

Indian Statistical Institute
End-Semester Examination: PGDBA 2025
Fundamentals of Database Systems

Part II

Duration: 1 Hour 30 Minutes Maximum Marks: 50

Date: 15 December 2025

1. Consider the relation

$$R(A, B, C, D, E)$$

with the following functional dependencies:

$$A \rightarrow C, \quad B \rightarrow C, \quad CD \rightarrow E.$$

Identify all candidate keys of R and show that those are the only candidate keys.

(5 marks)

2. Consider the relation

$$R(A, B, C, D)$$

with functional dependencies:

$$A \rightarrow D, \quad B \rightarrow D, \quad CD \rightarrow A, \quad CD \rightarrow B.$$

Determine the highest normal form (among 2NF, 3NF and BCNF) that this relation achieves and justify.

(5 marks)

3. Consider the relation

$$R(A, B, C, D, E)$$

with functional dependencies:

$$AB \rightarrow C, \quad C \rightarrow D, \quad D \rightarrow E.$$

Consider the decomposition of R into the two relations

$$R_1(A, B, C) \quad \text{and} \quad R_2(A, B, D, E).$$

Determine whether this decomposition is *lossless* and whether it is *dependency preserving*. Give brief justifications for both parts.

(2.5 + 2.5 = 5 marks)

4. Suppose R is a relation schema with a certain set of functional dependencies and $X \subset R$ is the only candidate key for R . Then, prove or disprove the following statement: if R is in BCNF, then for any attribute $A \in R - X$, $A^+ = A$.

(5 marks)

5. Consider the two sets of functional dependencies:

$$\mathcal{F}_1 = \{A \rightarrow B, AE \rightarrow B, A \rightarrow D, AB \rightarrow D, B \rightarrow C, C \rightarrow A, BC \rightarrow A\}$$

and

$$\mathcal{F}_2 = \{A \rightarrow B, B \rightarrow C, C \rightarrow D, C \rightarrow A, CE \rightarrow A, BC \rightarrow D\}.$$

Determine whether $\mathcal{F}_1$ and $\mathcal{F}_2$ are equivalent, with justification.

(5 marks)

6. Consider the relation

$$R(A, B, C, D)$$

with the functional dependencies

$$A \rightarrow B, \quad B \rightarrow C, \quad C \rightarrow A.$$

Determine whether R is in BCNF. If not, decompose R such that each of the resulting relations are in BCNF ensuring that the decomposition is lossless. Analyze whether your decomposition is also dependency preserving (Note: it is alright if the decomposition is not dependency preserving, you just have to determine whether it is).

(3 + 2 = 5 marks)

7. What is a *sparse index*? Can both the primary and secondary indices be sparse? Explain your answer.

(2 + 3 = 5 marks)

8. Recall that a B⁺ tree of order n stores between n and $2n$ keys in each internal node (except the root).

Answer the following:

- During deletion, when does a node become *underfilled*? What are the two possible ways a B⁺ tree restores balance?
- Why are *leaf nodes linked* in a B⁺ tree?

((1+2) + 2 = 5 marks)

9. You are given a very large dataset of sales records, one record per line, in the format

```
custID, itemID, qty
```

Example:

```
C1, apple, 2  
C1, banana, 1  
C2, apple, 3  
C3, orange, 4  
C2, banana, 2
```

Design a *single* MapReduce job that computes, for each *itemID*, the *total quantity* sold across all customers. Clearly specify:

- (a) the key-value pairs emitted by the map function, and
- (b) the reduce function.

(3 + 2 = 5 marks)

10. Answer the following multiple-choice questions. Choose the correct option from (i)–(iv) and write them in the answersheet.

- (a) Which of the following is an advantage of NoSQL database management systems in general?
 - i. Supports referential integrity
 - ii. Supports elastic scaling
 - iii. Provides strong data security
 - iv. Has a powerful database administrator
- (b) Which of the following guarantees are *not* provided by NoSQL database management systems in general?
 - i. Partition tolerance
 - ii. Availability
 - iii. Consistency
 - iv. Isolation
- (c) Under which category of NoSQL database management systems does MongoDB fall?
 - i. Document based
 - ii. Graph based
 - iii. Key-value based
 - iv. Wide-column based

(d) What is done by the `updateOne(<query>)` function in MongoDB?

- i. Updates all documents that satisfy the query
- ii. Updates the very last document that satisfies the query
- iii. Updates the very first document that satisfies the query
- iv. Updates documents one after another in the collection

(e) What will be returned by the `find({})` query in MongoDB?

- i. None of the documents in the collection
- ii. All the documents in the collection
- iii. The very first document in the collection
- iv. The very last document in the collection

(1 × 5 = 5 marks)