A37260

Calculators may be used in this examination provided they are not capable of being used to store alphabetical information other than hexadecimal numbers



UNIVERSITY OF BIRMINGHAM

School of Computer Science

Fourth Year Undergraduate/Postgraduate

06-34140

LM Data Structures, Algorithms, and Databases

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Note

Answer ALL questions.

Question 1 BST and AVL [25 marks]

(a) Consider the following formulas:

- $T_1 = Fork(10, EMPTY, EMPTY)$
- $T_2 = Fork(15, T_1, EMPTY)$
- $T_3 = Fork(35, EMPTY, Fork(36, EMPTY, EMPTY))$
- $T_4 = Fork(30, T3, Fork(40, EMPTY, EMPTY)$
- $T_5 = Fork(20, T_2, T_4)$

(i) Draw the T_5 tree and determine the balance factor for each node. **[4 marks]**

(ii) Is T_5 an AVL tree? Justify your answer. **[4 marks]**

(iii) What is the most suitable traversal method when all descendants of a node must be processed before the node itself? What will be the resulting output if this method is applied to T_5? **[5 marks]**

(b) Consider a function named `arrayToAVL` that inserts the elements of `_array` in an AVL tree. The `insert_withRebalance()` function will perform a rebalance if required.

```
1 function arrayToAVL(_array)
2     tree = EMPTY
3     for element in _array
4         tree = insert_withRebalance (element, tree)
5     return tree
```

Give the output for this function when given the input `_array=[25,40,10,15,23,19,40,65,80]`. Illustrate the intermediate stages (before and after each rebalance) as well as the final tree. **[12 marks]**

Question 2 Entity-Relationship modelling [25 marks]

A gym wants to build a database to track gym memberships. The gym has several branches. A gym member can join any branch, but their membership is valid for that branch only for the subscribed duration. A branch can offer several fitness classes, each led by a trainer. A member can enroll in as many fitness classes as they like.

(a) Develop an Entity-Relationship model for the application. Explain the key design decisions made in your choice of entities, relationships and any other (ownership or hierarchical) aspects. Annotate your model with the necessary multiplicities and hierarchy annotations. **[10 marks]**

(b) Carry out logical design for the model, representing the design with relational schemas for tables. Specify primary keys and possibly null values using appropriate notations.

Explain how each relationship in your model has been handled. **[10 marks]**

(c) Write CREATE TABLE statements for 2–3 tables of your model. One of the tables must be one that represents a relationship or incorporates a relationship, or one that represents a weak entity. The other tables must be those linked to the first table. **[5 marks]**

Question 3 Relational databases and normalisation [25 marks]

(a) Consider the following schemas for a database used by an airline reservation system

Table flight	
fid	integer
from	varchar(40)
to	varchar(40)

Table passenger	
pid	integer
name	varchar(40)

Table booking	
pid	integer
fid	integer
date	date

The table *booking* describes which passengers have booked which flights and the date they booked them.

(i) Write an SQL query for the following problem: *Find the passenger ids and names of passengers who have made more than one booking.* **[5 marks]**

(ii) Write a relational algebra expression for the following problems: *Find the names of passengers who have booked flights to 'Dubai' in January 2025.* **[4 marks]**

(iii) Is your solution to part (ii) as efficient as it could be? If so, explain why. If not, propose an efficient version. **[4 marks]**

(b) Consider a schema $T(A, B, C, D)$ with the functional dependencies

$$A \longrightarrow B;\ B, C \longrightarrow D;\ D, E \longrightarrow A$$

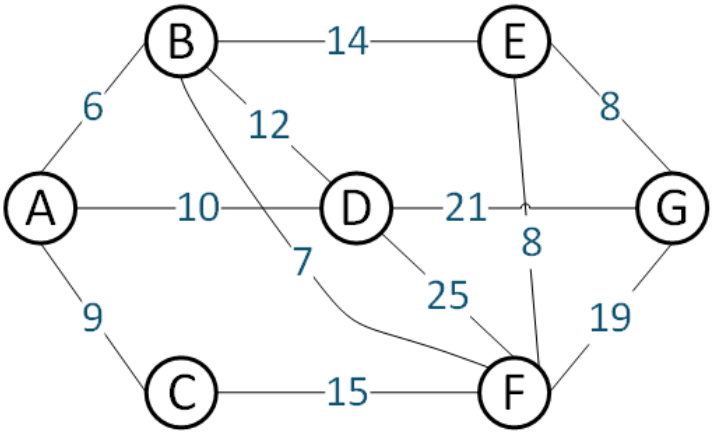
(i) Use the closure algorithm to find all the attributes that are functionally dependent on A, C. **[5 marks]**

(ii) Use this fact to suggest a **lossless decomposition** of the schema T. **[4 marks]**

(iii) Are the tables obtained in your decomposition in **Boyce-Codd normal form**? Explain your answer. **[3 marks]**

Question 4 Graphs and Hashtables [25 marks]

(a) Shown below is a weighted undirected graph (with 7 vertices and 12 edges). Construct a **Minimal Spanning Tree** (MST) for the graph using the Jarnik-Prim's algorithm, and the starting node is A.



(i) Draw the final MST. You are not required to draw the complete graph for each step of the algorithm. Just indicate the selected edge (like A-B) that becomes part of the MST. **[12 marks]**

(ii) What is the total weight of this MST? **[3 marks]**

(b) Below is a table that represents the information from the above graph:

Keys	Values
AB	6
AC	9
AD	10
BD	12
BE	14
BF	7
CF	15
DF	25
DG	21
EF	8
EG	8
FG	19

We treat the characters as a number in base 26 (A=0,B=1,...,Z=25). So that AB=0*26^1+1*26^0=1, AC=0*26^1+2*26^0=2, ... , EA=4*26^1+0*26^0=104.

Modular hashing is then used to compute the hash code: $h(k) = k\%12$. For example, $h(AC) = 2\%12 = 2$.

Complete the below Hash Table (by using **Linear Probing**) to store all the Key-Value Pairs in the above table. Please note that the input order of the Hash Table consistent with the order shows in the above table (e.g. the first input is AB, the second is AC etc.), and we will consider a simplified situation where no rehash is required (load factor equals to 1). **[10 marks]**

Indexes	(Key, Value)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

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A37260 **LM Data Structures, Algorithms, and Non-alpha only Databases**

Do not complete the attendance slip, fill in the front of the answer book or turn over the question paper until you are told to do so

Important Reminders

- Coats/outwear should be placed in the designated area.
- Unauthorised materials (e.g. notes or Tippex) must be placed in the designated area.
- Check that you do not have any unauthorised materials with you (e.g. in your pockets, pencil case).
- Mobile phones and smart watches **must** be switched off and placed in the designated area or under your desk. They must not be left on your person or in your pockets.
- You are not permitted to use a mobile phone as a clock. If you have difficulty seeing a clock, please alert an Invigilator.
- You are not permitted to have writing on your hand, arm or other body part.
- Check that you do not have writing on your hand, arm or other body part – if you do, you must inform an Invigilator immediately
- Alert an Invigilator immediately if you find any unauthorised item upon you during the examination.

Any students found with non-permitted items upon their person during the examination, or who fail to comply with Examination rules may be subject to Student Conduct procedures.