Normalization

* Normalization is the process of organizing the data in the database.
* Normalization is used to minimize the redundancy from a relation or set of relations. It is also used to eliminate the undesirable characteristics like Insertion, Update and Deletion Anomalies.
* Normalization divides the larger table into the smaller table and links them using relationship.
* The normal form is used to reduce redundancy from the database table.

## **Types of Normal Forms**

There are the four types of normal forms:



|  |  |
| --- | --- |
| **Normal Form** | **Description** |
| [1NF](https://www.javatpoint.com/dbms-first-normal-form) | A relation is in 1NF if it contains an atomic value. |
| [2NF](https://www.javatpoint.com/dbms-second-normal-form) | A relation will be in 2NF if it is in 1NF and all non-key attributes are fully functional dependent on the primary key. |
| [3NF](https://www.javatpoint.com/dbms-third-normal-form) | A relation will be in 3NF if it is in 2NF and no transition dependency exists. |
| [4NF](https://www.javatpoint.com/dbms-forth-normal-form) | A relation will be in 4NF if it is in Boyce Codd normal form and has no multi-valued dependency. |
| [5NF](https://www.javatpoint.com/dbms-fifth-normal-form) | A relation is in 5NF if it is in 4NF and not contains any join dependency and joining should be lossless. |

First Normal Form (1NF)

* A relation will be 1NF if it contains an atomic value.
* It states that an attribute of a table cannot hold multiple values. It must hold only single-valued attribute.
* First normal form disallows the multi-valued attribute, composite attribute, and their combinations.

**Example:** Relation EMPLOYEE is not in 1NF because of multi-valued attribute EMP\_PHONE.

**EMPLOYEE table:**

|  |  |  |  |
| --- | --- | --- | --- |
| **EMP\_ID** | **EMP\_NAME** | **EMP\_PHONE** | **EMP\_STATE** |
| 14 | John | 7272826385, 9064738238 | UP |
| 20 | Harry | 8574783832 | Bihar |
| 12 | Sam | 7390372389, 8589830302 | Punjab |

The decomposition of the EMPLOYEE table into 1NF has been shown below:

|  |  |  |  |
| --- | --- | --- | --- |
| **EMP\_ID** | **EMP\_NAME** | **EMP\_PHONE** | **EMP\_STATE** |
| 14 | John | 7272826385 | UP |
| 14 | John | 9064738238 | UP |
| 20 | Harry | 8574783832 | Bihar |
| 12 | Sam | 7390372389 | Punjab |
| 12 | Sam | 8589830302 | Punjab |

Second Normal Form (2NF)

* In the 2NF, relational must be in 1NF.
* In the second normal form, all non-key attributes are fully functional dependent on the primary key

**Example:** Let's assume, a school can store the data of teachers and the subjects they teach. In a school, a teacher can teach more than one subject.

**TEACHER table**

|  |  |  |
| --- | --- | --- |
| **TEACHER\_ID** | **SUBJECT** | **TEACHER\_AGE** |
| 25 | Chemistry | 30 |
| 25 | Biology | 30 |
| 47 | English | 35 |
| 83 | Math | 38 |
| 83 | Computer | 38 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Second Normal Form (2NF)   * In the 2NF, relational must be in 1NF. * In the second normal form, all non-key attributes are fully functional dependent on the primary key   **Example:** Let's assume, a school can store the data of teachers and the subjects they teach. In a school, a teacher can teach more than one subject.  **TEACHER table**   |  |  |  | | --- | --- | --- | | **TEACHER\_ID** | **SUBJECT** | **TEACHER\_AGE** | | 25 | Chemistry | 30 | | 25 | Biology | 30 | | 47 | English | 35 | | 83 | Math | 38 | | 83 | Computer | 38 |   In the given table, non-prime attribute TEACHER\_AGE is dependent on TEACHER\_ID which is a proper subset of a candidate key. That's why it violates the rule for 2NF.  To convert the given table into 2NF, we decompose it into two tables:  **TEACHER\_DETAIL table:**   |  |  | | --- | --- | | **TEACHER\_ID** | **TEACHER\_AGE** | | 25 | 30 | | 47 | 35 | | 83 | 38 |   **TEACHER\_SUBJECT table:**   |  |  | | --- | --- | | **TEACHER\_ID** | **SUBJECT** | | 25 | Chemistry | | 25 | Biology | | 47 | English | | 83 | Math | | 83 | Computer | |

Third Normal Form (3NF)

* A relation will be in 3NF if it is in 2NF and not contain any transitive partial dependency.
* 3NF is used to reduce the data duplication. It is also used to achieve the data integrity.
* If there is no transitive dependency for non-prime attributes, then the relation must be in third normal form.

A relation is in third normal form if it holds atleast one of the following conditions for every non-trivial function dependency X → Y.

1. X is a super key.
2. Y is a prime attribute, i.e., each element of Y is part of some candidate key.

**Example:**

**EMPLOYEE\_DETAIL table:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EMP\_ID** | **EMP\_NAME** | **EMP\_ZIP** | **EMP\_STATE** | **EMP\_CITY** |
| 222 | Harry | 201010 | UP | Noida |
| 333 | Stephan | 02228 | US | Boston |
| 444 | Lan | 60007 | US | Chicago |
| 555 | Katharine | 06389 | UK | Norwich |
| 666 | John | 462007 | MP | Bhopal |

**Super key in the table above:**

* 1. {EMP\_ID}, {EMP\_ID, EMP\_NAME}, {EMP\_ID, EMP\_NAME, EMP\_ZIP}....so on

**Candidate key:** {EMP\_ID}

**Non-prime attributes:** In the given table, all attributes except EMP\_ID are non-prime.

Here, EMP\_STATE & EMP\_CITY dependent on EMP\_ZIP and EMP\_ZIP dependent on EMP\_ID. The non-prime attributes (EMP\_STATE, EMP\_CITY) transitively dependent on super key(EMP\_ID). It violates the rule of third normal form.

That's why we need to move the EMP\_CITY and EMP\_STATE to the new <EMPLOYEE\_ZIP> table, with EMP\_ZIP as a Primary key.

**EMPLOYEE table:**

|  |  |  |
| --- | --- | --- |
| **EMP\_ID** | **EMP\_NAME** | **EMP\_ZIP** |
| 222 | Harry | 201010 |
| 333 | Stephan | 02228 |
| 444 | Lan | 60007 |
| 555 | Katharine | 06389 |
| 666 | John | 462007 |

**EMPLOYEE\_ZIP table:**

|  |  |  |
| --- | --- | --- |
| **EMP\_ZIP** | **EMP\_STATE** | **EMP\_CITY** |
| 201010 | UP | Noida |
| 02228 | US | Boston |
| 60007 | US | Chicago |
| 06389 | UK | Norwich |
| 462007 | MP | Bhopal |

Boyce Codd normal form (BCNF)

* BCNF is the advance version of 3NF. It is stricter than 3NF.
* A table is in BCNF if every functional dependency X → Y, X is the super key of the table.
* For BCNF, the table should be in 3NF, and for every FD, LHS is super key.

**Example:** Let's assume there is a company where employees work in more than one department.

**EMPLOYEE table:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EMP\_ID** | **EMP\_COUNTRY** | **EMP\_DEPT** | **DEPT\_TYPE** | **EMP\_DEPT\_NO** |
| 264 | India | Designing | D394 | 283 |
| 264 | India | Testing | D394 | 300 |
| 364 | UK | Stores | D283 | 232 |
| 364 | UK | Developing | D283 | 549 |

**In the above table Functional dependencies are as follows:**

1. EMP\_ID  →  EMP\_COUNTRY
2. EMP\_DEPT  →   {DEPT\_TYPE, EMP\_DEPT\_NO}

**Candidate key: {EMP-ID, EMP-DEPT}**

The table is not in BCNF because neither EMP\_DEPT nor EMP\_ID alone are keys.

To convert the given table into BCNF, we decompose it into three tables:

**EMP\_COUNTRY table:**

|  |  |
| --- | --- |
| **EMP\_ID** | **EMP\_COUNTRY** |
| 264 | India |
| 264 | India |

**EMP\_DEPT table:**

|  |  |  |
| --- | --- | --- |
| **EMP\_DEPT** | **DEPT\_TYPE** | **EMP\_DEPT\_NO** |
| Designing | D394 | 283 |
| Testing | D394 | 300 |
| Stores | D283 | 232 |
| Developing | D283 | 549 |

**EMP\_DEPT\_MAPPING table:**

|  |  |
| --- | --- |
| **EMP\_ID** | **EMP\_DEPT** |
| D394 | 283 |
| D394 | 300 |
| D283 | 232 |
| D283 | 549 |

**Functional dependencies:**

1. EMP\_ID   →    EMP\_COUNTRY
2. EMP\_DEPT   →   {DEPT\_TYPE, EMP\_DEPT\_NO}

**Candidate keys:**

**For the first table:** EMP\_ID  
**For the second table:** EMP\_DEPT  
**For the third table:** {EMP\_ID, EMP\_DEPT}

Now, this is in BCNF because left side part of both the functional dependencies is a key.

# Fourth normal form (4NF)

* A relation will be in 4NF if it is in Boyce Codd normal form and has no multi-valued dependency.
* For a dependency A → B, if for a single value of A, multiple values of B exists, then the relation will be a multi-valued dependency.

### **Example**

**STUDENT**

|  |  |  |
| --- | --- | --- |
| **STU\_ID** | **COURSE** | **HOBBY** |
| 21 | Computer | Dancing |
| 21 | Math | Singing |
| 34 | Chemistry | Dancing |
| 74 | Biology | Cricket |
| 59 | Physics | Hockey |

The given STUDENT table is in 3NF, but the COURSE and HOBBY are two independent entity. Hence, there is no relationship between COURSE and HOBBY.

In the STUDENT relation, a student with STU\_ID, **21** contains two courses, **Computer** and **Math** and two hobbies, **Dancing** and **Singing**. So there is a Multi-valued dependency on STU\_ID, which leads to unnecessary repetition of data.

So to make the above table into 4NF, we can decompose it into two tables:

**STUDENT\_COURSE**

|  |  |
| --- | --- |
| **STU\_ID** | **COURSE** |
| 21 | Computer |
| 21 | Math |
| 34 | Chemistry |
| 74 | Biology |
| 59 | Physics |

**STUDENT\_HOBBY**

|  |  |
| --- | --- |
| **STU\_ID** | **HOBBY** |
| 21 | Dancing |
| 21 | Singing |
| 34 | Dancing |
| 74 | Cricket |
| 59 | Hockey |

# Fifth normal form (5NF)

* A relation is in 5NF if it is in 4NF and not contains any join dependency and joining should be lossless.
* 5NF is satisfied when all the tables are broken into as many tables as possible in order to avoid redundancy.
* 5NF is also known as Project-join normal form (PJ/NF).

### **Example**

|  |  |  |
| --- | --- | --- |
| **SUBJECT** | **LECTURER** | **SEMESTER** |
| Computer | Anshika | Semester 1 |
| Computer | John | Semester 1 |
| Math | John | Semester 1 |
| Math | Akash | Semester 2 |
| Chemistry | Praveen | Semester 1 |

In the above table, John takes both Computer and Math class for Semester 1 but he doesn't take Math class for Semester 2. In this case, combination of all these fields required to identify a valid data.

Suppose we add a new Semester as Semester 3 but do not know about the subject and who will be taking that subject so we leave Lecturer and Subject as NULL. But all three columns together acts as a primary key, so we can't leave other two columns blank.

So to make the above table into 5NF, we can decompose it into three relations P1, P2 & P3:

**P1**

|  |  |
| --- | --- |
| **SEMESTER** | **SUBJECT** |
| Semester 1 | Computer |
| Semester 1 | Math |
| Semester 1 | Chemistry |
| Semester 2 | Math |

**P2**

|  |  |
| --- | --- |
| **SUBJECT** | **LECTURER** |
| Computer | Anshika |
| Computer | John |
| Math | John |
| Math | Akash |
| Chemistry | Praveen |

**P3**

|  |  |
| --- | --- |
| **SEMSTER** | **LECTURER** |
| Semester 1 | Anshika |
| Semester 1 | John |
| Semester 1 | John |
| Semester 2 | Akash |
| Semester 1 | Praveen |