

Database Management (4331603) - Summer 2024 Solution

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Question 1(a) [3 marks]

Define Following Terms: 1. Data 2. Information 3. Metadata

Solution

Table 1. Data vs Information vs Metadata

| Term | Definition | Example |
|--------------------|---|--|
| Data | Raw facts and figures without context | ”25”, ”John”, ”Mumbai” |
| Information | Processed data with meaning and context | ”John is 25 years old and lives in Mumbai” |
| Metadata | Data about data describing structure and properties | ”Age field: Integer, Max length: 3” |

- **Data:** Basic building blocks of information systems
- **Information:** Result of data processing for decision making
- **Metadata:** Essential for database design and management

Mnemonic

“DIM - Data gives Information using Metadata”

Question 1(b) [4 marks]

Compare File System vs Database System

Solution

Table 2. File System vs Database System Comparison

| Aspect | File System | Database System |
|--------------------------|-------------------------------------|-----------------------------------|
| Data Storage | Separate files for each application | Centralized storage |
| Data Redundancy | High redundancy | Minimal redundancy |
| Data Consistency | Poor consistency | High consistency |
| Data Security | Limited security | Advanced security features |
| Concurrent Access | Limited support | Full concurrent support |
| Data Independence | No independence | Physical and logical independence |

- **File System:** Simple but with data duplication issues
- **Database System:** Complex but efficient data management
- **Main Advantage:** DBMS eliminates data redundancy and inconsistency

Mnemonic

“DBMS = Data Better Managed Systematically”

Question 1(c) [7 marks]

Draw and Explain Network Data Model

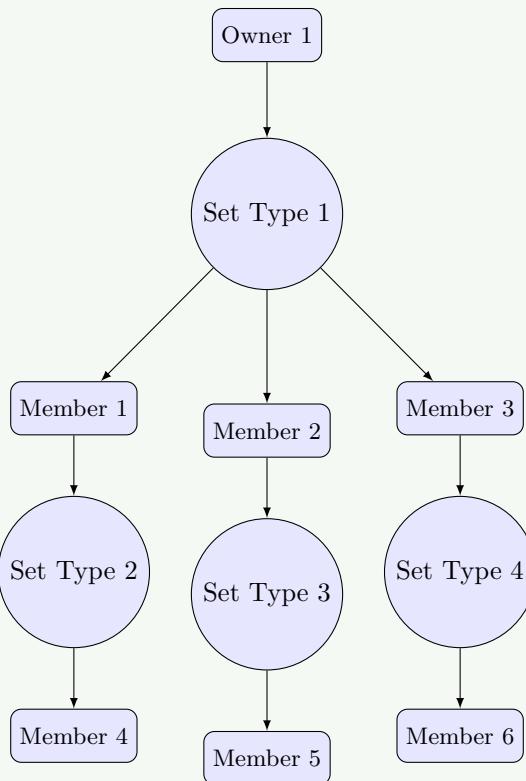
Solution

Figure 1. Network Data Model Structure

Table 3. Network Model Components

| Component | Description | Example |
|--------------------|-------------------------------|----------------------|
| Record Type | Entity representation | Employee, Department |
| Set Type | Relationship between records | Works-In, Manages |
| Owner | Parent record in relationship | Department (owner) |
| Member | Child record in relationship | Employee (member) |

- **Owner Record:** Controls the set and can have multiple members
- **Member Record:** Belongs to one or more sets
- **Set Occurrence:** Instance of set type linking owner to members
- **Navigation:** Uses pointers for record access

Mnemonic

“Network = Nodes with Multiple Connections”

Question 1(c) OR [7 marks]

What is Schema? Explain different types of Schema with example

Solution

Definition: Schema is the logical structure or blueprint of a database that defines how data is organized.

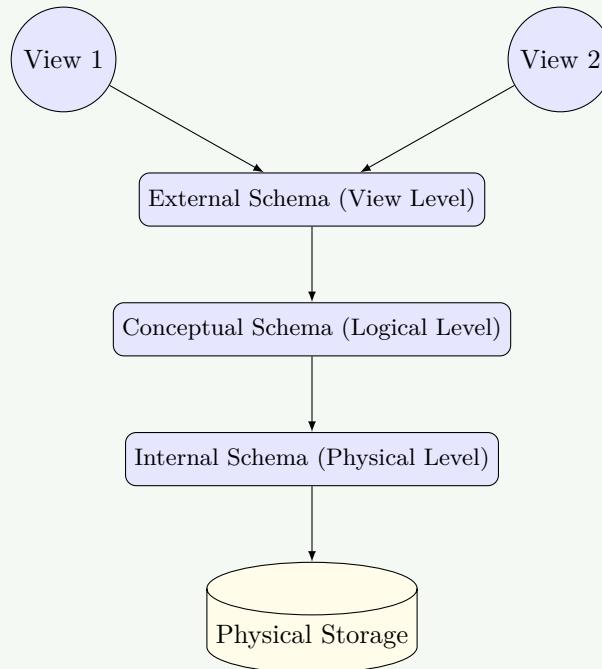


Figure 2. Three-Schema Architecture

Table 4. Types of Schema

| Schema Type | Level | Description | Example |
|--------------------------|----------------|--------------------------------|--|
| External Schema | View Level | User-specific view of database | Student grades view for teachers |
| Conceptual Schema | Logical Level | Complete logical structure | All tables, relationships, constraints |
| Internal Schema | Physical Level | Physical storage structure | Index files, storage allocation |

- **External Schema:** Provides data independence for users
- **Conceptual Schema:** Database designer's complete view
- **Internal Schema:** Database administrator's physical view

Mnemonic

“ECI - External Conceptual Internal”

Question 2(a) [3 marks]

Define Following Terms: 1. Entity 2. Attributes 3. Relationship

Solution

Table 5. ER Model Basic Concepts

| Term | Definition | Example |
|---------------------|--|---------------------------|
| Entity | Real-world object with independent existence | Student, Course, Teacher |
| Attributes | Properties that describe an entity | Student: ID, Name, Age |
| Relationship | Association between two or more entities | Student ENROLLS IN Course |

- **Entity:** Represented by rectangles in ER diagrams
- **Attributes:** Represented by ovals connected to entities
- **Relationship:** Represented by diamonds connecting entities

Mnemonic

“EAR - Entity has Attributes and Relationships”

Question 2(b) [4 marks]

Describe Weak Entity Sets with example

Solution

Definition: Weak entity is an entity that cannot be uniquely identified by its own attributes and depends on a strong entity.

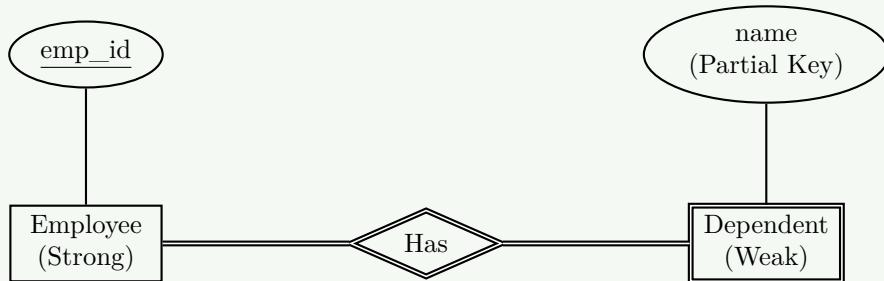


Figure 3. Strong vs Weak Entity

Table 6. Weak vs Strong Entity

| Aspect | Strong Entity | Weak Entity |
|-----------------------|-------------------------|--------------------------|
| Primary Key | Has its own primary key | No primary key |
| Existence | Independent existence | Depends on strong entity |
| Representation | Single rectangle | Double rectangle |
| Example | Employee | Dependent of Employee |

- **Partial Key:** Attribute that partially identifies weak entity
- **Identifying Relationship:** Connects weak entity to strong entity
- **Total Participation:** Weak entity must participate in relationship

Mnemonic

“Weak entities are DEPENDent”

Question 2(c) [7 marks]

Draw ER Diagram for University Management System

Solution

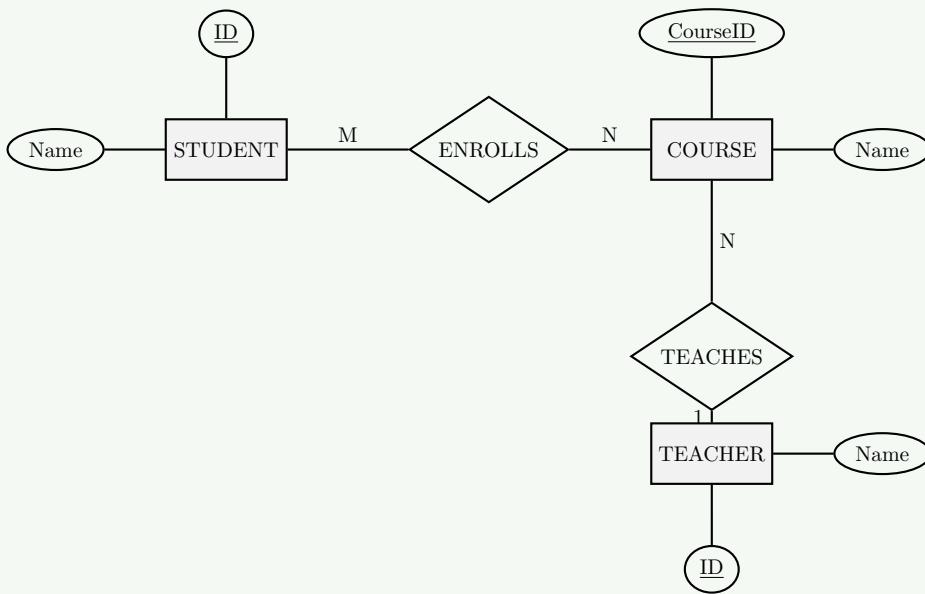


Figure 4. University ER Diagram

Table 7. Entity Relationships

| Relationship | Cardinality | Description |
|-------------------------------|-------------|--|
| Student ENROLLS Course | M:N | Many students can enroll in many courses |
| Teacher TEACHES Course | 1:N | One teacher teaches multiple courses |
| Course HAS Enrollment | 1:N | One course has multiple enrollments |

- **Primary Entities:** Student, Course, Teacher
- **Associative Entity:** Enrollment (resolves M:N relationship)
- **Key Attributes:** All entities have unique identifier

Mnemonic

“University = Students Take Courses from Teachers”

Question 2(a) OR [3 marks]

Define Following Terms: 1. Primary Key 2. Foreign Key 3. Candidate Key

Solution

Table 8. Database Keys

| Key Type | Definition | Example |
|----------------------|---|--------------------------------|
| Primary Key | Unique identifier for each record | Student_ID in Student table |
| Foreign Key | References primary key of another table | Student_ID in Enrollment table |
| Candidate Key | Potential primary key attribute | Email, Phone in Student table |

- **Primary Key:** Cannot be NULL and must be unique
- **Foreign Key:** Maintains referential integrity
- **Candidate Key:** Alternative unique identifiers

Mnemonic

"PFC - Primary Foreign Candidate"

Question 2(b) OR [4 marks]

Write a Short note on Generalization and Specialization

Solution

Generalization: Process of extracting common attributes from multiple entities to create a general entity.
Specialization: Process of defining subclasses of an entity based on distinguishing characteristics.

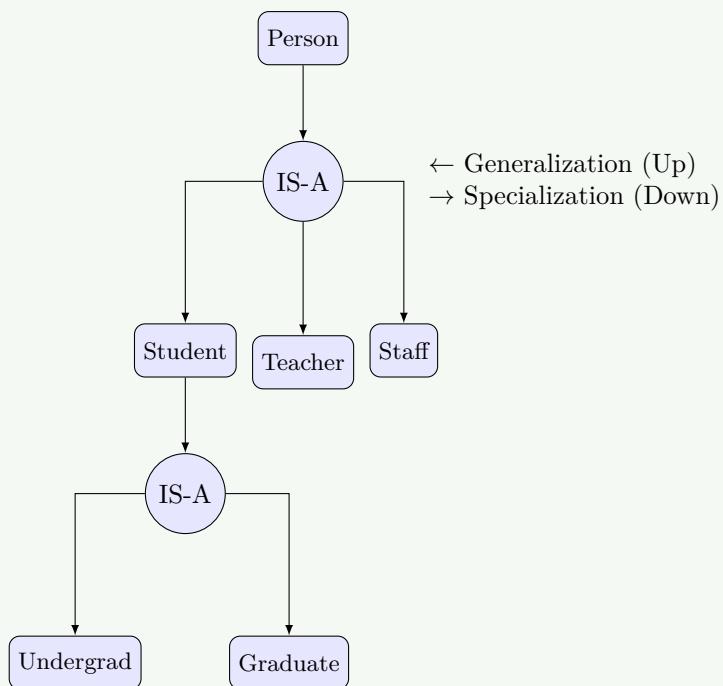


Figure 5. Generalization and Specialization Hierarchy

Table 9. Generalization vs Specialization

| Aspect | Generalization | Specialization |
|------------------|---------------------|-------------------------|
| Direction | Bottom-up approach | Top-down approach |
| Purpose | Remove redundancy | Add specific attributes |
| Result | Superclass creation | Subclass creation |

- **ISA Relationship:** "Is-A" relationship between superclass and subclass
- **Inheritance:** Subclasses inherit attributes from superclass

Mnemonic

"General goes UP, Special goes DOWN"

Question 2(c) OR [7 marks]

Explain different Relational Algebra operation with example

Solution

Table 10. Relational Algebra Operations

| Operation | Symbol | Description | Example |
|--------------|-----------|---------------------------------|------------------------------|
| Select | σ | Selects rows based on condition | $\sigma_{age > 20}(Student)$ |
| Project | π | Selects specific columns | $\pi_{name, age}(Student)$ |
| Union | \cup | Combines two relations | $R \cup S$ |
| Intersection | \cap | Common tuples from relations | $R \cap S$ |
| Difference | $-$ | Tuples in R but not in S | $R - S$ |
| Join | \bowtie | Combines related tuples | $Student \bowtie Enrollment$ |

Example Relations: Student: (ID=1, Name=John, Age=20)

Course: (CID=101, CName=DBMS, Credits=3)

- **Selection:** $\sigma_{Age > 18}(Student)$ returns students above 18
- **Projection:** $\pi_{Name}(Student)$ returns only names
- **Join:** $Student \bowtie Enrollment$ combines student and enrollment data

Mnemonic

“SPUDIJ - Select Project Union Difference Intersection Join”

Question 3(a) [3 marks]

List out Numeric Functions in SQL. Explain any Two

Solution

Table 11. SQL Numeric Functions

| Function | Purpose | Example |
|----------------|-------------------------------|--------------------------|
| ABS() | Absolute value | $ABS(-15) = 15$ |
| CEIL() | Smallest integer \geq value | $CEIL(4.3) = 5$ |
| FLOOR() | Largest integer \leq value | $FLOOR(4.7) = 4$ |
| ROUND() | Round to specified places | $ROUND(15.76, 1) = 15.8$ |
| SQRT() | Square root | $SQRT(16) = 4$ |
| POWER() | Raise to power | $POWER(2, 3) = 8$ |

Detailed Examples:

- **ABS(number):** Returns absolute value, removing negative sign
- **ROUND(number, decimal_places):** Rounds number to specified decimal places

Mnemonic

“Math functions make Numbers Nice”

Question 3(b) [4 marks]

Describe Having and Order by Clause with example

Solution

HAVING Clause: Used with GROUP BY to filter groups based on aggregate conditions.

ORDER BY Clause: Used to sort result set in ascending or descending order.

Table 12. HAVING vs WHERE

| Aspect | WHERE | HAVING |
|-----------------|-------------------------|-----------------------------|
| Usage | Filters individual rows | Filters grouped results |
| With Aggregates | Cannot use | Can use aggregate functions |
| Position | Before GROUP BY | After GROUP BY |

Example:

```

1 SELECT department, COUNT(*) as emp_count
2   FROM employees
3 WHERE salary > 30000
4 GROUP BY department
5 HAVING COUNT(*) > 5
6 ORDER BY emp_count DESC;
```

- **WHERE:** Filters employees with salary > 30000
- **HAVING:** Shows only departments with more than 5 employees
- **ORDER BY:** Sorts by employee count in descending order

Mnemonic

“WHERE filters rows, HAVING filters groups, ORDER BY sorts results”

Question 3(c) [7 marks]

Perform the following Query on the table student having the fields Student_ID, Stu_Name, Stu_Subject_ID, Stu_Marks, Stu_Age in SQL

Solution

1. Create student table:

```

1 CREATE TABLE student (
2   Student_ID INT PRIMARY KEY,
3   Stu_Name VARCHAR(50),
4   Stu_Subject_ID INT,
5   Stu_Marks INT,
6   Stu_Age INT
7 );
```

2. Insert record in student table:

```

1 INSERT INTO student VALUES
2   (1, "John", 101, 85, 22),
3   (2, "Mary", 102, 90, 21);
```

3. Find minimum and maximum marks:

```

1   SELECT MIN(Stu_Marks) as Min_Marks,
```

```

2     MAX(Stu_Marks) as Max_Marks
3   FROM student;

```

4. Students with marks > 82 and age = 22:

```

1 SELECT * FROM student
2 WHERE Stu_Marks > 82 AND Stu_Age = 22;

```

5. Students whose name begins with "m":

```

1 SELECT * FROM student
2 WHERE Stu_Name LIKE "m%";

```

6. Find average marks:

```

1 SELECT AVG(Stu_Marks) as Average_Marks
2 FROM student;

```

7. Add Stu_address column:

```

1 ALTER TABLE student
2 ADD Stu_address VARCHAR(100);

```

Mnemonic

“CRUD + Analytics = Complete Database Operations”

Question 3(a) OR [3 marks]

Describe different date function in SQL with example

Solution

Table 13. SQL Date Functions

| Function | Purpose | Example |
|-------------------------|------------------------|--|
| SYSDATE | Current system date | SYSDATE returns '2024-06-12' |
| ADD_MONTHS() | Add months to date | ADD_MONTHS('2024-01-15', 3) |
| MONTHS_BETWEEN() | Months between dates | MONTHS_BETWEEN('2024-06-12', '2024-01-12') |
| LAST_DAY() | Last day of month | LAST_DAY('2024-02-15') = '2024-02-29' |
| NEXT_DAY() | Next occurrence of day | NEXT_DAY('2024-06-12', 'FRIDAY') |

Examples:

- **SYSDATE:** Returns current system date and time
- **ADD_MONTHS:** Useful for calculating future dates like loan due dates

Mnemonic

“Date functions help with Time Management”

Question 3(b) OR [4 marks]

List out Constraints in SQL. Explain any two with example

Solution**Table 14.** SQL Constraints

| Constraint | Purpose | Example |
|--------------------|--------------------------|-------------------------------------|
| PRIMARY KEY | Unique identifier | Student_ID INT PRIMARY KEY |
| FOREIGN KEY | References another table | REFERENCES Student(Student_ID) |
| NOT NULL | Prevents null values | Name VARCHAR(50) NOT NULL |
| UNIQUE | Ensures uniqueness | Email VARCHAR(100) UNIQUE |
| CHECK | Validates data | Age INT CHECK (Age >= 18) |
| DEFAULT | Default value | Status VARCHAR(10) DEFAULT 'Active' |

Detailed Examples:**PRIMARY KEY Constraint:**

```

1 CREATE TABLE Student (
2     Student_ID INT PRIMARY KEY,
3     Name VARCHAR(50)
4 );

```

CHECK Constraint:

```

1 CREATE TABLE Employee (
2     Emp_ID INT,
3     Salary INT CHECK (Salary > 0)
4 );

```

- **PRIMARY KEY:** Ensures each record has unique identifier
- **CHECK:** Validates business rules during data entry

Mnemonic

“Constraints Control Data Quality”

Question 3(c) OR [7 marks]

Explain different types of joins with example in SQL

Solution**Table 15.** Types of SQL Joins

| Join Type | Description | Syntax |
|------------------------|---|--|
| INNER JOIN | Returns matching records from both tables | Table1 INNER JOIN Table2 ON condition |
| LEFT JOIN | All records from left table + matching from right | Table1 LEFT JOIN Table2 ON condition |
| RIGHT JOIN | All records from right table + matching from left | Table1 RIGHT JOIN Table2 ON condition |
| FULL OUTER JOIN | All records from both tables | Table1 FULL OUTER JOIN Table2 ON condition |

Example Tables: Students: (ID=1, Name=John), (ID=2, Name=Mary)

Enrollments: (StudentID=1, Course=DBMS), (StudentID=3, Course=Java)

INNER JOIN Example:

```

1 SELECT s.Name, e.Course
2 FROM Students s
3 INNER JOIN Enrollments e ON s.ID = e.StudentID;

```

Result: Only John with DBMS course

LEFT JOIN Example:

```

1 SELECT s.Name, e.Course
2 FROM Students s
3 LEFT JOIN Enrollments e ON s.ID = e.StudentID;

```

Result: John-DBMS, Mary-NULL

Mnemonic

“JOIN connects Related Tables”

Question 4(a) [3 marks]

Give an example of Grant and Revoke command in SQL

Solution

GRANT Command: Provides specific privileges to users on database objects.

REVOKE Command: Removes previously granted privileges from users.

Table 16. Common Privileges

| Privilege | Description | Example |
|---------------|-------------------------|----------------------------------|
| SELECT | Read data | GRANT SELECT ON Student TO user1 |
| INSERT | Add new records | GRANT INSERT ON Student TO user1 |
| UPDATE | Modify existing records | GRANT UPDATE ON Student TO user1 |
| DELETE | Remove records | GRANT DELETE ON Student TO user1 |
| ALL | All privileges | GRANT ALL ON Student TO user1 |

Examples:

```

1 -- Grant SELECT privilege
2 GRANT SELECT ON Student TO john;
3
4 -- Revoke INSERT privilege
5 REVOKE INSERT ON Student FROM john;

```

- **WITH GRANT OPTION:** Allows user to grant privileges to others
- **CASCADE:** Revokes privileges from all users who received them

Mnemonic

“GRANT gives rights, REVOKE removes rights”

Question 4(b) [4 marks]

Write a short note on SQL Views

Solution

Definition: A view is a virtual table based on the result of an SQL statement containing rows and columns like a real table.

Table 17. View Characteristics

| Aspect | Description | Example |
|--------------------------|---|---|
| Virtual Table | Does not store data physically | CREATE VIEW student_view AS... |
| Security | Hides sensitive columns | Hide salary column from employees |
| Simplification | Simplifies complex queries | Join multiple tables in single view |
| Data Independence | Changes in base tables don't affect users | Modify table structure without affecting applications |

Example:

```

1 CREATE VIEW active_students AS
2 SELECT Student_ID, Name, Age
3 FROM Student
4 WHERE Status = 'Active';
5
6 -- Using the view
7 SELECT * FROM active_students;

```

- **Security:** Restrict access to sensitive data
- **Simplicity:** Hide complex joins from end users
- **Consistency:** Standardized data access

Mnemonic

“Views are Virtual Windows to Data”

Question 4(c) [7 marks]

What is Normalization? Explain 2NF with example

Solution

Normalization: Process of organizing database to reduce redundancy and improve data integrity by dividing large tables into smaller related tables.

2NF (Second Normal Form):

- Must be in 1NF
- Remove partial functional dependencies
- Non-key attributes must depend on entire primary key

Example - Unnormalized Table:

| Student_ID | Course_ID | Student_Name | Course_Name | Instructor |
|------------|-----------|--------------|-------------|------------|
| 101 | C1 | John | DBMS | Dr. Smith |
| 101 | C2 | John | Java | Dr. Jones |
| 102 | C1 | Mary | DBMS | Dr. Smith |

Problems:

- Student_Name depends only on Student_ID (partial dependency)
- Course_Name and Instructor depend only on Course_ID

After 2NF:

Student Table:

| Student_ID | Student_Name |
|------------|--------------|
| 101 | John |
| 102 | Mary |

Course Table:

| Course_ID | Course_Name | Instructor |
|-----------|-------------|------------|
| C1 | DBMS | Dr. Smith |
| C2 | Java | Dr. Jones |

Enrollment Table:

| Student_ID | Course_ID |
|------------|-----------|
| 101 | C1 |
| 101 | C2 |
| 102 | C1 |

- **Eliminates Redundancy:** Student names not repeated
- **Reduces Storage:** Less duplicate data
- **Improves Consistency:** Update student name in one place

Mnemonic

“2NF = No Partial Dependencies”

Question 4(a) OR [3 marks]

Give an example of Group By Clause in SQL

Solution

GROUP BY Clause: Groups rows with same values in specified columns and allows aggregate functions on each group.

Table 18. GROUP BY Usage

| Purpose | Function | Example |
|-----------------|-------------|-------------------------------|
| Counting | COUNT() | Count students per department |
| Summing | SUM() | Total salary per department |
| Averaging | AVG() | Average marks per course |
| Finding Min/Max | MIN()/MAX() | Highest salary per department |

Example:

```

1  SELECT Department, COUNT(*) as Total_Students, AVG(Marks) as Avg_Marks
2  FROM Student
3  GROUP BY Department;
```

Result:

| Department | Total_Students | Avg_Marks |
|------------|----------------|-----------|
| IT | 25 | 78.5 |
| CS | 30 | 82.1 |

- **Groups:** Creates separate groups for each department
- **Aggregates:** Calculates count and average for each group

Mnemonic

“GROUP BY creates Summary Reports”

Question 4(b) OR [4 marks]

Describe Set Operators in SQL with example

Solution

Set Operators: Combine results from two or more SELECT statements.

Table 19. SQL Set Operators

| Operator | Description | Requirement | Example |
|------------------|---------------------------------------|-----------------------|---|
| UNION | Combines results, removes duplicates | Same column structure | SELECT name FROM students UNION SELECT name FROM teachers |
| UNION ALL | Combines results, keeps duplicates | Same column structure | SELECT name FROM students UNION ALL SELECT name FROM alumni |
| INTERSECT | Returns common records | Same column structure | SELECT course FROM current_courses INTERSECT SELECT course FROM popular_courses |
| MINUS | Records in first query but not second | Same column structure | SELECT student_id FROM enrolled MINUS SELECT student_id FROM graduated |

Example:

```

1  -- Students who are also teachers
2  SELECT name FROM students
3  INTERSECT
4  SELECT name FROM teachers;
5
6  -- All people in university
7  SELECT name, 'Student' as type FROM students
8  UNION
9  SELECT name, 'Teacher' as type FROM teachers;
```

- **Column Count:** Must be same in all queries
- **Data Types:** Corresponding columns must have compatible types
- **Order:** ORDER BY can only be used at the end

Mnemonic

“Set operators Unite, Intersect, and Subtract data”

Question 4(c) OR [7 marks]

Justify the importance of Normalization. Explain 1NF with example

Solution

Importance of Normalization:

Table 20. Benefits of Normalization

| Benefit | Description | Impact |
|------------------------------|---|-------------------------------|
| Eliminates Redundancy | Reduces duplicate data storage | Saves storage space |
| Prevents Anomalies | Avoids insertion, deletion, update problems | Maintains data consistency |
| Improves Integrity | Ensures data accuracy | Reliable information system |
| Flexible Design | Easy to modify and extend | Adaptable to business changes |

1NF (First Normal Form):

- Eliminate duplicate columns from same table
- Create separate tables for related data
- Each cell contains single value (atomic values)

Example - Unnormalized Table:

| Student_ID | Name | Subjects |
|------------|------|------------------------|
| 101 | John | Math, Science, English |
| 102 | Mary | Science, History |

Problems:

- Subjects column contains multiple values
- Difficult to query specific subjects
- Update anomalies when adding/removing subjects

After 1NF:**Student Table:**

| Student_ID | Name |
|------------|------|
| 101 | John |
| 102 | Mary |

Student_Subject Table:

| Student_ID | Subject |
|------------|---------|
| 101 | Math |
| 101 | Science |
| 101 | English |
| 102 | Science |
| 102 | History |

- **Atomic Values:** Each cell contains single value
- **Flexible Queries:** Easy to find students studying specific subjects
- **Easy Updates:** Add/remove subjects without affecting other data

Mnemonic

“1NF = One value per cell, No repeating groups”

Question 5(a) [3 marks]**Explain Serializability in Transaction Management****Solution**

Serializability: Property that ensures concurrent execution of transactions produces same result as some serial execution of those transactions.

Table 21. Types of Serializability

| Type | Description | Method |
|---------------------------------|---------------------------------|------------------|
| Conflict Serializability | Based on conflicting operations | Precedence graph |
| View Serializability | Based on read-write patterns | View equivalence |

Example: Transaction T1: R(A), W(A), R(B), W(B)

Transaction T2: R(A), W(A), R(B), W(B)

Serial Schedule: T1 → T2 or T2 → T1

Concurrent Schedule: Interleaved operations

- **Conflict Operations:** Operations on same data item where at least one is write
- **Serializable Schedule:** Equivalent to some serial schedule
- **Non-serializable:** May lead to inconsistent database state

Mnemonic

“Serializability ensures Transaction Consistency”

Question 5(b) [4 marks]

Describe Partial Functional Dependency with example

Solution

Partial Functional Dependency: When a non-key attribute is functionally dependent on only part of a composite primary key.

Table 22. Functional Dependency Types

| Type | Definition | Example |
|---------------------------|--------------------------------|--|
| Full Dependency | Depends on entire primary key | (Student_ID, Course_ID) → Grade |
| Partial Dependency | Depends on part of primary key | (Student_ID, Course_ID) → Student_Name |

Example:

Enrollment Table:

Primary Key: (Student_ID, Course_ID)

| Student_ID | Course_ID | Student_Name | Course_Name | Grade |
|------------|-----------|--------------|-------------|-------|
| 101 | C1 | John | DBMS | A |
| 101 | C2 | John | Java | B |

Partial Dependencies:

- Student_ID → Student_Name (Student_Name depends only on Student_ID)
- Course_ID → Course_Name (Course_Name depends only on Course_ID)

Problems:

- **Update Anomaly:** Changing student name requires multiple updates
- **Insertion Anomaly:** Cannot add student without enrolling in course
- **Deletion Anomaly:** Deleting enrollment may lose student information

Solution: Normalize to 2NF by removing partial dependencies

Mnemonic

“Partial dependency = Part of key determines attribute”

Question 5(c) [7 marks]

Write a Short note on Locking Mechanism with example in Transaction Management

Solution

Locking Mechanism: Concurrency control technique that prevents simultaneous access to data items during transaction execution.

Table 23. Types of Locks

| Lock Type | Description | Usage |
|--------------------|---|----------------------|
| Shared Lock (S) | Multiple transactions can read | Read operations |
| Exclusive Lock (X) | Only one transaction can access | Write operations |
| Intention Lock | Indicates intent to lock at lower level | Hierarchical locking |

Two-Phase Locking (2PL) Protocol:

- **Growing Phase:** Acquire locks, cannot release any lock
- **Shrinking Phase:** Release locks, cannot acquire new locks

Example:

```

1 Transaction T1: Read(A), Write(A), Read(B), Write(B)
2 Transaction T2: Read(A), Write(A), Read(C), Write(C)
3
4 T1: S-lock(A), Read(A), X-lock(A), Write(A), S-lock(B),
5     Read(B), X-lock(B), Write(B), Unlock(A), Unlock(B)
6
7 T2: Wait for A, S-lock(A), Read(A), X-lock(A), Write(A),
8     S-lock(C), Read(C), X-lock(C), Write(C), Unlock(A), Unlock(C)

```

Lock Compatibility Matrix:

| Current/Requested | S | X |
|-------------------|---|---|
| S | ✓ | ✗ |
| X | ✗ | ✗ |

- **Deadlock:** Two transactions waiting for each other's locks
- **Starvation:** Transaction waits indefinitely for lock

Solutions:

- **Deadlock Detection:** Use wait-for graph
- **Deadlock Prevention:** Timestamp-based protocols

Mnemonic

“Locking prevents Concurrent Conflicts”

Question 5(a) OR [3 marks]

Explain Deadlock in Transaction Management

Solution

Deadlock: Situation where two or more transactions are waiting indefinitely for each other to release locks, creating a circular wait condition.

Table 24. Deadlock Components

| Component | Description | Example |
|-------------------------|---------------------------------------|-------------------------|
| Mutual Exclusion | Resources cannot be shared | Exclusive locks |
| Hold and Wait | Process holds resources while waiting | T1 holds A, waits for B |
| No Preemption | Resources cannot be forcibly taken | Locks cannot be revoked |
| Circular Wait | Circular chain of waiting processes | T1→T2→T1 |

Example:

```

1 Transaction T1: Lock(A), Lock(B)
2 Transaction T2: Lock(B), Lock(A)

3
4 Time 1: T1 gets Lock(A)
5 Time 2: T2 gets Lock(B)
6 Time 3: T1 waits for Lock(B) - held by T2
7 Time 4: T2 waits for Lock(A) - held by T1
8 Result: DEADLOCK!

```

- **Detection:** Use wait-for graph to identify cycles
- **Prevention:** Use timestamp ordering or wound-wait protocols

Mnemonic

“Deadlock = Circular Waiting for Resources”

Question 5(b) OR [4 marks]

Describe Full Functional Dependency with example

Solution

Full Functional Dependency: A non-key attribute is functionally dependent on the entire primary key (not just part of it).

Table 25. Dependency Comparison

| Type | Definition | Example |
|---------------------------|---------------------------------|--|
| Full Dependency | Depends on complete primary key | (Student_ID, Course_ID) → Grade |
| Partial Dependency | Depends on part of primary key | (Student_ID, Course_ID) → Student_Name |

Example:

Enrollment Table:

Primary Key: (Student_ID, Course_ID)

| Student_ID | Course_ID | Grade | Hours |
|------------|-----------|-------|-------|
| 101 | C1 | A | 4 |
| 101 | C2 | B | 3 |
| 102 | C1 | B | 4 |

Full Functional Dependencies:

- (Student_ID, Course_ID) → Grade ✓
- (Student_ID, Course_ID) → Hours ✓

Explanation:

- **Grade** depends on both Student_ID AND Course_ID (specific student in specific course)
- **Hours** also depends on both (student's hours in specific course)
- Cannot determine Grade from Student_ID alone

- Cannot determine Grade from Course_ID alone

Benefits:

- **No Update Anomalies:** Changes affect only relevant records
- **Proper Normalization:** Supports 2NF requirements
- **Data Integrity:** Ensures accurate relationships

Mnemonic

“Full dependency needs Complete Key”

Question 5(c) OR [7 marks]

Explain ACID Properties of Transaction with example

Solution

ACID Properties: Four fundamental properties that guarantee database transaction reliability.

Table 26. ACID Properties

| Property | Description | Example |
|--------------------|---------------------------------|--|
| Atomicity | All or nothing execution | Bank transfer: both debit and credit must happen |
| Consistency | Database remains in valid state | Account balance cannot be negative |
| Isolation | Transactions don't interfere | Concurrent transactions appear sequential |
| Durability | Committed changes are permanent | Data survives system crashes |

Detailed Examples:**Atomicity Example:**

```

1 BEGIN TRANSACTION;
2 UPDATE Account SET Balance = Balance - 1000 WHERE AccNo = 'A001';
3 UPDATE Account SET Balance = Balance + 1000 WHERE AccNo = 'A002';
4 COMMIT;
```

If either update fails, entire transaction is rolled back

Consistency Example:

```

1 --- Before: A001 = 5000, A002 = 3000, Total = 8000
2 --- Transfer 1000 from A001 to A002
3 --- After: A001 = 4000, A002 = 4000, Total = 8000
4 --- Total money in system remains constant
```

Isolation Example:

```

1 T1: Read(A=100), A=A+50, Write(A=150)
2 T2: Read(A=100), A=A*2, Write(A=200)
3 Serial Result: A=300 or A=250
4 Isolated execution must produce one of these results
```

Durability Example:

```

1 After COMMIT is executed, even if system crashes,
2 the transferred amount remains in destination account
```

Implementation:

- **Atomicity:** Using transaction logs and rollback
- **Consistency:** Using constraints and triggers
- **Isolation:** Using locking mechanisms
- **Durability:** Using write-ahead logging

Mnemonic

“ACID keeps Transactions Reliable”