**Review 4**

Functional Dependency:

A functional dependency occurs when one attribute uniquely determines another attribute. Notation:

If attribute A determines attribute B, we write: (A → B )

This means: if we know the value of A, we can determine the value of B.

Super Key:

A super key is any combination of attributes that can uniquely identify a row in a table. Includes the primary key and Can contain extra attributes not necessary for uniqueness

Candidate Key:

A candidate key is the minimal super key, i.e., it has no extra attributes and can uniquely identify each tuple (row).

There can be multiple candidate keys in a table.

**Prime Attribute:** A prime attribute is an attribute that is part of any candidate key of a relation.

**NonPrime Attribute:** A non prime attribute is an attribute that is not part of any candidate key.

**Trival :** A functional Dependency is trivial if the dependent (right hand value ) is a subset of the determinant (left hand side). [ ex: AB — A ]

**Non Trival:** A functional dependency is non trivial if the dependent (right hand side) is not a subset of the determinant (left hand side). [ ex: AB — C]

Normalisation:

Normalization is a step-by-step process of organizing data in a database to reduce redundancy and avoid undesirable characteristics like insertion, update, and deletion anomalies.

First Normal Form (1NF):

Rule: All attribute values must be atomic (indivisible). No multivalued or composite attributes.

Second Normal Form (2NF):

Rule: Must be in 1NF, and no partial dependency.

Partial Dependency: A partial dependency occurs when a non-prime attribute is functionally dependent on part of a composite primary key and not the whole key.

Third Normal Form (3NF):

Rule: Must be in 2NF, and no transitive dependency.

Transitive Dependency: A non-prime attribute depends on another non-prime attribute.

Boyce Codd Normal Form (BCNF):

Rule: For every non-trivial functional dependency X → Y, X must be a super key.

Fourth Normal Form (4NF):

Rule: Must be in BCNF and no multivalued dependency.

A multivalued dependency occurs when one attribute in a table determines multiple independent values of another attribute, and those values are not dependent on any other attribute.

Fifth Normal Form (5NF):

Rule: Must be in 4NF and lossless join dependency.

A join dependency occurs when a table can be decomposed into two or more tables, and when those tables can be joined back without any loss of information.

**Payroll Management System – Database Normalization Report** Tables:

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### 1. Table: attendance

| Attendance_ID | Employee_ID | Check_in | Check_out |
|---|---|---|---|
| 1 | 1 | 2024-03-06 09:00:00 | 2024-03-06 18:00:00 |
| 2 | 2 | 2024-03-07 09:00:00 | 2024-03-07 17:00:00 |
| 3 | 3 | 2024-03-07 09:30:00 | 2024-03-07 17:30:00 |
| 4 | 1 | 2024-03-08 08:30:00 | 2024-03-08 17:30:00 |
| 5 | 2 | 2024-03-08 09:15:00 | 2024-03-08 18:15:00 |
| 6 | 3 | 2024-03-08 09:45:00 | 2024-03-08 18:45:00 |

Functional Dependency:

1. Attendance_ID → Employee_ID, Check_in, Check_out
2. Employee_ID → Check_in, Check_out (not always, only for participation view, not FD for the whole table)

Super Keys:

- Attendance_ID
- (Attendance_ID, Employee_ID)

Candidate Keys:

- Attendance_ID

First Normal Form [1NF]:

- All attributes contain atomic (indivisible) values.
- No repeating groups or arrays.
- So, the attendance table satisfies the First Normal Form.

Second Normal Form [2NF]:

- Already in 1NF.
- Primary key is Attendance_ID (single attribute).
- All non-prime attributes (Employee_ID, Check_in, Check_out) are fully dependent on the entire primary key.

- No partial dependency.
- So, this table satisfies the Second Normal Form.

Third Normal Form [3NF]:

- Already in 2NF.
- No transitive dependencies (i.e., non-prime → non-prime via another non-prime).
- All non-prime attributes are directly dependent on the primary key.
- So, this table satisfies the Third Normal Form.

Boyce-Codd Normal Form [BCNF]:

- Already in 3NF.
- Every determinant is a super key (Attendance_ID → all other attributes).
- ✓ So, the table satisfies BCNF.

Fourth Normal Form [4NF]

- In BCNF.
- No multivalued dependencies.
- ✓ So, this table satisfies the Fourth Normal Form.

Fifth Normal Form [5NF]:

- No join dependency anomalies present.
- All join dependencies are implied by candidate keys. □ ✓ So, the table satisfies the Fifth Normal Form.

**2. Table: bonus**

| Bonus_ID | Employee_ID | Amount |
|---|---|---|
| 1 | 1 | 2000.00 |
| 2 | 2 | 2500.00 |
| 3 | 3 | 2200.00 |
| 4 | 1 | 1800.00 |
| 5 | 2 | 2100.00 |
| 6 | 3 | 1900.00 |

Functional Dependency:

1. BonusID → EmpID, BonusAmount, BonusDate

*Super Keys:*

- BonusID
- (BonusID, EmpID)

Candidate Keys:

- BonusID First Normal Form [1NF]:
- Atomic values only. Satisfies 1NF.

Second Normal Form [2NF]:

- Single attribute primary key.
  No partial dependency.
  Satisfies 2NF.

Third Normal Form [3NF]:

- No transitive dependencies. Satisfies 3NF.

Boyce-Codd Normal Form [BCNF]:

- All determinants are super keys.
  Satisfies BCNF.

Fourth Normal Form [4NF]:

- No multivalued dependencies.
  Satisfies 4NF.

Fifth Normal Form [5NF]:

- No join dependencies. Satisfies 5NF.

### 3. Table: deduction

| Deduction_ID | Employee_ID | Amount | Reason |
|---|---|---|---|
| 1 | 1 | 2000.00 | Late coming |
| 2 | 2 | 1500.00 | Absence |
| 3 | 3 | 1000.00 | Policy Violation |
| 4 | 1 | 500.00 | Half Day |
| 5 | 2 | 750.00 | Late Check-in |
| 6 | 3 | 300.00 | System Error |

Functional Dependency:

1. DeductionID → EmpID, DeductionType, Amount

Super Keys:

- DeductionID Candidate Keys:
- DeductionID

Satisfies **1NF to 5NF**

First Normal Form [1NF]:

- Atomic values only. Satisfies 1NF.

Second Normal Form [2NF]:

- Single attribute primary key.
  No partial dependency.
  Satisfies 2NF.

Third Normal Form [3NF]:

- No transitive dependencies. Satisfies 3NF.

Boyce-Codd Normal Form [BCNF]:

- All determinants are super keys.
  Satisfies BCNF.

Fourth Normal Form [4NF]:

- No multivalued dependencies.
  Satisfies 4NF.

Fifth Normal Form [5NF]:

- No join dependencies.  Satisfies 5NF.

**4. Table: department**

| Department_ID | Department_Name | Department_Location |
|---|---|---|
| 1 | HR | Building A |
| 2 | IT | Building B |
| 3 | Finance | Building C |
| 4 | Operations | Building D |

Functional Dependency:

1. DeptID → DeptName, DeptHead

Super Keys:

- DeptID

Candidate Keys:

- DeptID

Fully normalized:

- Atomic → ✓ 1NF
- Full dependence → ✓ 2NF
- No transitive → ✓ 3NF

- Determinant = super key → ✓ BCNF
- No multivalued dependency → ✓ 4NF
- No join dependency → ✓ 5NF

**5. Table: employee**

| Employee_ID | Employee_Name | Employee_DOB | Employee_Address | Employee_Phone_No | Department_ID |
|---|---|---|---|---|---|
| 1 | Alice Johnson | 1990-05-15 | 123 Street, NY | 9998887776 | 1 |
| 2 | Bob Williams | 1985-09-22 | 456 Avenue, CA | 8887776665 | 2 |
| 3 | Charlie Brown | 1992-08-10 | 789 Road, TX | 7776665554 | 3 |
| 1 | Clark Kent | 1985-06-18 | 344 Clinton St, Metropolis | 7777777771 | 1 |
| 2 | Barry Allen | 1990-03-14 | 123 Speedster Ave, Central City | 7777777772 | 2 |
| 3 | Hal Jordan | 1984-11-20 | Ferris Airbase, Coast City | 7777777773 | 3 |

Functional Dependency:

1. EmpID → Name, DOB, Gender, Address, Designation, DeptID, Email, Aadhar, PAN
2. Aadhar → EmpID
3. PAN → EmpID

Super Keys:

- EmpID, Aadhar, PAN Candidate Keys:
- EmpID, Aadhar, PAN

1NF:

- All fields are atomic.  Satisfies 1NF.

2NF:

- All fields depend fully on a single attribute key.
  Satisfies 2NF.

3NF:

- No non-key attributes depend on other non-key attributes. Satisfies 3NF.

BCNF:

- All functional dependencies have super keys as determinants. Satisfies BCNF.

4NF:

- No multivalued dependencies. Satisfies 4NF.

5NF:

- Table can't be decomposed further losslessly. Satisfies 5NF.

**6. Table: payroll**

| Payroll_ID | Employee_ID | Payroll_Final_Amount | Payroll_Type |
|---|---|---|---|
| 1 | 1 | 45000.00 | Bank Transfer |
| 2 | 2 | 38000.00 | Cheque |
| 3 | 2 | 1516.20 | Monthly |

Functional Dependency:

1. PayrollID → EmpID, Basic, HRA, Allowance, Tax, NetSalary

Super Keys:

- PayrollID

Candidate Keys:

- PayrollID

All forms from 1NF to 5NF are met:

- No transitive, multivalued, or join dependencies.

**7. Table: salary**

| | Salary_ID | Employee_ID | Salary_Final_Amount |
|---|---|---|---|
| | 1 | 1 | 50000.00 |
| | 2 | 2 | 60000.00 |
| | 3 | 3 | 55000.00 |
| | 1 | 1 | 1516.20 |
| | 2 | 2 | 45000 |
| | 3 | 3 | 78000 |

Functional Dependency:

1. SalaryID → EmpID, Month, Year, Gross, Deductions, Net

Super Keys:

- SalaryID

Candidate Keys:

- SalaryID

Normalization complete:

- Atomic fields → ✓ 1NF
- Full dependency → ✓ 2NF
- No transitives → ✓ 3NF
- Super key dependency → ✓ BCNF
- No MVD or JD → ✓ 4NF & 5NF

**8. Table: tax**

| Tax_ID | Salary_ID | Tax_Percentage | Tax_Amount |
|---|---|---|---|
| 1 | 1 | 1.00 | 500.00 |
| 2 | 2 | 2.00 | 750.00 |
| 3 | 3 | 3.00 | 600.00 |
| 1 | 1 | 10.00 | 5000.00 |
| 2 | 2 | 12.00 | 7200.00 |
| 3 | 3 | 11.00 | 6050.00 |

Attributes:

- TaxID (Primary Key)
- TaxType
- Rate

Functional Dependencies:

1. **TaxID → TaxType, Rate**

Super Keys:

- TaxID
- (TaxID, TaxType), (TaxID, Rate)

Candidate Keys:

- TaxID

First Normal Form (1NF):

- **Definition:** All columns must contain only atomic (indivisible) values; no repeating groups or arrays.
- **Analysis:**
  - All attributes (TaxID, TaxType, Rate) contain atomic values.
  - There are no repeating groups or nested tables. ✓ **The tax table satisfies the First Normal Form.**

Second Normal Form (2NF):

- **Definition:** Table must be in 1NF and all non-prime attributes must be fully functionally dependent on the **entire primary key**.
- **Primary Key:** TaxID (a single attribute).
- **Analysis:**
    - TaxType and Rate are fully dependent on the primary key TaxID.
    - There is **no partial dependency** (since there is no composite key). ✓ **The tax table satisfies the Second Normal Form.**

Third Normal Form (3NF):

- **Definition:** Table must be in 2NF, and there should be **no transitive dependencies** (i.e., non-prime attributes should not depend on other non-prime attributes).
- **Analysis:**
    - TaxType and Rate are directly dependent on the primary key TaxID, not on each other.
    - There is **no non-prime attribute depending on another nonprime attribute**. ✓ **The tax table satisfies the Third Normal Form.**

Boyce-Codd Normal Form (BCNF):

- **Definition:** Every functional dependency should have a **super key** as the determinant.
- **Analysis:**
    - The only functional dependency is: TaxID → TaxType, Rate ○ TaxID is a **candidate key** and also a **super key**. **The tax table satisfies the Boyce-Codd Normal Form.**

Fourth Normal Form (4NF):

- **Definition:** A table is in 4NF if it is in BCNF and has **no multi-valued dependencies (MVDs)**.
- **Analysis:**

○ No attribute in the tax table has multiple independent values (e.g., a single TaxID doesn't have multiple TaxTypes or Rates).

○ There are no multivalued dependencies. **The tax table satisfies the Fourth Normal Form.**

Fifth Normal Form (5NF):

- **Definition:** Table is in 5NF if it is in 4NF and there are **no join dependencies** that can lead to lossless decomposition.
- **Analysis:**
  - The tax table cannot be meaningfully decomposed into smaller tables without losing information or introducing redundancy.
  - No join dependencies exist. **The tax table satisfies the Fifth Normal Form.**

**9. Table: users**

| User_ID | User_Name | User_Mobile |
|---|---|---|
| 1 | John Doe | 9876543210 |
| 2 | Jane Smith | 8765432109 |
| 3 | Admin | 9998887770 |
| 4 | User_4 | 999000004 |
| 5 | User_5 | 999000005 |
| 9 | User_9 | 999000009 |
| 10 | User_10 | 999000010 |
| 11 | User_11 | 999000011 |

Attributes:

- UserID (Primary Key)
- Name
- Email
- Role
- ContactNo

Functional Dependencies:

1. UserID → Name, Email, Role, ContactNo

Super Keys:

- UserID
- (UserID, Email), (UserID, ContactNo)

Candidate Keys:

- UserID

First Normal Form (1NF):

- All attributes contain atomic values.
- No multi-valued or composite attributes. **Satisfies 1NF** Second Normal Form (2NF):

- Already in 1NF.
- Primary key is a single attribute (UserID).
- All non-prime attributes are fully functionally dependent on the entire primary key. **Satisfies 2NF**

Third Normal Form (3NF):

- No transitive dependencies.
- Non-prime attributes (Name, Email, Role, ContactNo) do not depend on each other. **Satisfies 3NF**

Boyce-Codd Normal Form (BCNF):

- All functional dependencies have super keys as their determinants. **Satisfies BCNF**

Fourth Normal Form (4NF):

- No multivalued dependencies (a user has one contact, role, etc.).

**Satisfies 4NF**

Fifth Normal Form (5NF):

- No join dependencies exist. **Satisfies 5NF**

**10. Table: shift**

| | Shift_ID | Employee_ID | Shift_Type |
|---|---|---|---|
| | 1 | 1 | Morning |
| | 2 | 2 | Evening |
| | 3 | 3 | Night |
| | 1 | 1 | Night |
| | 2 | 2 | Morning |

Attributes:

- ShiftID (Primary Key)
- ShiftType
- StartTime
- EndTime

Functional Dependencies:

1. ShiftID → ShiftType, StartTime, EndTime

Super Keys:

- ShiftID

Candidate Keys:

- ShiftID

First Normal Form (1NF):

All attributes are atomic. **Satisfies 1NF**

Second Normal Form (2NF):

- Single attribute primary key.
- All non-prime attributes are fully dependent on ShiftID. **Satisfies 2NF**

Third Normal Form (3NF):

- No transitive dependency. **Satisfies 3NF**

Boyce-Codd Normal Form (BCNF):

- ShiftID is a super key and determinant. **Satisfies BCNF**

Fourth Normal Form (4NF):

- No multi-valued dependencies. **Satisfies 4NF**

Fifth Normal Form (5NF):

- No join dependencies or potential decompositions. **Satisfies 5NF**

**11. Bank Details**

| Bank_ID | Employee_ID | Account_No |
|---|---|---|
| 1 | 1 | 1234567890 |
| 2 | 2 | 0987654321 |
| 3 | 3 | 1122334455 |
| 4 | 1 | 2233445566 |
| 5 | 2 | 6677889900 |
| 6 | 3 | 3344556677 |

Attributes:

- EmpID (Primary Key)
- BankID
- AccountNumber

Functional Dependencies:

1. EmpID → BankID, AccountNumber

Super Keys:

- EmpID
- (EmpID, BankID), (EmpID, AccountNumber)

Candidate Keys:

- EmpID

First Normal Form (1NF):

- All attributes are atomic. **Satisfies 1NF**

Second Normal Form (2NF):

- Single attribute primary key.
- All attributes are fully dependent on EmpID. **Satisfies 2NF**

Third Normal Form (3NF):

- No transitive dependencies exist. **Satisfies 3NF**

Boyce-Codd Normal Form (BCNF):

- All dependencies have a super key as the determinant. **Satisfies BCNF**

Fourth Normal Form (4NF):

- No multivalued dependencies. **Satisfies 4NF**

Fifth Normal Form (5NF):

- Table cannot be further decomposed without loss. **Satisfies 5NF**

## 12. Login Details

| User_ID | Password | Login_History |
|---|---|---|
| 1 | password123 | 2025-03-06 19:37:28 |
| 2 | securepass456 | 2025-03-06 19:37:28 |
| 3 | admin@123 | 2025-03-06 19:37:28 |
| 9 | pass1234 | Logged in on 2025-04-16 |
| 10 | pass1234 | Logged in on 2025-04-16 |
| 11 | pass1234 | Logged in on 2025-04-16 |

Attributes:

- Username (Primary Key)
- Password
- Role

Functional Dependencies:

1. Username → Password, Role

Super Keys:

- Username
- (Username, Role)

Candidate Keys:

- Username

First Normal Form (1NF):

- All fields contain atomic values. **Satisfies 1NF**

Second Normal Form (2NF):

- Primary key is Username.
- All other attributes depend fully on it. **Satisfies 2NF** Third Normal Form (3NF):

- No transitive dependency between Password and Role. **Satisfies 3NF**

Boyce-Codd Normal Form (BCNF):

- Username is the determinant and also a super key. **Satisfies BCNF**

Fourth Normal Form (4NF):

- No multivalued dependencies. **Satisfies 4NF**

Fifth Normal Form (5NF):

- Table cannot be decomposed further without loss of information. **Satisfies 5NF**

## 13. Payment

| Payment_ID | Payroll_ID | Transaction_ID | Payment_Mode |
|---|---|---|---|
| 1 | 1 | 1001 | Online |
| 2 | 2 | 1002 | Cash |
| 4 | 1 | TXN1004 | Bank Transfer |
| 5 | 1 | TXN1005 | Bank Transfer |
| 6 | 2 | TXN1006 | Bank Transfer |

Attributes:

- PaymentID (Primary Key)
- EmpID
- Amount
- Date
- Mode

Functional Dependencies:

1. PaymentID → EmpID, Amount, Date, Mode

Super Keys:

- PaymentID
- (PaymentID, EmpID)

Candidate Keys:

- PaymentID

First Normal Form (1NF):

- Each cell contains only atomic values. **Satisfies 1NF**

Second Normal Form (2NF):

- All non-prime attributes depend entirely on PaymentID. **Satisfies 2NF**

Third Normal Form (3NF):

- No transitive dependency (e.g., Amount does not depend on Date). **Satisfies 3NF**

Boyce-Codd Normal Form (BCNF):

- All functional dependencies have super keys as determinants. **Satisfies BCNF**

Fourth Normal Form (4NF):

- No multi-valued dependencies. **Satisfies 4NF**

Fifth Normal Form (5NF):

- No lossless decomposition possible. **Satisfies 5NF**

**Conclusion**

All 13 tables in the Payroll Management System database are fully normalized up to Fifth Normal Form (5NF).
This ensures:

- Minimal redundancy
- Strong data integrity
- Clear and efficient schema structure

This level of normalization guarantees reliable and maintainable system performance for any operations or analytics performed on the data.