* 1. **Normal Forms**

**1. First Normal Form (1NF)**

**Rule:**

* All columns must have only single (atomic) values.
* No repeating groups or arrays.

**Example – Not in 1NF (invalid):**

| **Student ID** | **Name** | **Courses** |
| --- | --- | --- |
| 1 | Alice | Math, Science |
| 2 | Bob | History |

The "Courses" column has multiple values in one field.

**Correct in 1NF:**

| **Student ID** | **Name** | **Course** |
| --- | --- | --- |
| 1 | Alice | Math |
| 1 | Alice | Science |
| 2 | Bob | History |

Each field now contains only one value.

**2. Second Normal Form (2NF)**

**Rule:**

* Must be in 1NF.
* Every non-key column must depend on the entire primary key (no partial dependencies).

**Example – Not in 2NF:**

| **Student ID** | **Course** | **Student Name** |
| --- | --- | --- |
| 1 | Math | Alice |
| 1 | Science | Alice |

"Student Name" depends only on "Student ID", not on the combination of Student ID and Course.

**Correct in 2NF:**

**Students Table**

| **Student ID** | **Student Name** |
| --- | --- |
| 1 | Alice |

**Enrollments Table**

| **Student ID** | **Course** |
| --- | --- |
| 1 | Math |
| 1 | Science |

"Student Name" is now separated to avoid partial dependency.

**3. Third Normal Form (3NF)**

**Rule:**

* Must be in 2NF.
* No non-key column should depend on another non-key column (no transitive dependency).

**Example – Not in 3NF:**

| **Student ID** | **Name** | **Department ID** | **Department Name** |
| --- | --- | --- | --- |
| 1 | Alice | D01 | Science |

"Department Name" depends on "Department ID", which is not a key.

**Correct in 3NF:**

**Students Table**

| **Student ID** | **Name** | **Department ID** |
| --- | --- | --- |
| 1 | Alice | D01 |

**Departments Table**

| **Department ID** | **Department Name** |
| --- | --- |
| D01 | Science |

Now there’s no transitive dependency.

**Boyce-Codd Normal Form (BCNF)**

**Rule:**

* Must be in 3NF.
* Every determinant (any column that determines others) must be a candidate key.

**Example – Not in BCNF:**

| **Professor** | **Course** | **Classroom** |
| --- | --- | --- |
| Smith | Math | Room A |
| Smith | Physics | Room A |

"Professor" determines "Classroom", but "Professor" is not the full key (the primary key is Professor + Course).

**Correct in BCNF:**

**Professor Table**

| **Professor** | **Classroom** |
| --- | --- |
| Smith | Room A |

**Course Assignment Table**

| **Professor** | **Course** |
| --- | --- |
| Smith | Math |
| Smith | Physics |

**Fourth Normal Form (4NF)**

**Rule:**

* Must be in BCNF.
* No table should have more than one independent many-to-many relationship.

**Example – Not in 4NF:**

| **Student** | **Course** | **Language** |
| --- | --- | --- |
| Alice | Math | English |
| Alice | Math | French |

Course and Language are unrelated, but both linked to Student in the same table.

**Correct in 4NF:**

**Student Courses**

| **Student** | **Course** |
| --- | --- |
| Alice | Math |

**Student Languages**

| **Student** | **Language** |
| --- | --- |
| Alice | English |
| Alice | French |

**Fifth Normal Form (5NF)**

**Rule:**

* Must be in 4NF.
* Designed to remove join dependencies in complex relationships.