worst?

(5 marks)

- (e)** Write down the complexity of heap sort and outline how it is arrived at. In your own words, contrast it with that of bubble sort and quick sort.

(7 marks)

- 3 (a) Given the following Depth First Search algorithm and graph, show step by step how it traverses the graph by computing  $u.d$ ,  $u.f$ ,  $u.\text{color}$  and  $u.\pi$  for each vertex  $u$ .

**DFS( $G$ )**

```

1  for each vertex  $u \in G.V$ 
2       $u.\text{color} = \text{WHITE}$ 
3       $u.\pi = \text{NIL}$ 
4       $\text{time} = 0$ 
5  for each vertex  $u \in G.V$ 
6      if  $u.\text{color} == \text{WHITE}$ 
7          DFS-VISIT( $G, u$ )

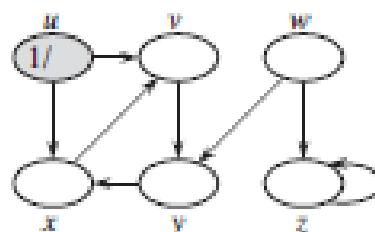
```

**DFS-VISIT( $G, u$ )**

```

1   $\text{time} = \text{time} + 1$            // white vertex  $u$  has just been discovered
2   $u.d = \text{time}$ 
3   $u.\text{color} = \text{GRAY}$ 
4  for each  $v \in G.\text{Adj}[u]$       // explore edge  $(u, v)$ 
5      if  $v.\text{color} == \text{WHITE}$ 
6           $v.\pi = u$ 
7          DFS-VISIT( $G, v$ )
8   $u.\text{color} = \text{BLACK}$            // blacken  $u$ ; it is finished
9   $\text{time} = \text{time} + 1$ 
10  $u.f = \text{time}$ 

```

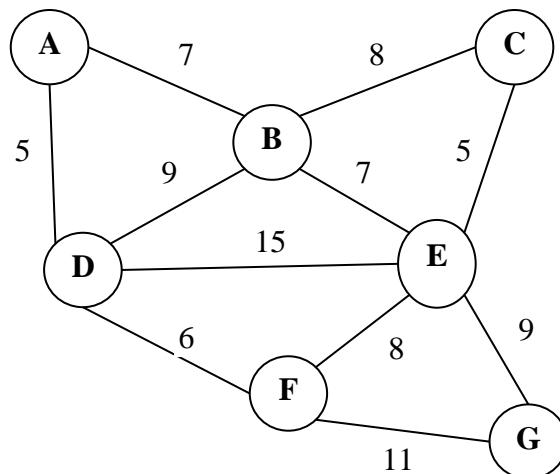


(10 marks)

- (b) Using the pseudocode in part (a) as a basis, derive the complexity of  $DFS(G)$  assuming that  $G$  is a single connected graph.

(6 marks)

- (c) Write down in pseudocode Dijkstra's *shortest path tree* algorithm assuming an adjacency-lists representation of the graph and then show its detailed working on the following graph.



(17 marks)

4. (a) Show how binary search works when searching for **17** in the following array:

1	5	6	9	10	12	14	17	21
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(4 marks)

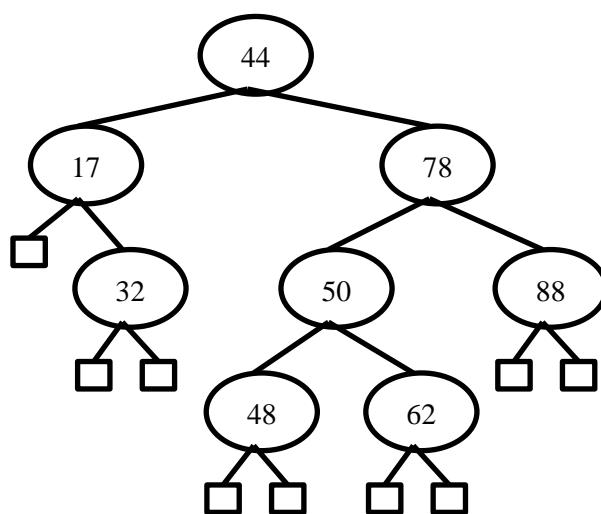
(b) What is a binary search tree (BST)? Mention any specific advantage or possible disadvantage. What is the complexity of searching a BST?

(6 marks)

(c) Write in pseudocode the algorithm for searching a BST.

(6 marks)

(d) Given the following binary search tree, show how it would be modified by inserting 54.



(5 marks)

(e) What is an AVL-tree? Include in your answer the idea of a *rotation*.

Show how the tree that results from inserting 54 in part (d) would be rebalanced if it were an AVL-tree.

(12 marks)