**DATABSE MANAGEMENT SYSTEM CHEATSHEET BY TECHIE CODEBUDDY**

**(This Cheatsheet is free, don't pay any money for it)**

## ### What is a Database?

**Definition:**

A database is a systematic collection of data that is stored and accessed electronically from a computer system. It is designed to manage and organize large amounts of information efficiently.

**Key Features:**

- Structured Storage: Data is organized into tables, records, and fields.

- Accessibility: Users can easily retrieve, update, and manage data.

- Consistency: Ensures data accuracy and integrity through constraints and rules.

- Scalability: Can handle large volumes of data and grow with the needs of the organization.

**Real-World Example:**

Think of a library catalog. Instead of keeping book information on individual cards or pieces of paper, all details (title, author, genre, availability) are stored in a structured, organized system. This system helps librarians quickly find and manage books, and it makes it easy for users to search for specific titles or authors.

## ### Evaluation of Database Models (In Short)

**1. Hierarchical Model:**

- Structure: Data is organized in a tree-like structure with a parent-child relationship.

- Pros: Easy to understand and implement.

- Cons: Rigid structure and not flexible for complex queries.

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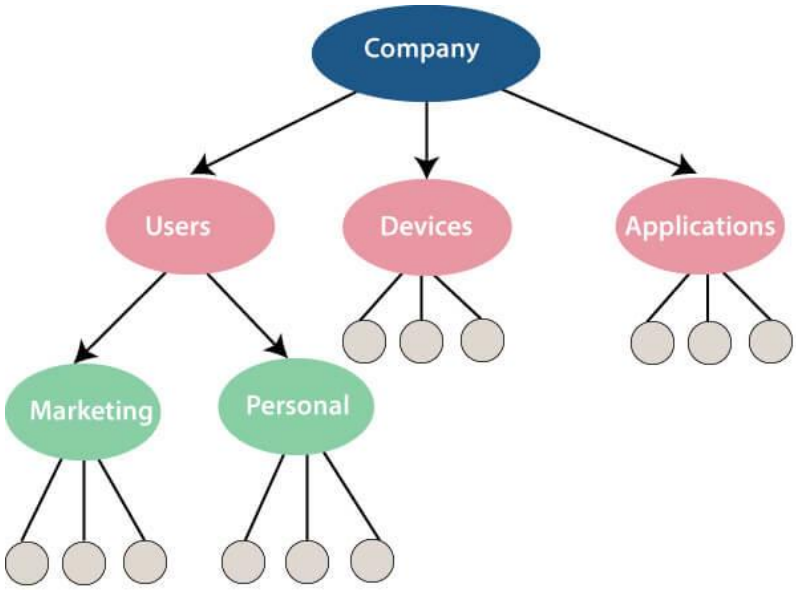
**Example:** A company's organizational chart where each manager has a list of employees reporting to them.




**2. Network Model:**

- Structure: Data is organized in a graph structure with nodes representing entities and edges representing relationships.

- Pros: More flexible than hierarchical models; supports many-to-many relationships.

- Cons: Complex to design and manage.

**Example:** A social network where users are connected to other users, and connections can have multiple types (friends, colleagues).

**3. Relational Model:**

- Structure: Data is organized into tables (relations) with rows and columns. Tables can be linked using primary and foreign keys.

- Pros: Easy to use, flexible, and supports complex queries. It is the most widely used model.

- Cons: Can become complex with very large datasets.

**Example:** A database for an online store with tables for customers, products, and orders. Relationships between these tables (e.g., customers placing orders) are managed using keys.

**4. Object-Oriented Model:**

- Structure: Data is represented as objects, similar to object-oriented programming concepts. Each object contains data and methods.

- Pros: Aligns well with object-oriented programming, supports complex data types.

- Cons: Less mature compared to relational models; can be more complex to design.

**Example:** A database for a graphics application where shapes and their properties are represented as objects.

**5. NoSQL Model:**

- Structure: Non-relational databases that use various data models (document, key-value, column-family, graph).

- Pros: Highly scalable and flexible; suitable for unstructured or semi-structured data.

- Cons: May lack support for complex queries and transactions.

**Example:** A document store like MongoDB where each document (e.g., a user profile) can have different structures.

Each database model has its strengths and is suited for different types of applications and data requirements.

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### Types of Databases

**1. Centralized Database**

**- Definition:**

A centralized database is stored, managed, and maintained in a single location or server. All data operations are performed on this central system.

**- Advantages:**

- Simplified Management: Easier to manage and maintain because everything is in one place.

- Consistency: Ensures data consistency since there is only one copy of the data.

- Security: Easier to implement security measures since there is a single point of access.

**Disadvantages:**

- Single Point of Failure: If the central server fails, the entire system is affected.

- Scalability Issues: Can become a bottleneck as the number of users or volume of data grows.

**- Use Case/Example:**

A company's internal HR system where all employee records, payroll data, and performance evaluations are stored on a single central server.

**2. Distributed Database**

**- Definition:**

A distributed database is spread across multiple locations, servers, or nodes. The data is distributed to provide better performance and reliability.

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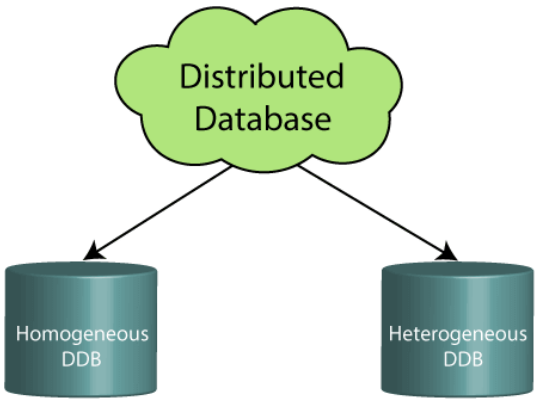


**Advantages:**

- Scalability: Can handle a large number of transactions and data volumes by distributing the load.

- Fault Tolerance: Reduces risk of a single point of failure as data is replicated across multiple sites.

**Disadvantages:**

- Complex Management: More complex to manage and synchronize data across multiple locations.

- Consistency Challenges: Ensuring data consistency and synchronization can be challenging.

**Use Case/Example:**

A global e-commerce platform where user data, transaction records, and product information are stored across servers in different regions to enhance performance and reliability.

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## 3. Relational Database

**Definition:**

A relational database organizes data into tables (relations) with rows and columns. It uses Structured Query Language (SQL) for managing and querying data.

**Advantages:**

- Flexibility: Supports complex queries and relationships between tables.
- Data Integrity: Enforces data integrity through constraints and keys.
- Widely Used: Mature and widely adopted with extensive support and tools.

**Disadvantages:**

- Scalability Limits: Can struggle with very large datasets or high transaction volumes.
- Complex Design: Schema design can be complex, especially for large applications.

**Use Case/Example:**

A university's student information system where tables store data about students, courses, and enrollments, and relationships between these entities are managed using foreign keys.

## 4. NoSQL Database

**Definition:**

NoSQL databases are non-relational databases designed for unstructured or semi-structured data. They use various models, including document, key-value, column-family, and graph.

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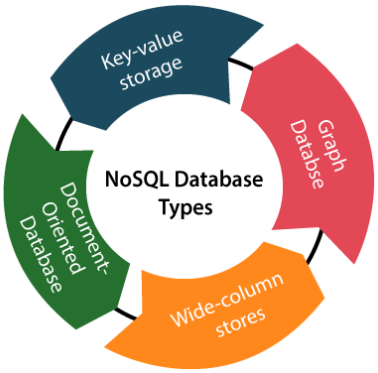


**Advantages:**

- Scalability: Highly scalable and can handle large volumes of diverse data types.
- Flexibility: Allows for a flexible schema and supports unstructured data.

**Disadvantages:**

- Limited Querying: May not support complex queries and transactions as well as relational databases.
- Consistency: May trade off consistency for availability and partition tolerance (CAP theorem).

**Use Case/Example:**

A content management system for a blog where articles, comments, and user profiles are stored as documents in a document store like MongoDB.

## 5. Cloud Database

**Definition:**

A cloud database is hosted and managed by a cloud service provider. It offers database services over the internet and is scalable on demand.

**Advantages:**

- Scalability: Easily scales resources up or down based on demand.
- Cost-Effective: Reduces the need for physical hardware and maintenance.

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- Accessibility: Accessible from anywhere with an internet connection.

### Disadvantages:

- Security Concerns: Data is stored off-site, which can raise security and privacy concerns.
- Reliance on Internet: Requires a stable internet connection for access.

**Use Case/Example:**

A startup using Amazon RDS (Relational Database Service) for managing its customer data and application transactions, benefiting from scalable resources and reduced management overhead.

## 6. Object-Oriented Database

**Definition:**

An object-oriented database stores data as objects, similar to object-oriented programming. Each object contains data and methods for manipulating that data.

**Advantages:**

- Alignment with OOP: Aligns well with object-oriented programming concepts, making it easier to work with complex data.
- Complex Data Types: Supports complex data structures and relationships.

**Disadvantages:**

- Less Mature: Less mature compared to relational databases, with fewer tools and support.
- Performance: Can have performance issues with certain types of queries.

### Use Case/Example:

A CAD (Computer-Aided Design) application where design objects like shapes, lines, and colors are stored as objects with methods for rendering and manipulating them.

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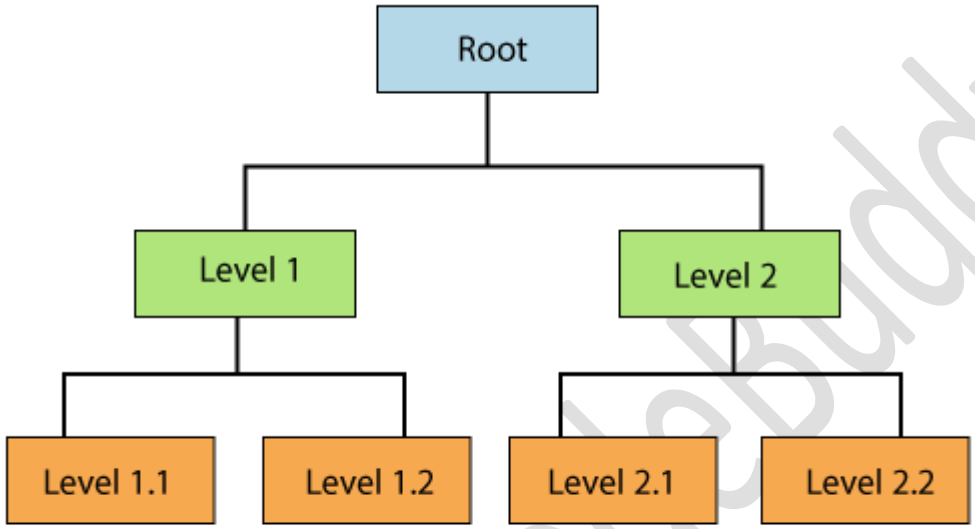
## 7. Hierarchical Database

**Definition:**

A hierarchical database organizes data in a tree-like structure, where each record has a single parent and possibly multiple children.




Hierarchical Database

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**Advantages:**

- Simplicity: Easy to understand and implement for simple data relationships.
- Performance: Efficient for hierarchical data retrieval.

**Disadvantages:**

- Rigid Structure: Not flexible for complex queries or relationships.
- Redundancy: Can lead to data redundancy and difficulty in managing many-to-many relationships.

**Use Case/Example:**

An organizational chart where each department has sub-departments and employees, with a clear parent-child relationship.

## 8. Network Database

- **Definition:**

A network database uses a graph structure where entities are represented as nodes and relationships are represented as edges, allowing multiple relationships between nodes.

- **Advantages:**

- Flexibility: Supports many-to-many relationships and complex data models.
- Performance: Efficient for complex queries with multiple relationships.

- **Disadvantages:**

- Complexity: More complex to design and manage compared to hierarchical databases.
- Maintenance: Harder to maintain and update due to intricate relationships.

- **Use Case/Example:**

A telecommunications network where connections between different network nodes (switches, routers) need to be modeled and managed.

## 9. Personal Database

**Definition:**

A personal database is designed for individual use, often for personal projects or small-scale applications. It is typically lightweight and user-friendly.

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**Advantages:**

- Ease of Use: Simple to set up and use without requiring extensive knowledge.

- Cost-Effective: Often free or inexpensive and does not require large-scale resources.

**Disadvantages:**

- Limited Scalability: Not suitable for large-scale or enterprise applications.

- Limited Features: May lack advanced features and support.

**Use Case/Example:**

A personal budget management system where an individual tracks their income, expenses, and savings using a desktop database application like Microsoft Access.

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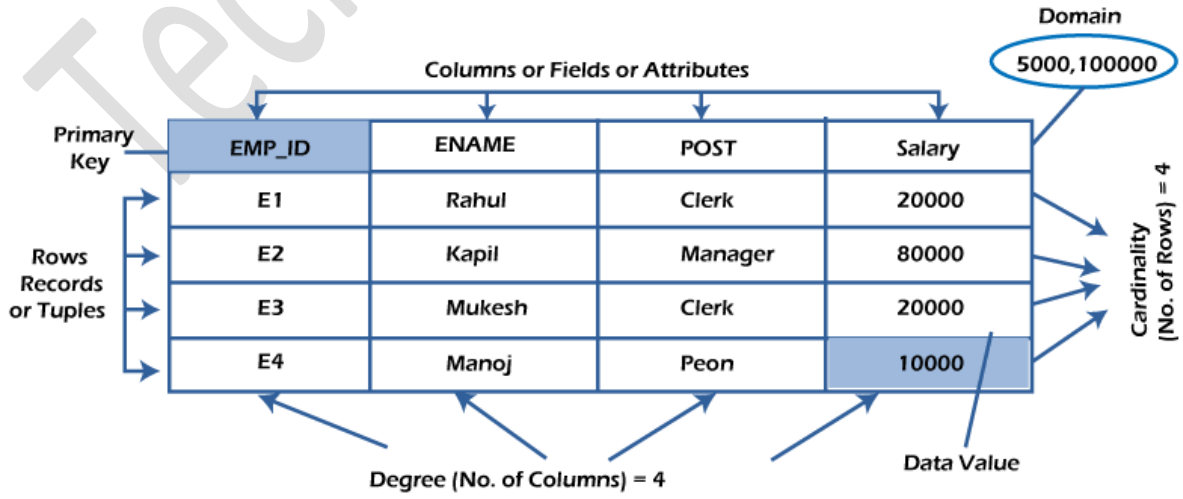
## ### What is RDBMS (Relational Database Management System)?

**Definition:**

A Relational Database Management System (RDBMS) is a type of database management system that stores data in a structured format, using rows and columns. It organizes data into tables (also called relations) that can be linked—or related—based on data common to each. RDBMS uses Structured Query Language (SQL) for querying and managing data



**Key Features:**

**1. Tables:**

- Data is stored in tables, which consist of rows and columns.
- Each table represents an entity, and columns represent attributes of that entity.

**2. Relationships:**

- Tables can be related to each other through primary and foreign keys.
- Primary Key: A unique identifier for a record in a table.
- Foreign Key: A field in one table that links to the primary key in another table.

**3. SQL Support:**

- SQL is used to perform various operations like querying, updating, inserting, and deleting data.
- SQL commands include `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `JOIN`, etc.

**4. Normalization:**

- The process of organizing data to reduce redundancy and improve data integrity.
- Involves dividing a database into two or more tables and defining relationships between them.

**5. Data Integrity:**

- Enforces rules and constraints to ensure the accuracy and consistency of data.
- Examples include unique constraints, foreign key constraints, and check constraints.

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**6. ACID Properties:**

- Atomicity: Ensures that all parts of a transaction are completed successfully or none are.

- Consistency: Ensures that a transaction brings the database from one valid state to another.

- Isolation: Ensures that transactions are executed independently and transparently.

- Durability: Ensures that once a transaction is committed, it remains in the database even if there is a system failure.

**Advantages:**

1. Data Integrity and Accuracy:
   - Ensures data accuracy through constraints and relationships between tables.

2. Flexibility:
   - Allows complex queries and operations to be performed using SQL.

3. Data Security:
   - Provides robust security features to control access and protect data.

4. Scalability:
   - Can handle large volumes of data and multiple users efficiently.

5. Ease of Maintenance:
   - Provides tools and interfaces for managing and maintaining the database easily.

## Disadvantages:

1. Complexity:

   - Can be complex to design, especially for large systems with many tables and relationships.

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2. Performance:
   - Performance can be affected as data volume and transaction complexity increase.

3. Cost:
   - Licensing costs for commercial RDBMS software can be high.

**Real-World Example:**

**1. Online Retail Store:**

- An e-commerce website uses an RDBMS to manage various data aspects, including customer information, product details, and order records.

**- Tables:**

- `Customers` table: Stores customer information like customer_id (Primary Key), name, email, etc.

- `Products` table: Stores product details like product_id (Primary Key), name, price, etc.

- `Orders` table: Stores order details like order_id (Primary Key), customer_id (Foreign Key), product_id (Foreign Key), order_date, etc.

**- Relationships:**

- The `Orders` table links to the `Customers` and `Products` tables through foreign keys, allowing the system to track which customer placed which order and what products were included in each order.

**2. Banking System:**

- A banking application uses an RDBMS to handle transactions, account management, and customer information.

**- Tables:**

- `Accounts` table: Stores account details such as account_id (Primary Key), account_type, balance, etc.

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- `Transactions` table: Records transaction details such as transaction_id (Primary Key), account_id (Foreign Key), amount, transaction_date, etc.

- **Relationships:**

- The `Transactions` table links to the `Accounts` table through a foreign key, allowing the system to associate each transaction with a specific account and maintain accurate financial records.

RDBMS is foundational in modern data management and remains widely used across various applications due to its structured approach and robustness.

**Differences between DBMS and RDBMS:**

| DBMS | RDBMS |
|---|---|
| DBMS applications store **data as file**. | RDBMS applications store **data in a tabular form**. |
| In DBMS, data is generally stored in either a hierarchical form or a navigational form. | In RDBMS, the tables have an identifier called primary key and the data values are stored in the form of tables. |
| **Normalization is not** present in DBMS. | **Normalization is** present in RDBMS. |
| DBMS does **not apply any security** with regards to data manipulation. | RDBMS **defines the integrity constraint** for the purpose of ACID (Atomocity, Consistency, Isolation and Durability) property. |
| DBMS uses file system to store data, so there will be **no relation between the tables**. | in RDBMS, data values are stored in the form of tables, so a **relationship** between these data values will be stored in the form of a table as well. |
| DBMS has to provide some uniform methods to access the stored information. | RDBMS system supports a tabular structure of the data and a relationship between them to access the stored information. |

| | |
|---|---|
| DBMS **does not support distributed database**. | RDBMS **supports distributed database**. |
| DBMS is meant to be for small organization and **deal with small data**. it supports **single user**. | RDBMS is designed to **handle large amount of data**. it supports **multiple users**. |
| Examples of DBMS are file systems, **xml** etc. | Example of RDBMS are **mysql**, **postgre**, **sql server**, **oracle** etc. |

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## ### DBMS Architecture

Database Management System (DBMS) architectures describe the way database systems are structured and how they interact with users and applications. There are three primary types of DBMS architecture: 1-Tier, 2-Tier, and 3-Tier.

### 1. 1-Tier Architecture

**Definition:**

In a 1-Tier architecture, also known as a single-tier or standalone architecture, the database system and the application run on the same machine. There is no distinction between the user interface, application logic, and database.

**Components:**

- Database: Directly managed and accessed by the application.

- Application: The application and database management system are integrated into a single layer.

**Advantages:**

- Simplicity: Easy to set up and use since everything is contained in one layer.

- No Network Latency: No network delays as everything runs on a single machine.

**Disadvantages:**

- Scalability: Limited scalability as the system depends on the capabilities of a single machine.

- Data Management: All data operations are handled by the local machine, which can be inefficient for larger applications.

**- Use Case/Example:**

A desktop application like Microsoft Access where the database and application are both installed on a user's personal computer.

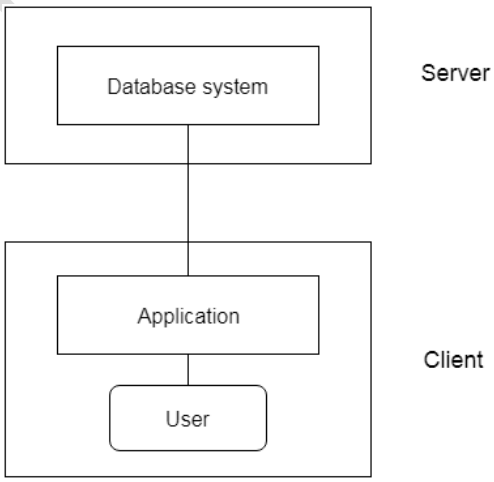
## 2. 2-Tier Architecture

### Definition:

In a 2-Tier architecture, the system is divided into two layers: the client layer and the server layer. The client layer interacts directly with the database server.

**Components:**

- Client Layer: The application or user interface that interacts with the database.
- Server Layer: The database server that manages and stores the data.

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**Advantages:**

- Separation of Concerns: The application and database are separated, making it easier to manage and scale.

- Improved Performance: Direct communication between the client and server can reduce latency.

**Disadvantages:**

- Limited Scalability: While it improves over 1-Tier, scaling can still be challenging for large numbers of users or complex applications.

- Network Dependency: Performance depends on network reliability and bandwidth.

**Use Case/Example:**

A client-server application where a business application installed on users' machines directly interacts with a central database server. For example, a sales application accessing a central database for customer information and sales records.

## 3. 3-Tier Architecture

**Definition:**

In a 3-Tier architecture, the system is divided into three layers: the presentation layer, the application layer, and the database layer. Each layer is responsible for different aspects of the application.

**Components:**

- Presentation Layer: The user interface that interacts with the user. It handles the display of data and user input.

- Application Layer (Business Logic Layer): The middle layer that processes user requests, applies business logic, and communicates with the database layer.

- Database Layer: The layer that manages and stores the data.

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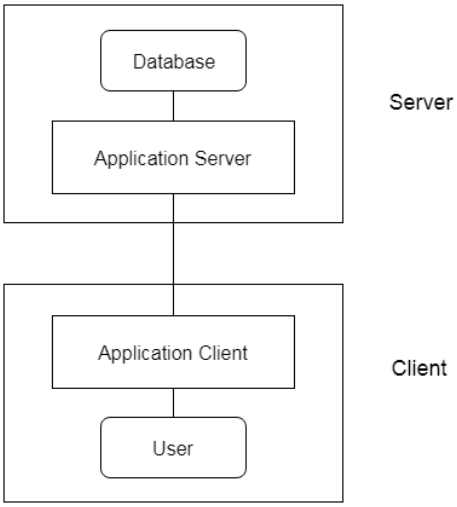


**Advantages:**

- Scalability: Easier to scale each layer independently. For instance, you can scale the application server or database server as needed.

- Maintainability: Changes in one layer (e.g., user interface) do not directly impact the other layers.

- Flexibility: Allows for different technologies to be used in each layer (e.g., different programming languages for business logic and database management).

**Disadvantages:**

- Complexity: More complex architecture, requiring careful design and integration.

- Performance Overhead: Additional layers can introduce latency due to the multiple steps involved in processing a request.

**Use Case/Example:**

**A web application where:**

- Presentation Layer: The web browser or web application that users interact with.

- Application Layer: The web server (e.g., Apache, Nginx) that processes business logic and requests.

- Database Layer: The database server (e.g., MySQL, PostgreSQL) that stores and manages data.

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### Summary

**1-Tier Architecture:** All-in-one system; simple but limited in scalability.

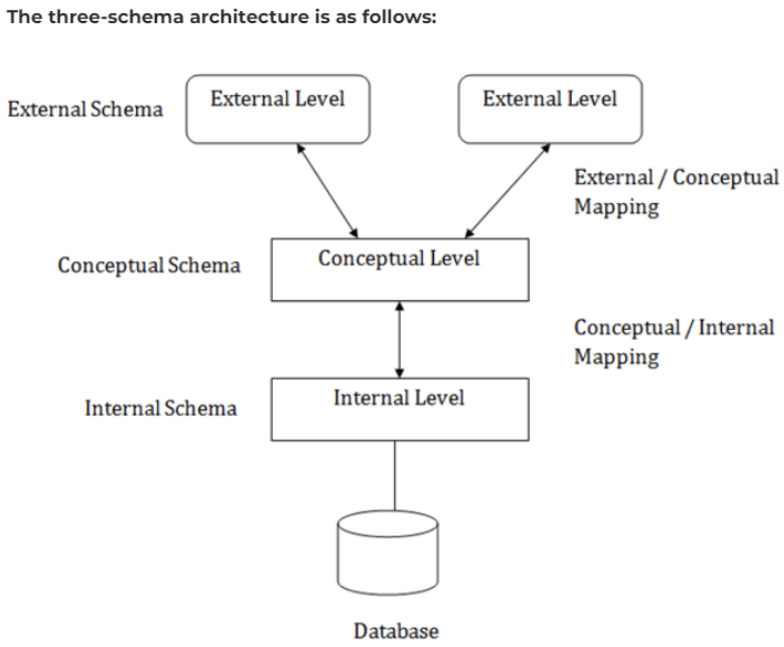
**2-Tier Architecture:** Client-server model; better scalability than 1-Tier but still limited.

**3-Tier Architecture:** Separation of presentation, business logic, and data; highly scalable and maintainable.

Each architecture has its own use cases and is chosen based on factors like application complexity, scalability needs, and maintainability requirements.

## ### Three-Schema Architecture

The Three-Schema Architecture is a framework used in database management systems to separate the database system's structure into three different levels. This architecture is designed to provide a clear separation between different aspects of the database system, facilitating data management and ensuring data abstraction.

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The three levels are:

1. **Internal Schema (Physical Level)**
2. **Conceptual Schema (Logical Level)**
3. **External Schema (View Level)**

## 1. Internal Schema (Physical Level)

**- Definition:**

The internal schema describes the physical storage of data in the database. It defines how data is stored on the hardware, including data structures, file organization, and indexing.

**- Key Aspects:**

- Data Storage: Details how data is stored on disk.
- Access Methods: Specifies how data is retrieved and manipulated efficiently.
- File Organization: Describes how data files are organized, such as through sequential or indexed file structures.

**- Advantages:**

- Efficiency: Optimizes data storage and retrieval operations.
- Flexibility: Allows changes in storage structures without affecting the higher levels.

**- Example:**

In a relational database, the internal schema might specify that tables are stored in indexed files, with data organized in B-trees for quick retrieval.

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## 2. Conceptual Schema (Logical Level)

**- Definition:**

The conceptual schema provides a unified view of the entire database, focusing on the logical structure of the data without considering how it is physically stored. It describes the data model, entities, relationships, constraints, and schema design.

**- Key Aspects:**

- Data Model: Defines the overall structure of the database, including tables, relationships, and constraints.

- Entity-Relationship Model: Represents entities (e.g., customers, products) and their relationships (e.g., orders placed by customers).

- Constraints: Enforces rules such as primary keys, foreign keys, and unique constraints.

**- Advantages:**

- Consistency: Provides a clear and consistent view of the data structure.

- Abstraction: Separates the logical design from physical implementation, making it easier to manage and design the database.

**- Example:**

The conceptual schema of a university database might define tables for `Students`, `Courses`, and `Enrollments`, and specify how these tables are related (e.g., students enroll in courses).

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## 3. External Schema (View Level)

**- Definition:**

The external schema, or view level, represents the user views of the database. It defines how different users or applications interact with the database, including what data is visible and how it is presented.

**Key Aspects:**

- User Views: Provides customized views for different users based on their needs and roles.

- Access Control: Determines which parts of the database users can access and modify.

- Data Presentation: Defines how data is formatted and presented to users.

**Advantages:**

- User Specific: Tailors the data presentation to different user requirements.

- Security: Restricts access to sensitive data based on user roles and permissions.

**Example:**

In a company database, the external schema might include different views for employees, managers, and HR personnel. Employees might see only their own data, while managers might have access to team data, and HR might have access to all employee records.

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## ### Summary

**- Internal Schema (Physical Level):** Focuses on how data is physically stored.

**- Conceptual Schema (Logical Level):** Defines the logical structure and relationships of data.

**- External Schema (View Level):** Provides tailored views of data for different users or applications.

# ### Data Models

Data models define the structure, organization, and relationships of data in a database. They provide a conceptual framework for understanding and managing data. Here are explanations of different types of data models:

## 1. Relational Data Model

**- Definition:**

The Relational Data Model organizes data into tables (relations) that are linked by common attributes. Each table consists of rows (records) and columns (attributes).

**- Key Components:**

- Tables: Represent entities (e.g., `Customers`, `Orders`).
- Rows: Each row is a record or instance of the entity.
- Columns: Each column represents an attribute or field of the entity.
- Primary Key: A unique identifier for each row in a table.
- Foreign Key: An attribute that creates a link between two tables by referencing the primary key of another table.

## - Advantages:

- Simplicity: Easy to understand and use.
- Flexibility: Supports complex queries using SQL.
- Data Integrity: Enforces constraints like primary and foreign keys to ensure accuracy.

**Example**: A `Customer` table with columns `CustomerID`, `Name`, and `Email`, and an `Order` table with columns `OrderID`, `CustomerID`, and `OrderDate`. The `CustomerID` in the `Order` table is a foreign key linking to the `Customer` table.

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## 2. Entity-Relationship (ER) Data Model

**- Definition:**

The Entity-Relationship (ER) Data Model is a conceptual framework that describes the data using entities, attributes, and relationships. It is often used to design the database schema.

**- Key Components:**

- Entities: Objects or concepts (e.g., `Student`, `Course`) that have data stored about them.

- Attributes: Properties or characteristics of entities (e.g., `StudentID`, `StudentName`).

- Relationships: Associations between entities (e.g., `Enrollment` relationship between `Student` and `Course`).

**- Advantages:**

- Conceptual Clarity: Provides a high-level view of the database structure.

- Design Tool: Useful for designing and visualizing the database schema before implementation.

**Example**: An ER diagram where `Student` and `Course` are entities. `Enrollment` is a relationship connecting `Student` and `Course`, with `StudentID` and `CourseID` as attributes.

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## 3. Object-Based Data Model

**- Definition:**

The Object-Based Data Model combines database capabilities with object-oriented programming concepts. It represents data as objects, similar to objects in programming languages like Java or C++.

- **Key Components:**

- Objects: Instances of classes, representing both data and methods (e.g., `Customer` object with methods to update customer information).

- Classes: Templates for creating objects, defining properties and methods.

- Inheritance: Ability to create new classes based on existing ones, inheriting attributes and behaviors.

- **Advantages:**

- Rich Data Representation: Supports complex data types and relationships.

- Integration: Aligns well with object-oriented programming languages, enabling easier integration.

**Example:** A `Customer` class with attributes `CustomerID`, `Name`, and `Email`, and methods to update or retrieve customer information. Objects of this class represent individual customers.

## 4. Semi-Structured Data Model

**Definition:**

The Semi-Structured Data Model represents data that does not conform to a rigid schema but still includes some organizational structure. It is used to handle data that is partially structured, such as documents or web data.

- **Key Components:**

- Tags or Markup: Used to annotate data with metadata (e.g., XML or JSON tags).

- Hierarchical Structure: Data is often organized in a tree-like structure but is flexible in terms of schema.

- **Advantages:**

- Flexibility: Accommodates data with varying structures.

- Scalability: Suitable for handling large amounts of diverse data types.

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**Example:** An XML document representing a book catalog, where each book element has child elements like `Title`, `Author`, and `Year`. Another example is JSON data used in web APIs, where data is represented in a nested, flexible format.

## ### Summary

- **Relational Data Model:** Uses tables to represent data and relationships; ideal for structured data and complex queries.

- **ER Data Model:** Provides a conceptual design of the database using entities and relationships; useful for database design.

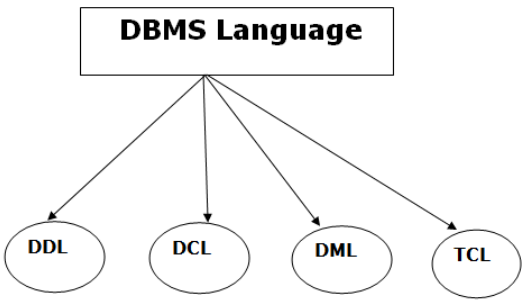
- **Object-Based Data Model:** Represents data as objects, integrating with object-oriented programming; supports complex data structures.

- **Semi-Structured Data Model:** Handles data with flexible structure, using tags or markup; suitable for diverse and unstructured data types.

Each data model has its own use cases and is chosen based on the requirements of the application and the nature of the data being managed.

## ### DBMS Languages

Database Management Systems (DBMS) use various languages to interact with and manage data. These languages can be broadly categorized into three types: Data Definition Language (DDL), Data Manipulation Language (DML), and Data Control Language (DCL). Here's a detailed overview:

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## 1. Data Definition Language (DDL)

- **Definition:**

DDL is used to define and manage the structure of the database schema. It includes commands that create, modify, and delete database objects such as tables, indexes, and schemas.

Key Commands:

- `CREATE` : Used to create database objects like tables, indexes, and views.
  - Example: `CREATE TABLE Employees (EmployeeID INT PRIMARY KEY, Name VARCHAR(100));`
- `ALTER` : Used to modify the structure of existing database objects.
  - Example: `ALTER TABLE Employees ADD COLUMN Department VARCHAR(50);`
- `DROP` : Used to delete database objects.
  - Example: `DROP TABLE Employees;`
- `TRUNCATE` : Used to remove all records from a table while keeping its structure.
  - Example: `TRUNCATE TABLE Employees;`

- **Use Case:**

When setting up a new database or changing the structure of existing tables, you use DDL commands to define or adjust the schema.

## 2. Data Manipulation Language (DML)

**Definition:**

DML is used for querying and manipulating data within the database. It includes commands to insert, update, delete, and retrieve data.

Key Commands:

- `SELECT`: Retrieves data from one or more tables.
  - Example: `SELECT * FROM Employees WHERE Department = 'Sales';`
- `INSERT`: Adds new records to a table.
  - Example: `INSERT INTO Employees (EmployeeID, Name, Department) VALUES (1, 'Alice', 'HR');`
- `UPDATE`: Modifies existing records in a table.
  - Example: `UPDATE Employees SET Department = 'Marketing' WHERE EmployeeID = 1;`
- `DELETE`: Removes records from a table.
  - Example: `DELETE FROM Employees WHERE EmployeeID = 1;`

### - Use Case:

When interacting with the database to manage or retrieve data, DML commands are used for everyday operations such as querying data or updating records.

## 3. Data Control Language (DCL)

**Definition:**

DCL is used to control access to data within the database. It includes commands to grant or revoke permissions to users.

Key Commands:

- `GRANT`: Provides specific privileges to users or roles.
  - Example: `GRANT SELECT, INSERT ON Employees TO User1;`
- `REVOKE`: Removes specific privileges from users or roles.
  - Example: `REVOKE INSERT ON Employees FROM User1;`

### - Use Case:

When managing user permissions and access control, DCL commands are used to specify who can access or modify the data in the database.

## ### Summary

- **DDL (Data Definition Language**): Manages the structure of database objects (e.g., `CREATE`, `ALTER`, `DROP`).

- **DML (Data Manipulation Language):** Handles the manipulation and retrieval of data (e.g., `SELECT`, `INSERT`, `UPDATE`, `DELETE`).

- **DCL (Data Control Language):** Controls user access and permissions (e.g., `GRANT`, `REVOKE`).

These languages are essential for managing and interacting with databases, each serving a specific purpose in the database management process.

## ### ACID Properties

**(Click here for more detailed Explanation with Diagrams)**

ACID properties are a set of principles that ensure reliable processing of database transactions. They are crucial for maintaining data integrity and consistency in a database system. ACID stands for Atomicity, Consistency, Isolation, and Durability.

### 1. Atomicity

- Definition:

Atomicity ensures that a transaction is treated as a single, indivisible unit of work. Either all the operations within the transaction are completed successfully, or none are applied.

- **Key Points:**

- All-or-Nothing: If any part of the transaction fails, the entire transaction is rolled back, and no changes are applied.

- Rollback: If a transaction encounters an error, any changes made are undone.

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- **Example:**

In a bank transfer, if a transaction involves transferring money from one account to another, atomicity ensures that either both the debit from one account and the credit to another account are completed successfully, or neither is done. If an error occurs during the process, both operations are rolled back.

## 2. Consistency

- **Definition:**

Consistency ensures that a transaction brings the database from one valid state to another valid state, maintaining all defined rules and constraints.

- **Key Points:**

- Data Integrity: The database must adhere to all constraints, rules, and relationships after a transaction.

- Integrity Constraints: Ensures that the database remains in a consistent state before and after the transaction.

- **Example:**

In an online store, if a transaction involves adding a new order, consistency ensures that the database will reflect the new order accurately and that inventory levels are updated accordingly. For instance, if a product's stock is reduced by one when an order is placed, consistency ensures that no negative stock values are recorded.

## 3. Isolation

- **Definition:**

Isolation ensures that concurrent transactions do not interfere with each other. Each transaction is executed in isolation from others, so its operations are not visible to other transactions until it is complete.

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- **Key Points:**

- Concurrency Control: Prevents data corruption caused by concurrent transactions.

- Isolation Levels: Different isolation levels (e.g., Read Uncommitted, Read Committed, Repeatable Read, Serializable) determine the degree of visibility and interaction between transactions.

**Example:**

If two transactions are concurrently updating the balance of the same bank account, isolation ensures that each transaction's operations do not affect the other's intermediate results. For instance, if one transaction is updating the balance while another is reading it, isolation ensures that the read operation will not see an inconsistent or intermediate state.

## 4. Durability

**Definition:**

Durability ensures that once a transaction has been committed, its changes are permanent and will survive any subsequent system failures or crashes.

- **Key Points:**

- Persistence: Changes made by a committed transaction are stored in non-volatile storage and are not lost even if there is a system failure.

- Recovery: The database can recover committed transactions after a crash or failure.

- **Example:**

After a transaction that updates a user's profile information is committed, durability ensures that the updated profile will remain in the database even if the system crashes immediately after the commit.

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## ### Summary

- **Atomicity:** Ensures transactions are all-or-nothing.

- **Consistency:** Ensures transactions bring the database from one valid state to another.

- **Isolation:** Ensures concurrent transactions do not interfere with each other.

- **Durability:** Ensures committed transactions are permanently recorded and survive system failures.

The ACID properties collectively ensure that database transactions are processed reliably and that data integrity is maintained, providing a robust framework for transaction management in database systems.

## ### Data Modeling and ER Model

Data Modeling is the process of creating a visual representation of a system's data and its relationships. It helps in understanding and organizing the data requirements for a system. The Entity-Relationship (ER) Model is one of the most widely used approaches in data modeling for designing databases.

**### Data Modeling**

**Definition:**

Data Modeling involves creating diagrams and documentation that define the structure, relationships, and constraints of data within a system. It is used to design and analyze the data needs of an organization or system.

**Purpose:**

- **Understand Requirements:** Helps in capturing the data requirements of the system.

- **Design Database Schema:** Provides a blueprint for creating the database structure.

- **Facilitate Communication**: Offers a clear representation of data to stakeholders and developers.

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**Components:**

- Entities: Objects or concepts about which data is stored (e.g., `Customer`, `Order`).

- Attributes: Properties or characteristics of entities (e.g., `CustomerID`, `OrderDate`).

- Relationships: Connections between entities that define how data is related (e.g., `Customer places Order`).

## ### Entity-Relationship (ER) Model

**Definition:**

The ER Model is a high-level conceptual data model that visually represents the data, its entities, attributes, and relationships. It is used for database design and helps in understanding the data requirements and structure of a database.

**Key Components:**

**1. Entities:**

- Definition: Objects or things in the domain that have a distinct existence. Entities can be physical objects or abstract concepts.

- Example: `Employee`, `Department`, `Product`.

**2. Attributes:**

- Definition: Characteristics or properties of an entity. Attributes provide more information about an entity.

- Types:

  - Simple Attribute: Cannot be divided further (e.g., `Name`).

  - Composite Attribute: Can be divided into smaller attributes (e.g., `Address` divided into `Street`, `City`, `ZipCode`).

  - Derived Attribute: Can be derived from other attributes (e.g., `Age` derived from `DateOfBirth`).

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- Multivalued Attribute: Can have multiple values (e.g., `PhoneNumbers`).

**3. Relationships:**

- Definition: Associations between entities that describe how they interact with each other.

- Types:

- One-to-One (1:1): One entity instance relates to one instance of another entity (e.g., `Person` has one `Passport`).

- One-to-Many (1:N): One entity instance relates to multiple instances of another entity (e.g., `Customer` places multiple `Orders`).

- Many-to-Many (M:N): Multiple instances of one entity relate to multiple instances of another entity (e.g., `Student` enrolls in multiple `Courses`, and `Course` has multiple `Students`).

**4. ER Diagram (ERD):**

- Definition: A visual representation of the ER Model that shows entities, attributes, and relationships.

- Components:

- Rectangles: Represent entities.

- Ellipses: Represent attributes.

- Diamonds: Represent relationships.

- Lines: Connect entities to relationships and attributes.

## Example ER Diagram:

**Consider a simple example of an ER Diagram for a university database:**

- Entities: `Student`, `Course`

- Attributes:

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- `Student` has `StudentID`, `Name`, `Email`

- `Course` has `CourseID`, `CourseName`, `Credits`

- Relationships: `Enrolls` (a student enrolls in multiple courses)

- ER Diagram:

- Draw `Student` and `Course` as rectangles.

- Draw `Enrolls` as a diamond connecting `Student` and `Course`.

- Add attributes to `Student` and `Course` using ellipses connected to the respective entities.

## ### Summary

**Data Modeling:** A method to design and represent data requirements and structures.

**ER Model:** A conceptual framework for designing databases using entities, attributes, and relationships, often visualized through an ER Diagram.

**Purpose of ER Model:**

- **Design Database Schema:** Provides a blueprint for creating and structuring the database.

- **Understand Data Relationships:** Helps in visualizing how different data elements are related.

The ER Model is a fundamental tool in database design, offering a clear and structured approach to defining and organizing data.

## ### DBMS Keys

Keys are fundamental concepts in relational databases used to uniquely identify records and establish relationships between tables. They play a crucial role in ensuring data integrity and efficient data retrieval. Here are the main types of keys in DBMS:

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## 1. Primary Key

**- Definition:**

A primary key is a unique identifier for a record in a table. It ensures that each record is uniquely identifiable and that no two records have the same primary key value.

**- Characteristics:**

- Uniqueness: Each value of the primary key must be unique.
- Non-null: A primary key cannot contain null values.

**- Example:**

In a `Students` table, `StudentID` can be used as the primary key to uniquely identify each student.

```sql
CREATE TABLE Students (
    StudentID INT PRIMARY KEY,
    Name VARCHAR(100),
    DateOfBirth DATE
);
```

**- Use Case:**

The primary key ensures that each student can be uniquely identified and retrieved from the `Students` table.

## 2. Foreign Key

**- Definition:**

A foreign key is an attribute in one table that refers to the primary key of another table. It establishes a link between the two tables, enforcing referential integrity.

**Characteristics:**

- Referential Integrity: Ensures that the value in the foreign key column matches a value in the primary key column of the referenced table.

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- Optional Nulls: Foreign key columns can contain null values if the relationship is optional.

- **Example:**

In an `Orders` table, `CustomerID` can be a foreign key that references the `CustomerID` in the `Customers` table.

```sql
CREATE TABLE Orders (
    OrderID INT PRIMARY KEY,
    CustomerID INT,
    OrderDate DATE,
    FOREIGN KEY (CustomerID) REFERENCES Customers(CustomerID)
);
```

- **Use Case:**

The foreign key ensures that each order in the `Orders` table is associated with a valid customer in the `Customers` table.

## 3. Candidate Key

- **Definition:**

A candidate key is an attribute or a set of attributes that can uniquely identify a record in a table. Each table can have multiple candidate keys, but one is selected as the primary key.

- **Characteristics:**

- Uniqueness: Each candidate key value must be unique.

- Minimality: It should not contain any unnecessary attributes; removing any attribute should make it no longer a candidate key.

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- **Example:**

In a `Users` table, both `Username` and `Email` might be candidate keys if they are both unique.

```sql
CREATE TABLE Users (
    Username VARCHAR(50) UNIQUE,
    Email VARCHAR(100) UNIQUE,
    Password VARCHAR(50)
);
```

- **Use Case:**

Candidate keys offer alternative ways to uniquely identify records. You can choose any candidate key as the primary key based on requirements.

## 4. Alternate Key

- **Definition:**

An alternate key is any candidate key that is not selected as the primary key. It still uniquely identifies records but is not used as the primary key.

- **Characteristics:**

- Uniqueness: Must be unique, like the primary key.
- Alternative Identification: Provides an alternative way to identify records.

- **Example:**

In the `Users` table mentioned earlier, if `Username` is chosen as the primary key, then `Email` is an alternate key.

- **Use Case:**

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Alternate keys are used when a table needs multiple unique identifiers, offering flexibility in data retrieval.

## 5. Composite Key

**- Definition:**

A composite key is a primary key that consists of two or more attributes that together uniquely identify a record.

**- Characteristics:**

- Combination: The combination of the attributes must be unique across all records.

- Multi-Attribute: Involves more than one attribute to ensure uniqueness.

**- Example:**

In a `CourseEnrollments` table, a composite key could be a combination of `StudentID` and `CourseID`.

```sql
CREATE TABLE CourseEnrollments (
    StudentID INT,
    CourseID INT,
    EnrollmentDate DATE,
    PRIMARY KEY (StudentID, CourseID)
);
```

- Use Case:

Composite keys are useful in many-to-many relationships where a single attribute is not sufficient to uniquely identify records.

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## 6. Super Key

- **Definition:**

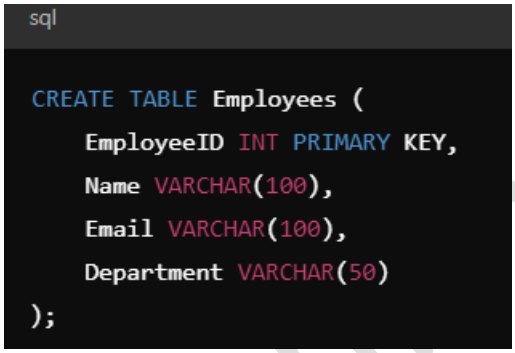
A super key is a set of one or more attributes that can uniquely identify a record in a table. It includes the primary key as well as any additional attributes that may be included.

- **Characteristics:**

- Uniqueness: Ensures uniqueness of records.
- Superset: Includes primary key and additional attributes.

- **Example:**

In a `Employees` table, `EmployeeID` alone could be a super key, but `EmployeeID` combined with `Email` is also a super key.




- **Use Case:**

Super keys are used to identify records uniquely, but only one super key is usually chosen as the primary key.

## ### Summary

- **Primary Key:** Uniquely identifies each record in a table. Cannot be null.

- **Foreign Key:** Establishes relationships between tables. Refers to the primary key of another table.

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- **Candidate Key:** A set of attributes that can uniquely identify records. Includes the primary key.

- **Alternate Key:** Candidate keys not selected as the primary key.

- **Composite Key:** A primary key composed of multiple attributes.

- **Super Key:** A set of attributes that uniquely identifies records, including the primary key and additional attributes.

Understanding these keys is essential for designing and managing relational databases effectively, ensuring data integrity, and establishing meaningful relationships between tables.

## ### Generalization, Specialization, and Aggregation

These concepts are part of the Entity-Relationship (ER) Model and are used to handle hierarchical relationships and abstraction in database design.

**1. Generalization**

- **Definition:**

Generalization is a process of extracting common characteristics from multiple entities to create a generalized entity. It is the opposite of specialization and is used to create a higher-level entity that abstracts common properties and relationships.

- **Characteristics:**

- Abstraction: Combines several lower-level entities into a higher-level entity based on shared attributes.

- Hierarchical: Helps in organizing data into a hierarchy where a generalized entity encompasses multiple specialized entities.

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**Example**: Consider entities `Car` and `Truck`, which share common attributes such as `Make`, `Model`, and `Year`. Generalization allows you to create a generalized entity `Vehicle` with these shared attributes, and `Car` and `Truck` would then be specialized entities of `Vehicle`.

**ER Diagram**:


- **Vehicle** is the generalized entity.
- **Car** and **Truck** are specialized entities that inherit attributes from **Vehicle**.

**- Use Case:**

Generalization is useful when you have multiple entities that share common attributes or behaviors, and you want to reduce redundancy by combining them into a single generalized entity.

## 2. Specialization

**- Definition:**

Specialization is the process of creating new entities from an existing, generalized entity by adding more specific attributes or relationships. It involves breaking down a generalized entity into more specific sub-entities.

**- Characteristics:**

- Detailing: Adds more detail and specificity to a generalized entity.

- Hierarchical: Creates a hierarchy where specialized entities inherit common attributes from a generalized entity but also have their own distinct attributes.

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**Example**: Starting with a generalized entity `Person`, you can specialize it into `Employee` and `Student` based on specific attributes or roles. `Employee` might have attributes like `EmployeeID` and `Department`, while `Student` might have `StudentID` and `Major`.

ER Diagram:

```
Person
├── Employee
└── Student
```

- **Person** is the generalized entity.
- **Employee** and **Student** are specialized entities with additional specific attributes.

**- Use Case:**

Specialization is used when you need to represent entities with more detailed or specific attributes that differ from the generalized entity, providing a clear distinction between various roles or types.

## 3. Aggregation

**- Definition:**

Aggregation is a concept used to express a relationship between a whole and its parts or between a complex entity and its components. It represents a higher-level abstraction that groups together entities and their relationships into a single higher-level entity.

**Characteristics:**

- Composite Relationships: Allows for complex relationships to be treated as a single entity.

- Hierarchical: Aggregates multiple entities and relationships into a higher-level entity, often to simplify the ER diagram.

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**Example**: Suppose you have entities `Project`, `Employee`, and `Department`. You might use aggregation to represent a relationship where `Project` involves `Employee` and `Department` in a higher-level entity called `ProjectAssignment`.

ER Diagram:

```markdown
Project
└── ProjectAssignment
    ├── Employee
    └── Department
```

- **ProjectAssignment** is the aggregated entity representing the involvement of both `Employee` and `Department` in a `Project`.

**- Use Case:**

Aggregation is useful when you need to simplify complex relationships or represent a composite entity that groups together multiple entities and their relationships.

# ### Summary

**- Generalization**: Combines multiple lower-level entities into a higher-level entity based on shared attributes.

**- Specialization**: Breaks down a generalized entity into more specific entities with additional attributes.

**- Aggregation:** Groups together entities and their relationships into a single higher-level entity for simplification**.**

These concepts help in organizing and abstracting data efficiently in database design, making the structure more manageable and comprehensible.

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### Normalization, Types of Normal Forms, and Anomalies

Normalization is a process in database design used to minimize redundancy and dependency by organizing data into related tables. The goal is to ensure data integrity and reduce anomalies that can occur when modifying the data. Normalization involves dividing a database into two or more tables and defining relationships between them.

## ### Normalization

**Definition:**

Normalization is the process of structuring a database to reduce redundancy and improve data integrity by organizing data into tables and establishing relationships between them.

**Purpose:**

- Eliminate Redundancy: Avoid storing the same data in multiple places.
- Improve Data Integrity: Ensure data is consistent and accurate.
- Simplify Queries: Make it easier to query and update data.

**Process:**

Normalization is achieved through a series of stages called normal forms, each addressing different types of redundancy and dependency.

## ### Types of Normal Forms

**1. First Normal Form (1NF) (Click to read JavaTpoint Arcticle)**

**- Definition:** A table is in 1NF if it only contains atomic (indivisible) values and each column contains only a single value. Each column must have a unique name, and the order in which data is stored does not matter.

**Characteristics:**

- Atomicity: Ensures that each field contains only one value.
- Uniqueness: No repeating groups or arrays in a column.

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Example:

```sql
Table: Students
+---------+-----------------+
| StudentID | Courses         |
+---------+-----------------+
| 1       | Math, English   |
| 2       | Science, History |
+---------+-----------------+
```

Converted to 1NF:

```sql
Table: Students
+---------+---------+
| StudentID | Course  |
+---------+---------+
| 1       | Math    |
| 1       | English |
| 2       | Science |
| 2       | History |
+---------+---------+
```

## 2. Second Normal Form (2NF) (Click to read JavaTpoint Article)

**Definition:** A table is in 2NF if it is in 1NF and all non-key attributes are fully functionally dependent on the primary key. It eliminates partial dependency, where a non-key attribute is dependent on part of a composite key.

- **Characteristics:**

- Full Functional Dependency: Ensures that all attributes depend on the entire primary key, not just part of it.

Example:

```sql
Table: Enrollments
+---------+---------+-----------+
| StudentID | CourseID | Instructor|
+---------+---------+-----------+
| 1       | 101     | Dr. Smith |
| 1       | 102     | Dr. Johnson|
+---------+---------+-----------+
```

Converted to 2NF:

- Table: Enrollments

```diff
+---------+---------+
| StudentID | CourseID |
+---------+---------+
| 1       | 101     |
| 1       | 102     |
+---------+---------+
```

Table: Courses

```diff
+---------+-----------+
| CourseID | Instructor|
+---------+-----------+
| 101     | Dr. Smith |
| 102     | Dr. Johnson|
+---------+-----------+
```

## 3. Third Normal Form (3NF)

- **Definition:** A table is in 3NF if it is in 2NF and all attributes are functionally dependent only on the primary key, eliminating transitive dependency (where non-key attributes depend on other non-key attributes).

**Characteristics:**

- No Transitive Dependency: Ensures that non-key attributes are not dependent on other non-key attributes.

Example:

```sql
Table: Employees
+---------+-----------+------------+
| EmpID   | EmpName   | DeptName   |
+---------+-----------+------------+
| 1       | John      | HR         |
| 2       | Jane      | IT         |
+---------+-----------+------------+
```

Converted to 3NF:

- Table: Employees

```diff
+---------+-----------+
| EmpID   | EmpName   |
+---------+-----------+
| 1       | John      |
| 2       | Jane      |
+---------+-----------+
```

- Table: Departments

```diff
+-----------+------------+
| DeptID    | DeptName   |
+-----------+------------+
| 1         | HR         |
| 2         | IT         |
+-----------+------------+
```

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## 4. Boyce-Codd Normal Form (BCNF)

- **Definition:** A table is in BCNF if it is in 3NF and every determinant is a candidate key. BCNF addresses situations where 3NF does not handle certain types of redundancy.

- **Characteristics:**

  - Stricter Form of 3NF: Ensures that every determinant in the table is a candidate key.

Example:

If a table with attributes `A`, `B`, and `C` has functional dependencies such that `A` and `B` determine `C`, and `A` is not a candidate key, it violates BCNF.

## 5. Fourth Normal Form (4NF)

- Definition: A table is in 4NF if it is in BCNF and has no multi-valued dependencies (where one attribute can have multiple values independent of other attributes).

- **Characteristics:**

  - Eliminates Multi-Valued Dependencies: Ensures that no attribute has multiple independent values.

- **Example:**

A table storing information about a student and their hobbies, where each student can have multiple hobbies and each hobby can belong to multiple students, should be decomposed to satisfy 4NF.

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### 6. Fifth Normal Form (5NF)

**Definition:** A table is in 5NF if it is in 4NF and all join dependencies are implied by candidate keys. It deals with cases where information can be reconstructed without any loss of information.

**Characteristics:**

- Join Dependency: Ensures that all relationships can be restored by joining tables based on candidate keys.

- **Example:**

A table with attributes `A`, `B`, `C`, and `D` that satisfies 5NF would ensure that any complex relationships are decomposed such that they can be reassembled without loss of information.

## ### Anomalies

**1. Insertion Anomaly**

- Definition: Occurs when certain data cannot be inserted into a database without the presence of other data. This often happens when a table design is not normalized.

- **Example:**

If you cannot add a new `Course` unless there is an associated `Student`, this indicates an insertion anomaly.

**2. Deletion Anomaly**

- Definition: Occurs when the deletion of data results in the loss of additional data that should be retained.

- **Example:**

If deleting an `Employee` record also unintentionally deletes the `Department` record, this is a deletion anomaly.

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**3. Update Anomaly**

- Definition: Occurs when changes to data in one place must be repeated in multiple places, leading to inconsistencies.

**Example:**

If an employee's department name needs to be updated in several records, and the update is not performed everywhere, this causes an update anomaly.

## ### Summary

**- Normalization:** The process of organizing data to reduce redundancy and improve integrity through normal forms.

**- Normal Forms:** Include 1NF, 2NF, 3NF, BCNF, 4NF, and 5NF, each addressing different types of data anomalies and dependencies.

**- Anomalies:** Include insertion, deletion, and update anomalies, which occur when data is not properly normalized.

Normalization is crucial for designing efficient and reliable databases that maintain data integrity and support consistent operations.

## ### Advantages and Disadvantages of Normalization

Normalization is a critical aspect of database design that helps ensure data integrity and minimize redundancy. However, it comes with both benefits and potential drawbacks. Here's a detailed look at the advantages and disadvantages of normalization:

**### Advantages of Normalization**

**1. Reduces Data Redundancy**

- Explanation: By organizing data into related tables and eliminating duplicate data, normalization minimizes the repetition of data.

- Example: In a normalized database, a customer's address information is stored in a separate table rather than repeating the address in multiple tables.

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**2. Improves Data Integrity**

- Explanation: Normalization ensures that data is consistent and accurate by enforcing rules that prevent anomalies.

- Example: A normalized database prevents the creation of inconsistent or contradictory data entries, such as multiple records for the same customer with different addresses.

**3. Facilitates Efficient Data Modification**

- Explanation: Changes to data need to be made in only one place, reducing the risk of inconsistencies.

- Example: Updating a customer's phone number in a normalized database requires changing it in only the `Customers` table, rather than in several places.

**4. Enhances Query Performance**

- Explanation: Although normalization might initially seem to complicate queries, it often improves performance by reducing the amount of redundant data.

- Example: Queries that join normalized tables can be more efficient because they avoid the overhead associated with redundant data.

**5. Simplifies Database Maintenance**

- Explanation: Maintaining a normalized database is easier because updates, deletions, and insertions are handled in a structured manner.

- Example: Adding a new product category only requires inserting it into the `Categories` table without affecting other tables.

**6. Promotes Data Consistency**

- Explanation: With normalized tables, data is stored in a consistent manner, which helps in maintaining data accuracy and consistency.

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- Example: Consistent data formats and relationships are maintained across different tables.

## ### Disadvantages of Normalization

**1. Increased Complexity**

Explanation: Normalizing a database can make the schema more complex, with many tables and relationships, which might be harder to understand and manage.

- Example: A highly normalized schema might involve numerous tables and complex joins, making it challenging for users to write and understand queries.

**2. Performance Overhead**

- Explanation: While normalization can improve data integrity, it might introduce performance overhead due to the need for multiple joins in queries.

- Example: Retrieving information from multiple normalized tables often requires complex joins, which can impact query performance, especially with large datasets.

**3. Potential for Increased Joins**

- Explanation: Normalized databases often require multiple joins to retrieve related data, which can lead to slower query performance.

- Example: To get a complete picture of a customer's order history, you might need to join several tables, potentially slowing down query execution.

**4. Complexity in Data Retrieval**

- Explanation: Querying normalized databases can be more complex and require more sophisticated SQL queries.

- Example: Retrieving detailed reports from a highly normalized database might require multiple subqueries or complex joins.

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**5. Overhead in Database Design**

- Explanation: The process of designing a normalized database can be time-consuming and requires careful planning and analysis.

- Example: Ensuring that all normalization rules are followed and balancing the need for normalization with performance considerations can be challenging.

**6. Possible Redundancy Trade-offs**

- Explanation: Sometimes, denormalization (introducing some redundancy) might be used deliberately to improve performance for certain queries, leading to a trade-off between normalization and efficiency.

- Example: Adding redundant data for performance reasons, such as storing aggregated values, might reduce the strict adherence to normalization.

# ### Summary

**Advantages:**

- Reduces data redundancy.
- Improves data integrity.
- Facilitates efficient data modification.
- Enhances query performance.
- Simplifies database maintenance.
- Promotes data consistency.

**Disadvantages:**

- Increased complexity.
- Performance overhead due to joins.
- Potential for increased joins.
- Complexity in data retrieval.
- Overhead in database design.
- Possible trade-offs with denormalization for performance.

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## ### Transaction Processing

Transaction Processing is a crucial concept in database management systems (DBMS) and is essential for ensuring the integrity and consistency of data. It involves managing and executing transactions in a way that ensures data remains accurate and reliable, even in the face of system failures or concurrent operations.

# ### Definition of a Transaction

**Transaction:**

A transaction is a sequence of one or more operations (such as read, write, update, or delete) that are executed as a single unit of work. A transaction must either be fully completed or fully rolled back to maintain data integrity.

### Properties of a Transaction (ACID):

**1. Atomicity:**

- Definition: Ensures that a transaction is an indivisible unit of work. Either all operations within the transaction are completed successfully, or none are applied.

- Example: In a bank transfer, both the debit from one account and the credit to another must succeed or fail together.

**2. Consistency:**

- Definition: Ensures that a transaction brings the database from one consistent state to another. The database must adhere to all predefined rules and constraints.

- Example: After a successful bank transfer, the total amount of money in the system remains the same, preserving financial consistency.

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3. **Isolation:**

- Definition: Ensures that transactions executed concurrently do not affect each other. Each transaction should be executed as if it were the only transaction in the system.

- Example: If two transactions are transferring money between accounts simultaneously, the system should handle them without causing data inconsistencies.

4. **Durability:**

- Definition: Ensures that once a transaction is committed, its changes are permanent, even in the case of system failures.

- Example: After a successful bank transfer, the updated account balances must be preserved even if the system crashes immediately afterward.

## ### Transaction Processing Phases

1. **Begin Transaction:**
- The start of a transaction is marked, indicating the beginning of a unit of work.

2. **Execute Operations:**
- Operations such as insertions, updates, or deletions are performed within the transaction.

3. **Commit Transaction:**
- If all operations are successfully executed and validated, the transaction is committed, making all changes permanent.

4. **Rollback Transaction:**
- If any operation fails or an error occurs, the transaction is rolled back to its initial state, undoing all changes to maintain consistency.

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## ### Transaction Management Techniques

**1. Locking:**

- Definition: Mechanism to control access to data items to prevent conflicts in concurrent transactions.

- Types:

  - Exclusive Locks: Prevents other transactions from accessing the locked data.

  - Shared Locks: Allows other transactions to read but not modify the data.

**2. Concurrency Control:**

- Definition: Techniques used to manage the execution of concurrent transactions to ensure isolation and avoid anomalies.

- Techniques:

  - Two-Phase Locking (2PL): Ensures transactions acquire locks in a way that avoids conflicts.

  - Optimistic Concurrency Control: Allows transactions to execute without immediate locking but validates before committing.

**3. Transaction Logs:**

- Definition: Records of all transactions and their operations, used to ensure durability and support recovery in case of failures.

- Example: A transaction log stores information about all changes made during a transaction, which can be used to redo or undo changes if needed.

**4. Recovery Techniques:**

- Definition: Methods used to restore the database to a consistent state after a failure.
- Techniques:
  - Checkpointing: Periodically saving the state of the database to reduce recovery time.
  - Redo/Undo Operations: Applying or reversing changes recorded in transaction logs to restore consistency.

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## ### Example Scenario

Consider an online banking application where a customer transfers money from their savings account to their checking account.

- **Begin Transaction: The transfer process starts.**
- **Execute Operations:**

1. Debit the savings account.
2. Credit the checking account.

- Commit Transaction: If both operations succeed, the transaction is committed.
- Rollback Transaction: If any operation fails (e.g., insufficient funds), the transaction is rolled back, and no changes are applied.

By ensuring that transactions adhere to the ACID properties and using appropriate transaction management techniques, a DBMS can maintain the reliability and consistency of data even in complex and concurrent environments.

## ### Summary

- Transaction: A sequence of operations executed as a single unit.
- ACID Properties: Atomicity, Consistency, Isolation, Durability.
- Transaction Processing Phases: Begin, Execute, Commit, Rollback.
- Management Techniques: Locking, Concurrency Control, Transaction Logs, Recovery Techniques.

Transaction processing is fundamental for maintaining data integrity and consistency in database systems, ensuring reliable and accurate data management.

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# ### Joins in SQL

Joins are used in SQL to combine rows from two or more tables based on a related column between them. They are essential for retrieving data from multiple tables in a single query.

**### Types of Joins**

**1. INNER JOIN**

- Definition: Returns rows when there is a match between columns in both tables involved in the join. Only the rows with matching values in both tables are included in the result set.

Syntax:

```sql
SELECT column_name(s)
FROM table1
INNER JOIN table2
ON table1.common_column = table2.common_column;
```

Example:

```sql
SELECT Employees.EmployeeID, Employees.EmployeeName, Departments.DeptName
FROM Employees
INNER JOIN Departments
ON Employees.DeptID = Departments.DeptID;
```

This query retrieves employee IDs and names along with their department names where there is a matching department ID in both tables.

## 2. LEFT JOIN (or LEFT OUTER JOIN)

**Definition:** Returns all rows from the left table and the matched rows from the right table. If there is no match, the result is NULL for columns from the right table.

Syntax:

```sql
SELECT column_name(s)
FROM table1
LEFT JOIN table2
ON table1.common_column = table2.common_column;
```

Example:

```sql
SELECT Employees.EmployeeID, Employees.EmployeeName, Departments.DeptName
FROM Employees
LEFT JOIN Departments
ON Employees.DeptID = Departments.DeptID;
```

This query retrieves all employees and their department names, including those employees who do not belong to any department (with NULL for department names).

## 3. RIGHT JOIN (or RIGHT OUTER JOIN)

- **Definition:** Returns all rows from the right table and the matched rows from the left table. If there is no match, the result is NULL for columns from the left table.

Syntax:

```sql
SELECT column_name(s)
FROM table1
RIGHT JOIN table2
ON table1.common_column = table2.common_column;
```

Example:

```sql
SELECT Employees.EmployeeID, Employees.EmployeeName, Departments.DeptName
FROM Employees
RIGHT JOIN Departments
ON Employees.DeptID = Departments.DeptID;
```

This query retrieves all departments and their employees, including departments that have no employees (with NULL for employee details).

## 4. FULL OUTER JOIN

Definition: Returns all rows when there is a match in one of the tables. It combines the results of both LEFT JOIN and RIGHT JOIN, with NULLs in places where there is no match.

Syntax:

```sql
SELECT column_name(s)
FROM table1
FULL OUTER JOIN table2
ON table1.common_column = table2.common_column;
```

Example:

```sql
SELECT Employees.EmployeeID, Employees.EmployeeName, Departments.DeptName
FROM Employees
FULL OUTER JOIN Departments
ON Employees.DeptID = Departments.DeptID;
```

This query retrieves all employees and all departments, including employees who are not in any department and departments that have no employees (with NULLs where there are no matches).

## ### Using Aliases in Joins

Aliases are used to create temporary names for tables or columns in SQL queries, which can simplify complex queries and improve readability.

**Definition: An alias is a temporary name given to a table or column in a SQL query.**

Syntax:

```sql
SELECT column_name(s)
FROM table1 AS alias1
INNER JOIN table2 AS alias2
ON alias1.common_column = alias2.common_column;
```

Example with Aliases:

```sql
SELECT E.EmployeeID, E.EmployeeName, D.DeptName
FROM Employees AS E
INNER JOIN Departments AS D
ON E.DeptID = D.DeptID;
```

- **Explanation:** In this query, `Employees` is aliased as `E`, and `Departments` is aliased as `D`. This makes the query easier to write and read, especially in cases with multiple joins or complex queries.

Another Example with LEFT JOIN and Aliases:

```sql
SELECT E.EmployeeID, E.EmployeeName, D.DeptName
FROM Employees AS E
LEFT JOIN Departments AS D
ON E.DeptID = D.DeptID;
```

- **Explanation**: This query uses aliases for both `Employees` and `Departments` tables and retrieves all employees and their department names, including those without a department.

## ### Summary

- INNER JOIN: Returns only matching rows between tables.
- LEFT JOIN: Returns all rows from the left table and matching rows from the right table.
- RIGHT JOIN: Returns all rows from the right table and matching rows from the left table.
- FULL OUTER JOIN: Returns all rows when there is a match in either table.
- Aliases: Simplify and improve readability of SQL queries by providing temporary names for tables or columns.

Joins and aliases are powerful tools in SQL for combining and simplifying data retrieval from multiple tables.

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# Advanced SQL

## *#### Subqueries and Nested Queries*

### Subqueries:

A subquery is a query nested inside another query. It can be used in `SELECT`, `INSERT`, `UPDATE`, and `DELETE` statements to provide results for the outer query.

Types of Subqueries:

1. Single-Row Subqueries:
   - Returns a single row and is used with operators like `=`, `>`, `<`, etc.
   - Example:

```sql
SELECT EmployeeName
FROM Employees
WHERE DeptID = (SELECT DeptID FROM Departments WHERE DeptName = 'HR');
```

2. Multiple-Row Subqueries:
   - Returns multiple rows and is used with operators like `IN`, `ANY`, `ALL`.
   - Example:

```sql
SELECT EmployeeName
FROM Employees
WHERE DeptID IN (SELECT DeptID FROM Departments WHERE DeptLocation = 'New York');
```

3. Correlated Subqueries:
   - References columns from the outer query and is evaluated once for each row processed by the outer query.
   - Example:

```sql
SELECT E.EmployeeName
FROM Employees E
WHERE EXISTS (SELECT 1 FROM Departments D WHERE E.DeptID = D.DeptID AND D.DeptName
```

Nested Queries:

- A type of subquery where one query is nested inside another query.
- Example:

```sql
SELECT EmployeeName
FROM Employees
WHERE DeptID = (SELECT DeptID FROM Departments WHERE DeptName = 'Sales');
```

## #### GROUP BY and HAVING

GROUP BY and HAVING

GROUP BY:

- **Definition:** Groups rows that have the same values in specified columns into summary rows.
- Syntax:

```sql
SELECT column_name(s), aggregate_function(column_name)
FROM table_name
GROUP BY column_name(s);
```

- Example:

```sql
SELECT DeptID, COUNT(*) AS EmployeeCount
FROM Employees
GROUP BY DeptID;
```

This query counts the number of employees in each department.

HAVING:

- **Definition:** Filters records after the `GROUP BY` clause has been applied.
- Syntax:

```sql
SELECT column_name(s), aggregate_function(column_name)
FROM table_name
GROUP BY column_name(s)
HAVING aggregate_function(column_name) condition;
```

- Example:

```sql
SELECT DeptID, COUNT(*) AS EmployeeCount
FROM Employees
GROUP BY DeptID
HAVING COUNT(*) > 10;
```

This query retrieves departments with more than 10 employees.

## #### Aggregate Functions

### Aggregate Functions

**Aggregate Functions:** Perform a calculation on a set of values and return a single value. Common aggregate functions include:

1. **COUNT():** Counts the number of rows.
   - **Example:**

```sql
SELECT COUNT(*) FROM Employees;
```

2. **SUM():** Calculates the total sum of a numeric column.
   - **Example:**

```sql
SELECT SUM(Salary) FROM Employees;
```

3. **AVG():** Calculates the average value of a numeric column.
    - **Example:**

```sql
SELECT AVG(Salary) FROM Employees;
```

4. **MAX():** Returns the maximum value of a column.
    - **Example:**

```sql
SELECT MAX(Salary) FROM Employees;
```

5. **MIN():** Returns the minimum value of a column.
    - **Example:**

```sql
SELECT MIN(Salary) FROM Employees;
```

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# Quick Revision in Short

Here's a quick revision guide covering the key concepts for each of the topics:

**### 1. Data Models**

**Relational Data Model:**

- Definition: Represents data in tables (relations) with rows and columns.
- Key Concepts: Tables, rows, columns, primary keys, foreign keys.
- Example: An `Employees` table with columns for `EmployeeID`, `EmployeeName`, `DeptID`.

**ER Data Model:**

- Definition: Uses entities and relationships to represent data.
- Key Concepts: Entities, attributes, relationships, ER diagrams.
- Example: An `Employee` entity with attributes like `EmployeeID` and `EmployeeName`, related to a `Department` entity.

**Object-Based Data Model:**

- Definition: Represents data as objects, similar to object-oriented programming.
- Key Concepts: Classes, objects, inheritance.
- Example: An `Employee` class with methods and attributes.

**Semi-Structured Data Model:**

- Definition: Represents data without a fixed schema, often used in XML/JSON.
- Key Concepts: Tags, attributes, nested structures.
- Example: JSON object representing employee details.

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### 2. DBMS Architecture and Components

1-Tier Architecture:

- Definition: Database and application reside on the same machine.
- Use Case: Single-user applications.

2-Tier Architecture:

- Definition: Client and database server are separate, connected directly.
- Use Case: Desktop applications with a centralized database.

3-Tier Architecture:

- Definition: Includes a client, application server, and database server.
- Use Case: Web applications with scalability and separation of concerns.

Components:

- Database Engine: Handles data storage and retrieval.
- Database Schema: Defines database structure.
- Query Processor: Executes SQL queries.
- Transaction Manager: Manages database transactions.

### 3. SQL Queries

Basic Queries:

- SELECT: Retrieve data.

```sql
SELECT column1, column2 FROM table_name;
```

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Filtering and Sorting:

- WHERE: Filter records.

```sql
SELECT * FROM table_name WHERE condition;
```

- ORDER BY: Sort results.

```sql
SELECT * FROM table_name ORDER BY column_name;
```

Aggregation:

- COUNT, SUM, AVG, MAX, MIN: Perform calculations.

```sql
SELECT COUNT(*) FROM table_name;
```

**### 4. ER Diagrams**

Components:

- Entities: Objects or things in the database.
- Attributes: Properties of entities.
- Relationships: Associations between entities.
- Cardinality: Specifies the number of instances.

Example:

- Entity: `Employee`

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- Attributes: `EmployeeID`, `Name`, `DeptID`
- Relationship: `Works_In` between `Employee` and `Department`

### 5. Normal Forms

1NF (First Normal Form):

- Definition: Ensure that all columns contain atomic values.
- Example: No repeating groups in rows.

2NF (Second Normal Form):

- Definition: Achieve 1NF and remove partial dependencies.
- Example: No partial dependencies on a composite key.

3NF (Third Normal Form):

- Definition: Achieve 2NF and remove transitive dependencies.
- Example: No non-key attributes dependent on other non-key attributes.

Boyce-Codd Normal Form (BCNF):

- Definition: Achieve 3NF and ensure every determinant is a candidate key.

### 6. Joins

INNER JOIN:

- Definition: Returns rows with matching values in both tables.
- Example:

```sql

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```

```
SELECT * FROM table1 INNER JOIN table2 ON table1.id = table2.id;
```

```

LEFT JOIN:

- Definition: Returns all rows from the left table and matched rows from the right table.

- Example:

```sql
SELECT * FROM table1 LEFT JOIN table2 ON table1.id = table2.id;
```

```

RIGHT JOIN:

- Definition: Returns all rows from the right table and matched rows from the left table.

- Example:

```sql
SELECT * FROM table1 RIGHT JOIN table2 ON table1.id = table2.id;
```

```

FULL OUTER JOIN:

- Definition: Returns all rows when there is a match in one of the tables.

- Example:

```sql
SELECT * FROM table1 FULL OUTER JOIN table2 ON table1.id = table2.id;
```

```

### 7. Keys

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Primary Key:

- Definition: Unique identifier for a record in a table.
- Example:

```sql
CREATE TABLE table_name (
  id INT PRIMARY KEY,
  name VARCHAR(100)
);
```

Foreign Key:

- Definition: A key used to link two tables together.
- Example:

```sql
ALTER TABLE table1
ADD CONSTRAINT fk_table2
FOREIGN KEY (table2_id)
REFERENCES table2(id);
```

Unique Key:

- Definition: Ensures all values in a column are unique.
- Example:

```sql
ALTER TABLE table_name
```

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ADD CONSTRAINT unique_column UNIQUE (column_name);
```

### 8. Constraints

NOT NULL:

- Definition: Ensures that a column cannot have NULL values.
- Example:

```sql
CREATE TABLE table_name (
  column_name INT NOT NULL
);
```

CHECK:

- Definition: Ensures that all values in a column satisfy a specific condition.
- Example:

```sql
CREATE TABLE table_name (
  age INT CHECK (age >= 18)
);
```

DEFAULT:

- Definition: Provides a default value for a column.
- Example:

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```

```sql
CREATE TABLE table_name (
  status VARCHAR(10) DEFAULT 'active'
);
```

### 9. Transactions and Concurrency Control

Transactions:

- Definition: A sequence of operations performed as a single unit of work.
- Commands: `BEGIN`, `COMMIT`, `ROLLBACK`.
- Example:

```sql
BEGIN;
UPDATE table_name SET column_name = value;
COMMIT;
```

Concurrency Control:

- Definition: Manages simultaneous transactions to ensure data consistency.
- Techniques:
  - Locking: Prevents other transactions from accessing the same data.
  - Isolation Levels: Defines the visibility of changes made by a transaction.

### 10. Query Optimization

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Indexing:

- Definition: Creates a data structure to improve query performance.
- Types: Primary index, secondary index.
- Example:

```sql
CREATE INDEX idx_name ON table_name (column_name);
```

Optimization Techniques:

- Use of Indexes: Index columns frequently used in queries.
- Avoiding Subqueries: Use joins where possible.
- Analyzing Query Execution Plans: Use tools like `EXPLAIN`.

### 11. Integrity Rules

Entity Integrity:

- Definition: Ensures that each table has a primary key and that the key is unique and not NULL.

Referential Integrity:

- Definition: Ensures that foreign key values in a table match primary key values in another table.

Domain Integrity:

- Definition: Ensures that values in a column fall within a specified range or set of values.

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User-Defined Integrity:

- Definition: Business rules that define constraints beyond standard integrity rules.

---

This guide provides a brief overview of the essential concepts and SQL syntax for each topic.

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