Experiment 4

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1. **Problem Title:** Functional Dependency And Keys.
2. **Problem Description:** In relational databases, keys are defined using functional dependencies (FDs). A super key is any set of one or more attributes that can uniquely identify a tuple in a relation; formally, if a set of attributes X functionally determines all attributes of the relation (X → R), then X is a super key. Among super keys, the candidate keys are those that are minimal, meaning no proper subset of them can still uniquely determine all attributes of the relation. From the set of candidate keys, one is chosen as the primary key, which serves as the main identifier for tuples in the relation. When a key is made up of two or more attributes, it is called a composite key, and this occurs when the combination of attributes together functionally determines all other attributes of the relation, but no single attribute in that set can do so individually. Thus, super keys guarantee uniqueness, candidate keys are the minimal super keys, the primary key is the selected candidate key, and composite keys are keys formed by combining multiple attributes.

   Questions:

   a. Consider a relation R having attributes as R(ABCD), functional dependencies are given below: AB->C, C->D, D->A. Identify the set of candidate keys possible in relation R. List all the set of prime and non prime attributes.

   Ans)

   - **Given:** R(A, B, C, D); **FDs:** AB → C, C → D, D → A.
   - **Closure Calculations:**
     - $(AB)^+$ = {A, B, C, D}. Since it determines all attributes, AB is a superkey.
     - $(BC)^+$ = {B, C, D, A}. Since it determines all attributes, BC is a superkey.

        - $(BD)^+ = \{B, D, A, C\}$. Since it determines all attributes, BD is a superkey.
        - $(A)^+ = \{A\}$, $(B)^+ = \{B\}$, $(C)^+ = \{C, D, A\}$, $(D)^+ = \{D, A\}$. None are superkeys.
    - The superkeys AB, BC, and BD are minimal (no subset of them is a superkey). Therefore, they are candidate keys.
    - **Candidate Keys:** {AB, BC, BD}
    - **Prime Attributes:** Attributes that are part of any candidate key. (A, B, C, D) are all prime.
    - **Non-Prime Attributes:** None.
    - **Normalisation:** The relation is in **3NF**. For every FD ($X \to Y$):
        - $AB \to C$: AB is a superkey.
        - $C \to D$: C is not a superkey, but D is a prime attribute.
        - $D \to A$: D is not a superkey, but A is a prime attribute.
          Since all attributes are prime, it is automatically in 3NF. It is not in BCNF due to the FDs $C \to D$ and $D \to A$ where the determinant (C or D) is not a superkey.

b. Relation R(ABCDE) having functional dependencies as: A->D, B->A, BC->D, AC->BE. Identify the set of candidate keys possible in relation R. List all the set of prime and non prime attributes.

Ans)

- **Given:** R(A, B, C, D, E); **FDs:** $A \to D$, $B \to A$, $BC \to D$, $AC \to BE$.
- **Closure Calculations:**
    - $(AC)^+ = \{A, C, D, B, E\}$. AC is a superkey.
    - $(BC)^+ = \{B, C, A, D, E\}$. BC is a superkey.
    - $(A)^+ = \{A, D\}$, $(B)^+ = \{B, A, D\}$, $(C)^+ = \{C\}$. None are superkeys.
- The superkeys AC and BC are minimal. Therefore, they are candidate keys.
- **Candidate Keys:** {AC, BC}
- **Prime Attributes:** Parts of the candidate keys. (A, B, C) are prime.
- **Non-Prime Attributes:** The remaining attributes. (D, E) are non-prime.
- **Normalisation:** The relation is in **1NF**. It violates 2NF due to a partial dependency:
    - The FD $A \to D$ is a problem. A is a proper subset of the candidate key AC, and it determines a non-prime attribute D. This is a partial dependency, so the relation is not in 2NF.

c. Consider a relation R having attributes as R(ABCDE), functional dependencies are given below: B->A, A->C, BC->D, AC->BE. Identify the set of candidate keys possible in relation R. List all the set of prime and non prime attributes.

Ans)

- **Given:** R(A, B, C, D, E); **FDs:** $B \to A$, $A \to C$, $BC \to D$, $AC \to BE$.
- **Closure Calculations:**
    - $(B)^+ = \{B, A, C, E, D\}$. B is a superkey.
    - $(A)^+ = \{A, C\}$. A is not a superkey.
- The superkey B is minimal. Therefore, it is the candidate key.
- **Candidate Key:** {B}

- **Prime Attributes:** The candidate key. (B) is prime.
- **Non-Prime Attributes:** All other attributes. (A, C, D, E) are non-prime.
- **Normalisation:** The relation is in **2NF**. Since the key is a single attribute, partial dependencies are impossible. It is not in 3NF because of the FD A → C: A is not a superkey and C is a non-prime attribute.

d. Consider a relation R having attributes as R(ABCDEF), functional dependencies are given below: A->BCD, BC->DE, B->D, D->A. Identify the set of candidate keys possible in relation R. List all the set of prime and non prime attributes.

Ans)

- **Given:** R(A, B, C, D, E, F); **FDs:** A → BCD, BC → DE, B → D, D → A.
- **Note:** Attribute F never appears on the Right-Hand Side (RHS) of any FD. Therefore, it must be part of every candidate key.
- **Closure Calculations:**
  - $(AF)^+$ = {A, F, B, C, D, E}. AF is a superkey.
  - $(BF)^+$ = {B, F, D, A, C, E}. BF is a superkey.
  - $(DF)^+$ = {D, F, A, B, C, E}. DF is a superkey.
  - $(F)^+$ = {F}. Not a superkey.
- The superkeys AF, BF, and DF are minimal. Therefore, they are candidate keys.
- **Candidate Keys:** {AF, BF, DF}
- **Prime Attributes:** Parts of the candidate keys. (A, B, D, F) are prime.
- **Non-Prime Attributes:** The remaining attributes. (C, E) are non-prime.
- **Normalisation:** The relation is in **1NF**. It violates 2NF due to a partial dependency. For example, using candidate key AF:
  - The FD A → BCD is a problem. A is a proper subset of the key AF, and it determines the non-prime attributes C and E (via BC→DE).

e. Designing a student database involves certain dependencies which are listed below: X ->Y, WZ ->X, WZ ->Y, Y ->W,Y ->X, Y ->Z. The task here is to remove all the redundant FDs for efficient working of the student database management system.

Ans)

- **Given:** R(W, X, Y, Z); **FDs:** X → Y, WZ → X, WZ → Y, Y → W, Y → X, Y → Z.
- **Finding Redundant FDs:**
  - WZ → Y is redundant. It can be inferred from WZ → X and X → Y (Transitivity).
  - WZ → X is not redundant. There is no other way to derive it from the remaining FDs.
  - Y → X is not redundant, as it is a fundamental dependency.
- **Minimal Set (After Removal):** {X → Y, WZ → X, Y → W, Y → X, Y → Z}
- **Closure Calculations (to find keys):**
  - $(Y)^+$ = {Y, W, X, Z}. Y is a superkey.
  - $(WZ)^+$ = {W, Z, X, Y}. WZ is a superkey.
  - $(X)^+$ = {X, Y, W, Z}. X is a superkey.
- **Candidate Keys:** {Y, WZ, X}
- **Prime Attributes:** Parts of all candidate keys. (W, X, Y, Z) are all prime.

- **Non-Prime Attributes:** None.
- **Normalisation:** The relation is in **BCNF (3.5NF)**. For every FD in the minimal set, the determinant (left side) is a superkey (candidate key).
  - X → Y: X is a superkey.
  - WZ → X: WZ is a superkey.
  - Y → W: Y is a superkey.
  - Y → X: Y is a superkey.
  - Y → Z: Y is a superkey.

f. Debix Pvt Ltd needs to maintain database having dependent attributes ABCDEF. These attributes are functionally dependent on each other for which functionally dependency set F given as: {A -> BC, D -> E, BC -> D, A -> D} Consider a universal relation R1(A, B, C, D, E, F) with functional dependency set F, also all attributes are simple and take atomic values only. Find the highest normal form along with the candidate keys with prime and non-prime attribute.

Ans)

- **Given:** R(A, B, C, D, E, F); **FDs:** A → BC, D → E, BC → D, A → D.
- **Note:** Attribute F never appears on the Right-Hand Side (RHS) of any FD. Therefore, it must be part of every candidate key.
- **Closure Calculations:**
  - $(AF)^+$ = {A, F, B, C, D, E}. AF is a superkey.
  - $(A)^+$ = {A, B, C, D, E}. Missing F, so not a superkey.
- The superkey AF is minimal. Therefore, it is the candidate key.
- **Candidate Key:** {AF}
- **Prime Attributes:** Parts of the candidate key. (A, F) are prime.
- **Non-Prime Attributes:** The remaining attributes. (B, C, D, E) are non-prime.
- **Normalisation:** The relation is in **1NF**. It violates 2NF due to multiple partial dependencies on the key AF:
  - A → BC: A is a subset of the key, and it determines the non-prime attributes B and C.
  - A → D: A is a subset of the key, and it determines the non-prime attribute D.
  - BC → D and D → E further describe dependencies among non-prime attributes, but the initial violation of 2NF is already confirmed by the partial dependencies.