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.

Example 2:

Let us see another one example:

Below we have a college enrolment table with columns student_id, subject and professor.

student_id	**subject**	**professor**
101	Java	P.Java
101	C++	P.Cpp
102	Java	P.Java2
103	C#	P.Chash
104	Java	P.Java

As you can see, we have also added some sample data to the table.

In the table above:

- One student can enrol for multiple subjects. For example, student with **student_id** 101, has opted for subjects - Java & C++
- For each subject, a professor is assigned to the student.
- And, there can be multiple professors teaching one subject like we have for Java.

What do you think should be the Primary Key?

- Well, in the table above student_id, subject together form the primary key, because using student_id and subject, we can find all the columns of the table.
- One more important point to note here is, one professor teaches only one subject, but one subject may have two different professors.
- Hence, there is a dependency between subject and professor here, where subject depends on the professor name.
- This table satisfies the **1st Normal form** because all the values are atomic, column names are unique and all the values stored in a particular column are of same domain.
- This table also satisfies the **2nd Normal Form** as their is no **Partial Dependency**.
- And, there is no **Transitive Dependency**, hence the table also satisfies the **3rd Normal Form**.

But this table is not in **Boyce-Codd Normal Form**.

Why this table is not in BCNF?

In the table above, student_id, subject form primary key, which means subject column is a **prime attribute**.

But, there is one more dependency, professor → subject.

And while subject is a prime attribute, professor is a **non-prime attribute**, which is not allowed by BCNF.

How to satisfy BCNF?

To make this relation(table) satisfy BCNF, we will decompose this table into two tables, **student** table and **professor** table.

Below we have the structure for both the tables.

Student Table

student_id	**p_id**
101	1
101	2
and so on...	

p_id	**professor**	**subject**
1	P.Java	Java
2	P.Cpp	C++

and so on...

And now, this relation satisfy Boyce-Codd Normal Form.

UNIT II

DATABASE DESIGN

A well-designed database shall:

- Eliminate Data Redundancy: the same piece of data shall not be stored in more than one place. This is because duplicate data not only waste storage spaces but also easily lead to inconsistencies.
- Ensure Data Integrity and Accuracy

Entity-Relationship Data Model

- Classical, popular conceptual data model
- First introduced (mid 70's) as a (relatively minor) improvement to the relational model: pictorial diagrams are easier to read than relational database schemas
- Then evolved as a popular model for the first conceptual representation of data structures in the process of database design

ER Model: Entity and Entity Set

- Considering the above example, Student is an entity, Teacher is an entity, similarly, Class, Subject etc are also entities.
- An Entity is generally a real-world object which has characteristics and holds **relationships** in a DBMS.
- If a Student is an Entity, then the complete dataset of all the students will be the **Entity Set**

ER Model: Attributes

If a Student is an Entity, then student's roll no., student's name, student's age, student's gender etc will be its attributes.

An attribute can be of many types, here are different types of attributes defined in ER database model:

1. Simple attribute: The attributes with values that are atomic and cannot be broken down further are simple attributes. For example, student's age.

2. Composite attribute: A composite attribute is made up of more than one simple attribute. For example, student's address will contain, house no., street name, pincode etc.

3. Derived attribute: These are the attributes which are not present in the whole database management system, but are derived using other attributes. For example, average age of students in a class.

4. Single-valued attribute: As the name suggests, they have a single value.

5. Multi-valued attribute: And, they can have multiple values.

ER Model: Relationships

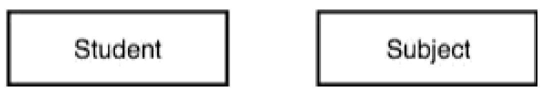
- When an Entity is related to another Entity, they are said to have a relationship. For example, A Class Entity is related to Student entity, because students study in classes, hence this is a relationship.
- Depending upon the number of entities involved, a degree is assigned to relationships.
- For example, if 2 entities are involved, it is said to be Binary relationship, if 3 entities are involved, it is said to be Ternary relationship, and so on.

Working with ER Diagrams

ER Diagram is a visual representation of data that describes how data is related to each other. In ER Model, we disintegrate data into entities, attributes and setup relationships between entities, all this can be represented visually using the ER diagram.

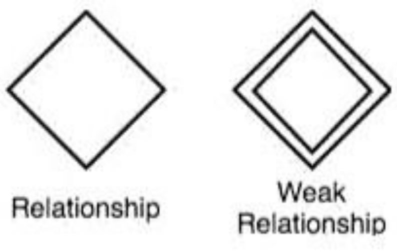
Components of ER Diagram

Entitiy, Attributes, Relationships etc form the components of ER Diagram and there are defined symbols and shapes to represent each one of them. Let's see how we can represent these in our ER Diagram. Entity Simple rectangular box represents an Entity.



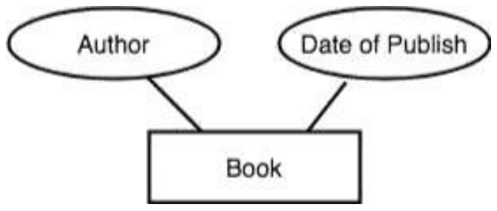
Relationships between Entities - Weak and Strong

Rhombus is used to setup relationships between two or more entities.

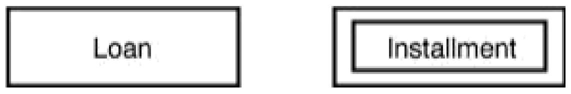


Attributes for any Entity

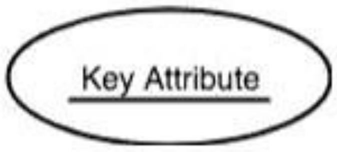
Ellipse is used to represent attributes of any entity. It is connected to the entity.



Weak Entity A weak Entity is represented using double rectangular boxes. It is generally connected to another entity.



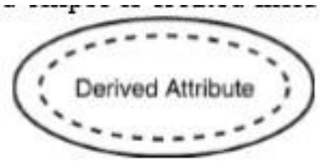
Key Attribute for any Entity To represent a Key attribute, the attribute name inside the Ellipse is underlined.



Derived Attribute for any Entity

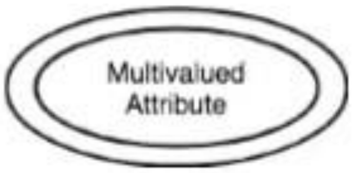
Derived attributes are those which are derived based on other attributes, for example, age can be derived from date of birth.

To represent a derived attribute, another dotted ellipse is created inside the main ellipse.

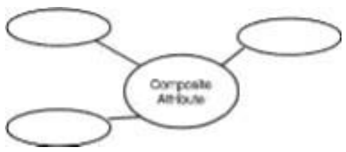


Multivalued Attribute for any Entity

Double Ellipse, one inside another, represents the attribute which can have multiple values.

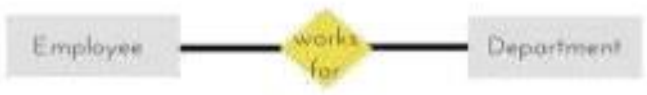


Composite Attribute for any Entity A composite attribute is the attribute, which also has Attributes



ER Diagram:

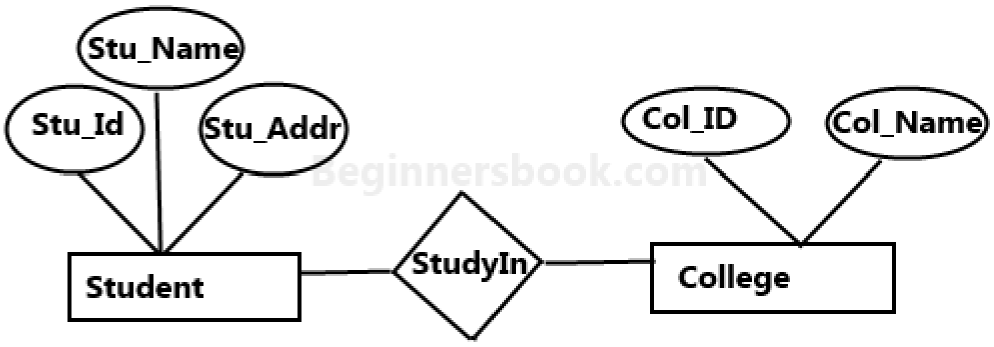
Entity : An Entity can be any object, place, person or class. In ER Diagram, an entity is represented using rectangles. Consider an example of an Organisation- Employee, Manager, Department, Product and many more can be taken as entities in an Organisation.



The yellow rhombus in between represents a relationship.

ER Diagram: **Key Attribute**

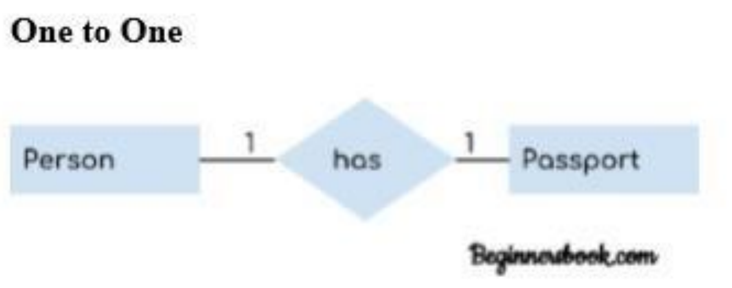
Key attribute represents the main characteristic of an Entity. It is used to represent a Primary key. Ellipse with the text underlined, represents Key Attribute.

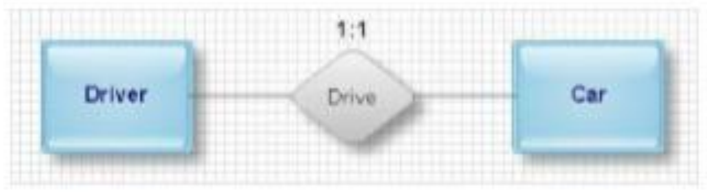


ER Diagram: Binary Relationship

Binary Relationship means relation between two Entities. This is further divided into three types.

One to One Relationship : This type of relationship is rarely seen in real world.



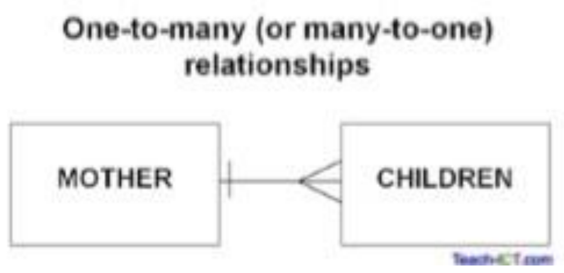


In the above examples, one person can have only one passport,also one passport can belongs to only one person.

One driver can be the driver of one car at a time. A car can have only one driver at a time.

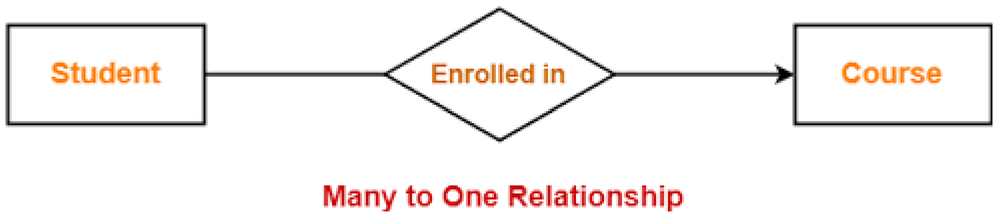
One to Many Relationship

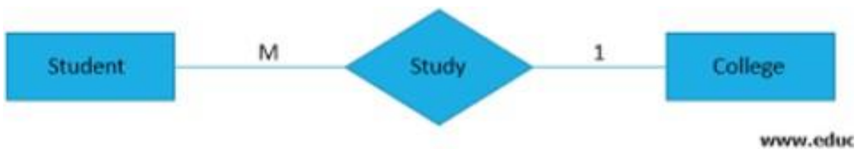
The below example showcases this relationship, which means that 1 student can opt for many courses, but a course can only have 1 student. Sounds weird! This is how it is.



Many to One Relationship

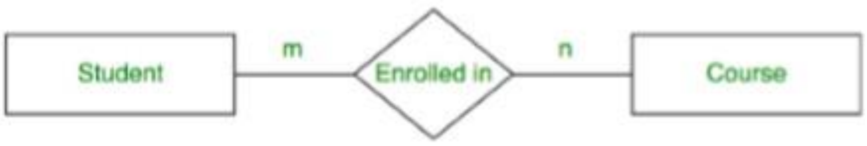
It reflects business rule that many entities can be associated with just one entity. For example, Student enrolls for only one Course but a Course can have many Students.





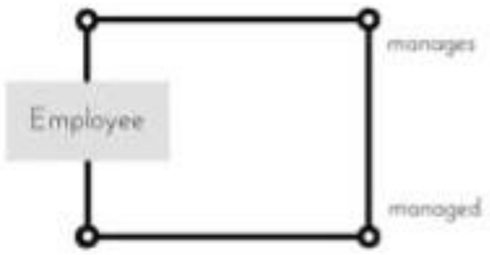
Many to Many Relationship

Many to many



The above diagram represents that one student can enroll for more than one courses. And a course can have more than 1 student enrolled in it.

ER Diagram: Recursive Relationship When an Entity is related with itself it is known as Recursive Relationship.

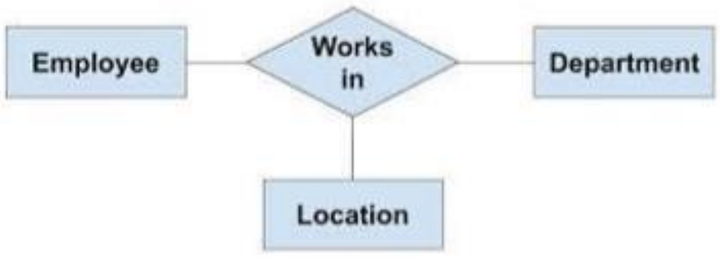


ER Diagram: Ternary Relationship

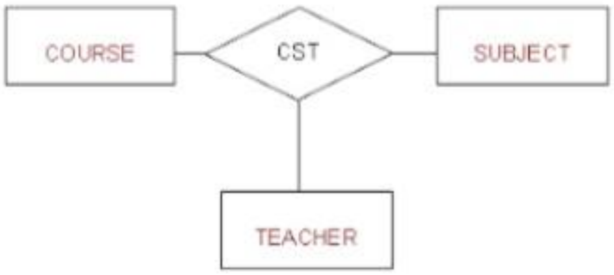
Relationship of degree three is called Ternary relationship.

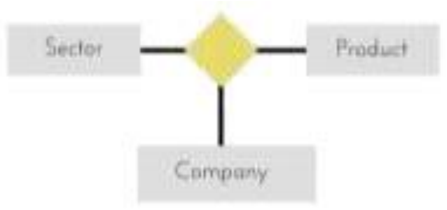
A Ternary relationship involves three entities. In such relationships we always consider two entites together and then look upon the third.

Ternary relationship



Ternary Relationship (degree 3)





- The above relationship involves 5 entities.
- Company operates in Sector, producing some Products.

For example, in the diagram above, we have three related entities, Company, Product and Sector. To understand the relationship better or to define rules around the model, we should relate two entities and then derive the third one. A Company produces many Products/ each product is produced by exactly one company. A Company operates in only one Sector / each sector has many companies operating in it.

Considering the above two rules or relationships, we see that although the complete relationship involves three entities, but we are looking at two entities at a time.

THE ENHANCED ER MODEL

As the complexity of data increased in the late 1980s, it became more and more difficult to use the traditional ER Model for database modelling. Hence some improvements or enhancements were made to the existing ER Model to make it able to handle the complex applications better.

EER is a high-level data model that incorporates the extensions to the original ER model.

It is a diagrammatic technique for displaying the following concepts

- Sub Class and Super Class
- Specialization and Generalization
- Union or Category
- Aggregation

These concepts are used when the comes in EER schema and the resulting schema diagrams called as EER Diagrams.

Features of EER Model

- EER creates a design more accurate to database schemas.
- It reflects the data properties and constraints more precisely.
- It includes all modeling concepts of the ER model.
- Diagrammatic technique helps for displaying the EER schema.
- It includes the concept of specialization and generalization.
- It is used to represent a collection of objects that is union of objects of different of

different entity types.

A. Sub Class and Super Class

- Sub class and Super class relationship leads the concept of Inheritance.
- The relationship between sub class and super class is denoted with ⓓ symbol.

1. Super Class

- Super class is an entity type that has a relationship with one or more subtypes.
- An entity cannot exist in database merely by being member of any super class.

For example: Shape super class is having sub groups as Square, Circle, Triangle.

2. Sub Class

- Sub class is a group of entities with unique attributes.

- Sub class inherits properties and attributes from its super class.

For example: Square, Circle, Triangle are the sub class of Shape super class.

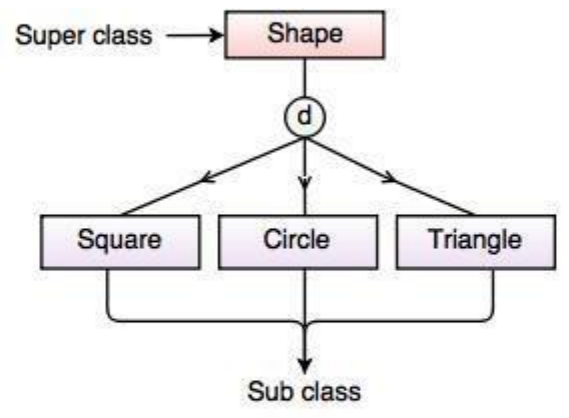


Fig. Super class/Sub class Relationship

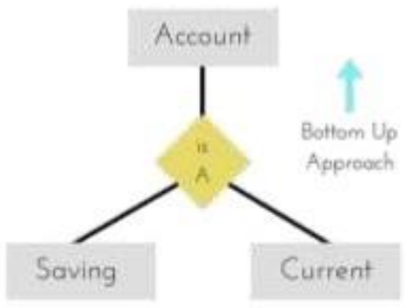
Hence, as part of the Enhanced ER Model, along with other improvements, three new concepts were added to the existing ER Model, they were:

1. Generalization
2. Specialization
3. Aggregration

1. Generalization

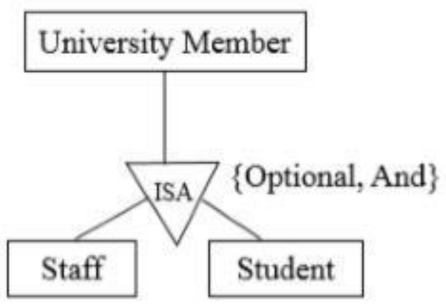
Generalization is a bottom-up approach in which two lower level entities combine to form a higher level entity. In generalization, the higher level entity can also combine with other lower level entities to make further higher level entity.

It's more like Superclass and Subclass system, but the only difference is the approach, which is bottom-up. Hence, entities are combined to form a more generalised entity, in other words, sub-classes are combined to form a super-class.



For example, Saving and Current account types entities can be generalised and an entity with name Account can be created, which covers both.

Generalization



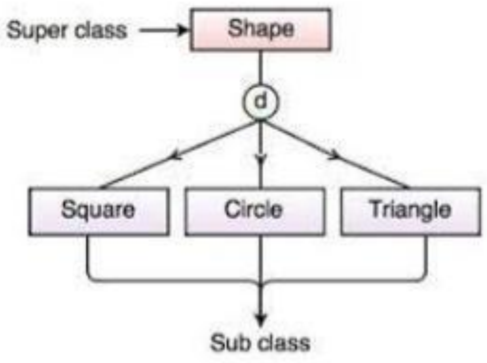


Fig. Super class/Sub class Relationship

2. Specialization

- Specialization is a process that defines a group entities which is divided into sub groups based on their characteristic.
- It is a top down approach, in which one higher entity can be broken down into two lower level entity.
- It maximizes the difference between the members of an entity by identifying the unique characteristic or attributes of each member.
- It defines one or more sub class for the super class and also forms the superclass/subclass relationship.

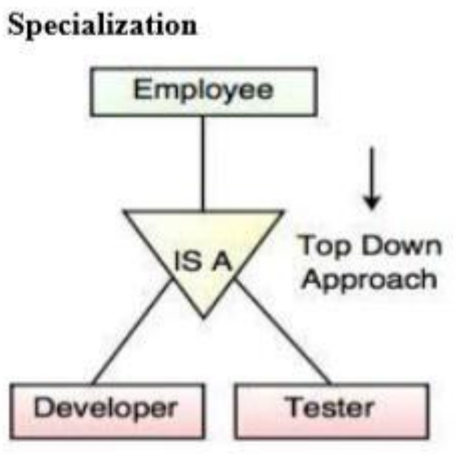


Fig. Specialization

3. Aggregation

- Aggregation is a process that represent a relationship between a whole object and its component parts.
- It abstracts a relationship between objects and viewing the relationship as an object.
- It is a process when two entity is treated as a single entity.

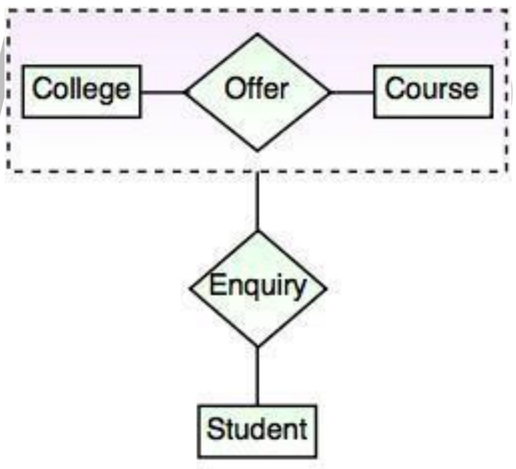
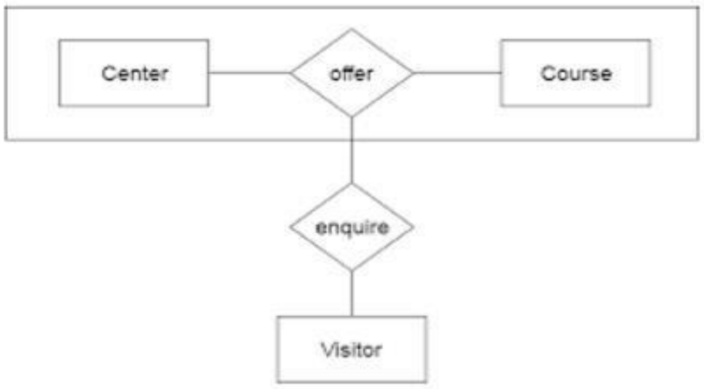
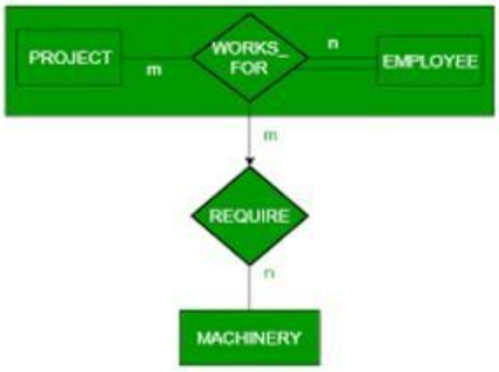


Fig. Aggregation

In the above example, the relation between College and Course is acting as an Entity in Relation with Student. In the diagram above, the relationship between Center and Course together, is acting as an Entity, which is in relationship with another entity Visitor. Now in real world, if a Visitor or a Student visits a Coaching Center, he/she will never enquire about the center only or just about the course, rather he/she will ask enquire about both.





Aggregation

Category or Union

- Category represents a single super class or sub class relationship with more than one super class.
- It can be a total or partial participation.

  For example Car booking, Car owner can be a person, a bank (holds a possession on a Car) or a company. Category (sub class) → Owner is a subset of the union of the three super classes → Company, Bank, and Person. A Category member must exist in at least one of its super classes.

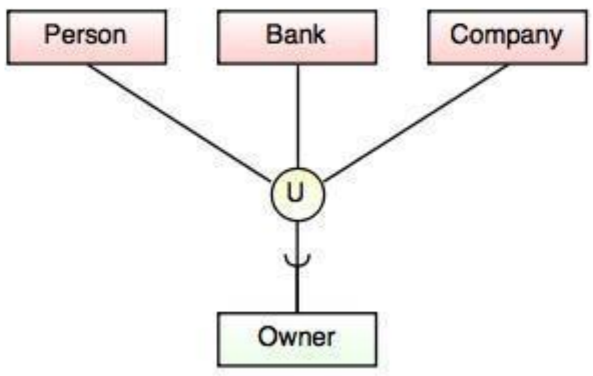


Fig. Categories (Union Type)

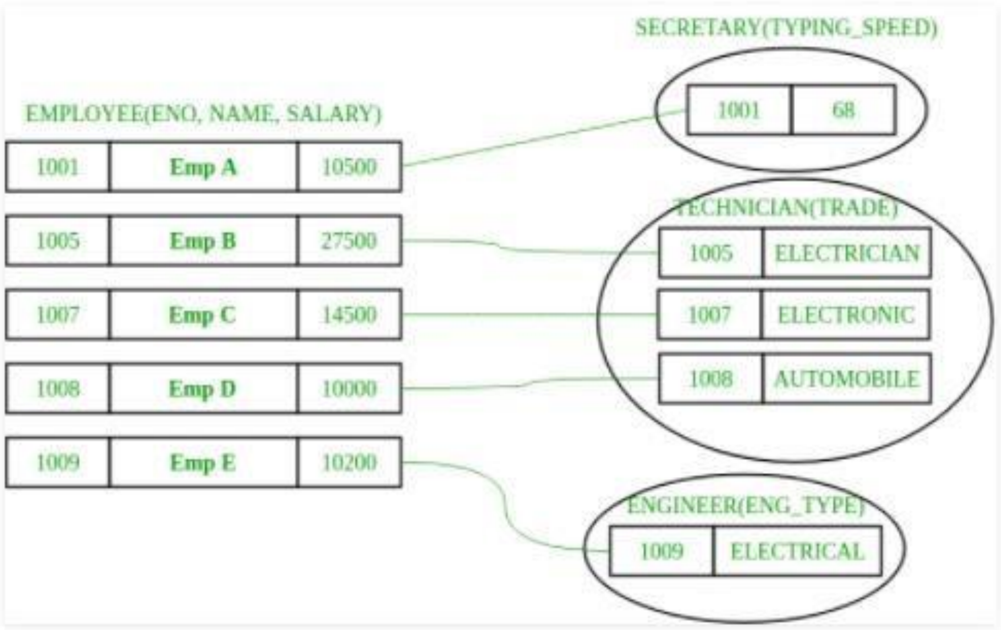
Generalization and Specialization –

These are very common relationships found in real entities. However, this kind of relationship was added later as an enhanced extension to the classical ER model.

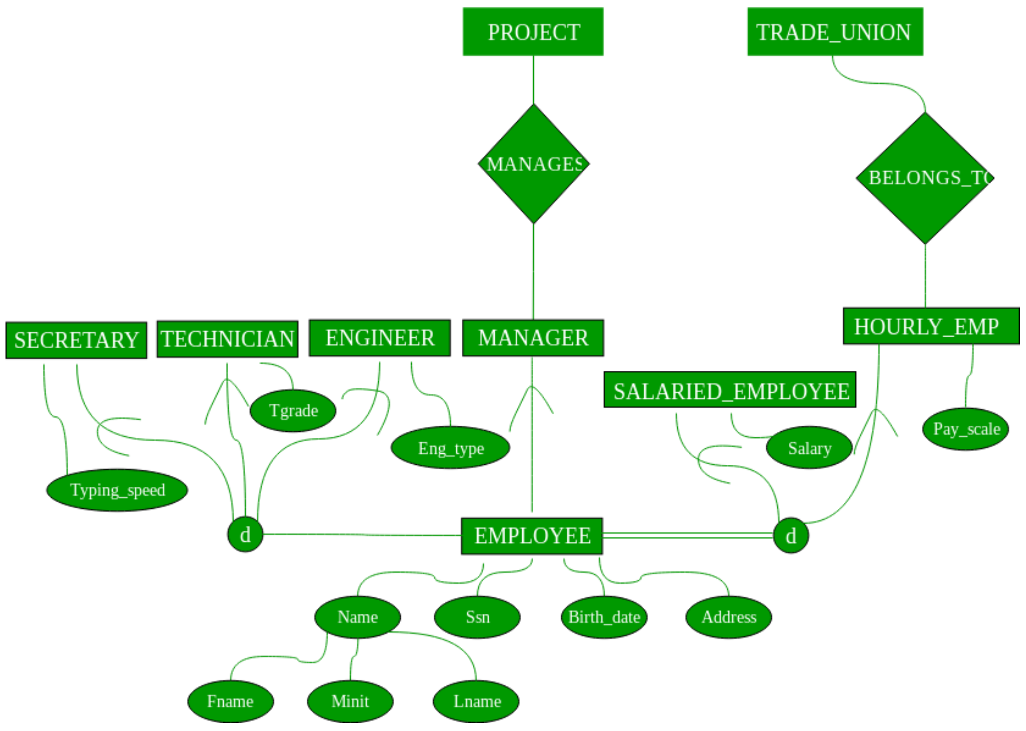
Specialized classes are often called **subclass** while a **generalized class** is called a superclass, probably inspired by object-oriented programming. A sub-class is best understood by **"IS-A analysis"**. Following statements hopefully makes some sense to your mind "Technician IS-A Employee", "Laptop IS-A Computer".

An entity is a specialized type/class of another entity. For example, a Technician is a special Employee in a university system Faculty is a special class of Employee. We call this phenomenon generalization/specialization. In the example here Employee is a generalized entity class while the Technician and Faculty are specialized classes of Employee.

Example – This example instance of **"sub-class"** relationships. Here we have four sets of employees: Secretary, Technician, and Engineer. The employee is super-class of the rest three sets of individual sub-class is a subset of Employee set.



- An entity belonging to a sub-class is related to some super-class entity. For instance emp, no 1001 is a secretary, and his typing speed is 68. Emp no 1009 is an engineer (sub-class) and her trade is "Electrical", so forth.
- Sub-class entity "inherits" all attributes of super-class; for example, employee 1001 will have attributes eno, name, salary, and typing speed.



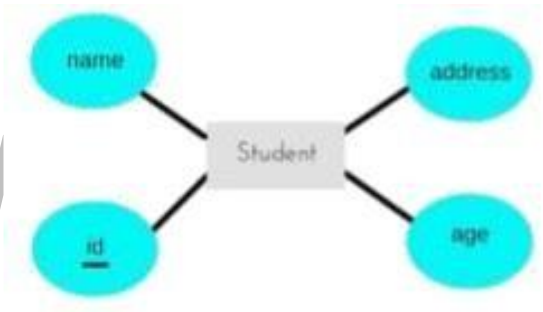
ER MODEL TO RELATIONAL MODEL

ER Model can be represented using ER Diagrams which is a great way of designing and representing the database design in more of a flow chart form.

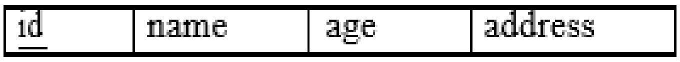
It is very convenient to design the database using the ER Model by creating an ER diagram and later on converting it into relational model to design your tables. Not all the ER Model constraints and components can be directly transformed into relational model, but an approximate schema can be derived. Few examples of ER diagrams and convert it into relational model schema, hence creating tables in RDBMS.

Entity becomes Table Entity in ER Model is changed into tables, or we can say for every Entity in ER model, a table is created in Relational Model. And the attributes of the Entity gets converted to columns of the table.

And the primary key specified for the entity in the ER model, will become the primary key for the table in relational model. For example, for the below ER Diagram in ER Model,



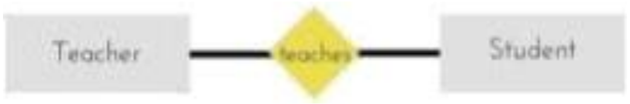
A table with name Student will be created in relational model, which will have 4 columns, id, name, age, address and id will be the primary key for this table.



id	name	age	address

Relationship becomes a Relationship Table, In ER diagram, we use diamond/rhombus to represent a relationship between two entities. In Relational model we create a relationship table for ER Model relationships too.

In the ER diagram below, we have two entities Teacher and Student with a relationship between them.



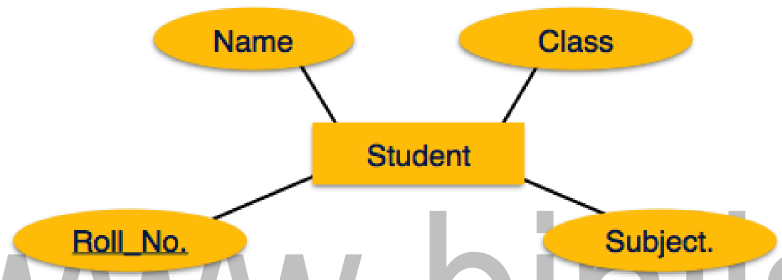
As discussed above, entity gets mapped to table, hence we will create table for Teacher and a table for Student with all the attributes converted into columns.

Now, an additional table will be created for the relationship, for example Student Teacher or give it any name you like. This table will hold the primary key for both Student and Teacher, in a tuple to describe the relationship, which teacher teaches which student.

If there are additional attributes related to this relationship, then they become the columns for this table, like subject name. Also proper foreign key constraints must be set for all the tables.

Mapping Entity

An entity is a real-world object with some attributes.

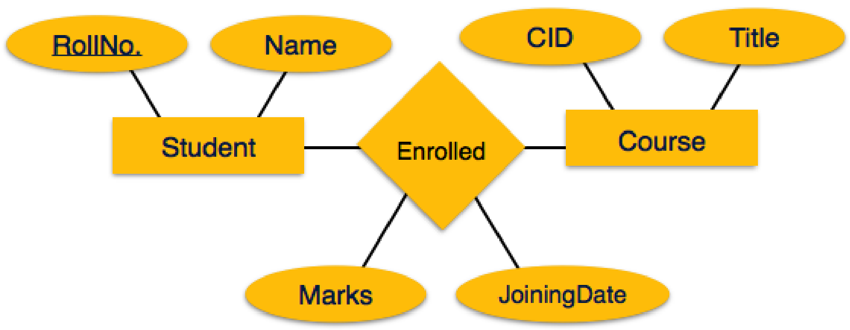


Mapping Process (Algorithm)

- Create table for each entity.
- Entity's attributes should become fields of tables with their respective data types.
- Declare primary key.

Mapping Relationship

A relationship is an association among entities.



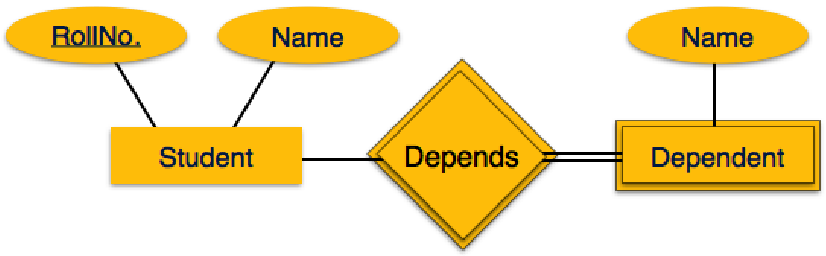
Mapping Process

- Create table for a relationship.
- Add the primary keys of all participating Entities as fields of table with their respective data types.

- If relationship has any attribute, add each attribute as field of table.
- Declare a primary key composing all the primary keys of participating entities.
- Declare all foreign key constraints.

Mapping Weak Entity Sets

A weak entity set is one which does not have any primary key associated with it.

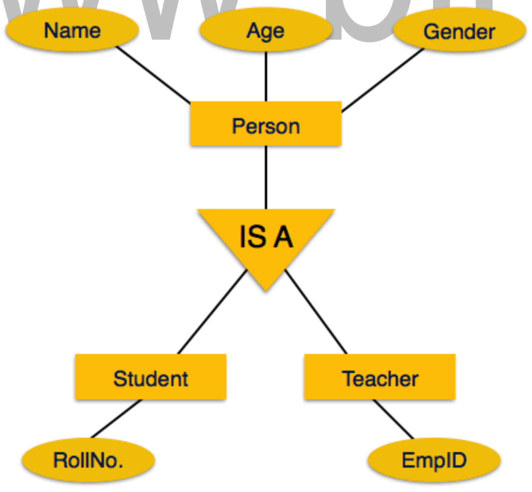


Mapping Process

- Create table for weak entity set.
- Add all its attributes to table as field.
- Add the primary key of identifying entity set.
- Declare all foreign key constraints.

Mapping Hierarchical Entities

ER specialization or generalization comes in the form of hierarchical entity sets.



Mapping Process

- Create tables for all higher-level entities.
- Create tables for lower-level entities.
- Add primary keys of higher-level entities in the table of lower-level entities.
- In lower-level tables, add all other attributes of lower-level entities.
- Declare primary key of higher-level table and the primary key for lower-level table.
- Declare foreign key constraint.

FUNCTIONAL DEPENDENCY

The functional dependency is a relationship that exists between two attributes. It typically exists between the primary key and non-key attribute within a table.

1. $X \rightarrow Y$

The left side of FD is known as a determinant, the right side of the production is known as a dependent.

For example:

Assume we have an employee table with attributes: Emp_Id, Emp_Name, Emp_Address.

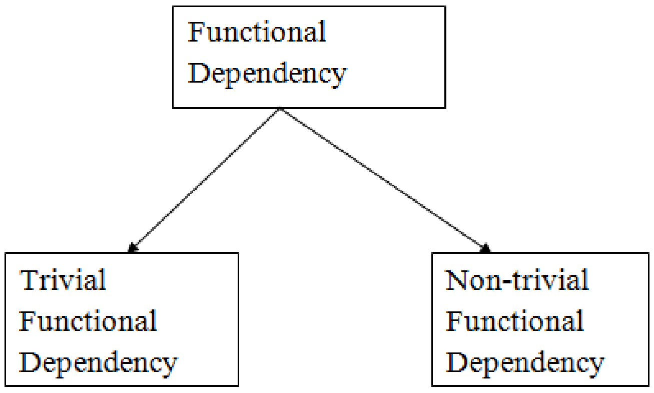
Here Emp_Id attribute can uniquely identify the Emp_Name attribute of employee table because if we know the Emp_Id, we can tell that employee name associated with it.

Functional dependency can be written as:

Emp_Id → Emp_Name

We can say that Emp_Name is functionally dependent on Emp_Id.

Types of Functional dependency


Functional Dependency
Trivial Functional Dependency
Non-trivial Functional Dependency

1. Trivial functional dependency

- A → B has trivial functional dependency if B is a subset of A.
- The following dependencies are also trivial like: A → A, B → B

Example:

1. Consider a table with two columns Employee_Id and Employee_Name.
2. {Employee_id, Employee_Name} → Employee_Id is a trivial functional dependency as

3. Employee_Id is a subset of {Employee_Id, Employee_Name}.
4. Also, Employee_Id → Employee_Id and Employee_Name → Employee_Name are trivi

al dependencies too.

2. Non-trivial functional dependency

- A → B has a non-trivial functional dependency if B is not a subset of A.
- When A intersection B is NULL, then A → B is called as complete non-trivial.

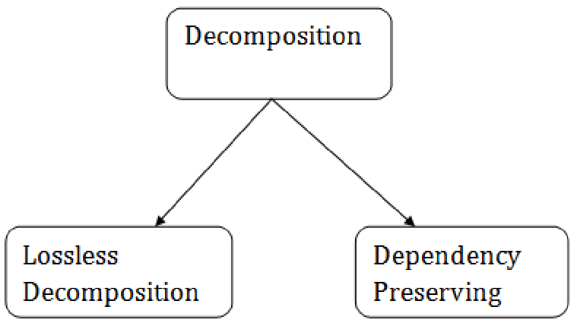
Example:

1. ID → Name,
2. Name → DOB

RELATIONAL DECOMPOSITION

- When a relation in the relational model is not in appropriate normal form then the decomposition of a relation is required.
- In a database, it breaks the table into multiple tables.
- If the relation has no proper decomposition, then it may lead to problems like loss of information.
- Decomposition is used to eliminate some of the problems of bad design like anomalies, inconsistencies, and redundancy.

Types of Decomposition



NONLOSS DECOMPOSITION Or (Lossless Decomposition)

- If the information is not lost from the relation that is decomposed, then the decomposition will be lossless.
- The lossless decomposition guarantees that the join of relations will result in the same relation as it was decomposed.
- The relation is said to be lossless decomposition if natural joins of all the decomposition give the original relation.

Example:

EMPLOYEE_DEPARTMENT table:

EMP_ID	EMP_NAME	EMP_AGE	EMP_CITY	DEPT_ID	DEPT_NAME
22	Denim	28	Mumbai	827	Sales
33	Alina	25	Delhi	438	Marketing
46	Stephan	30	Bangalore	869	Finance
52	Katherine	36	Mumbai	575	Production
60	Jack	40	Noida	678	Testing

The above relation is decomposed into two relations EMPLOYEE and DEPARTMENT

EMPLOYEE table:

EMP_ID	EMP_NAME	EMP_AGE	EMP_CITY
22	Denim	28	Mumbai
33	Alina	25	Delhi
46	Stephan	30	Bangalore
52	Katherine	36	Mumbai
60	Jack	40	Noida

DEPARTMENT table

DEPT_ID	EMP_ID	DEPT_NAME
827	22	Sales
438	33	Marketing
869	46	Finance
575	52	Production
678	60	Testing

Now, when these two relations are joined on the common column "EMP_ID", then the resultant relation will look like:

Employee ⋈ Department

EMP_ID	EMP_NAME	EMP_AGE	EMP_CITY	DEPT_ID	DEPT_NAME
22	Denim	28	Mumbai	827	Sales
33	Alina	25	Delhi	438	Marketing
46	Stephan	30	Bangalore	869	Finance
52	Katherine	36	Mumbai	575	Production
60	Jack	40	Noida	678	Testing

Hence, the decomposition is Lossless join decomposition.

JOIN DEPENDENCIES AND FIFTH NORMAL FORM

Join Dependency

A relation is said to have join dependency if it can be recreated by joining multiple sub relations and each of these sub relations has a subset of the attributes of the original relation.

Condition for join dependency:

If the join of R1 and R2 over Q is equal to relation R then we can say that a join dependency exists, where R1 and R2 are the decomposition R1 (P, Q) and R2 (Q, S) of a given relation R (P, Q, S). R1 and R2 are a lossless decomposition of R.

Example: Consider the relation **R** below having the schema R(supplier, product, consumer). The primary key is a combination of all three attributes of the relation.

Table 1

supplier	product	consumer
S1	P1	C1
S1	P2	C1
S2	P1	C1
S3	P3	C3

Table 2

supplier	product
S1	P1
S1	P2
S2	P1
S3	P3

Table 3

consumer	product
C1	P1
C1	P2
C3	P3

Table 4

supplier	consumer
S1	C1
S2	C1
S3	C3

Explanation:

Table 2, Table 3 and Table 4 when joined yield the original table (Table 1). Hence join dependency exists in Table 1, therefore Table 1 is not in 5NF or PJNF.

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 &

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

MULTIVALUED DEPENDENCY AND FOURTH NORMAL FORM (4NF)

Multivalued Dependency

Multivalued dependency occurs when two attributes in a table are independent of each other but, both depend on a third attribute. A multivalued dependency consists of at least two attributes that are dependent on a third attribute that's why it always requires at least three attributes.

Example: Suppose there is a bike manufacturer company which produces two colors(white and black) of each model every year.

BIKE_MODEL	MANUF_YEAR	COLOR
M2011	2008	White
M2001	2008	Black
M3001	2013	White
M3001	2013	Black
M4006	2017	White
M4006	2017	Black

Here columns COLOR and MANUF_YEAR are dependent on BIKE_MODEL and independent of each other.

In this case, these two columns can be called as multivalued dependent on BIKE_MODEL. The representation of these dependencies is shown below:

1. BIKE_MODEL → → MANUF_YEAR
2. BIKE_MODEL → → COLOR

This can be read as "BIKE_MODEL multidetermined MANUF_YEAR" and "BIKE_MODEL multidetermined COLOR".

FOURTH NORMAL FORM (4NF)

- A relation will be in 4NF if it is in Boyce Codd normal form and has no multi-valued dependency.

What is Multi-valued Dependency?

A table is said to have multi-valued dependency, if the following conditions are true,

1. For a dependency A→B, if for a single value of A, multiple value of B exists, then the table may have multi-valued dependency.
2. Also, a table should have at-least 3 columns for it to have a multi-valued dependency.
3. And, for a relation R(A,B,C), if there is a multi-valued dependency between, A and B, then B and C should be independent of each other.

If all these conditions are true for any relation(table), it is said to have 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

EXAMPLE 2:

Below we have a college enrolment table with columns s_id, course and hobby.

s_id	course	hobby
1	Science	Cricket
1	Maths	Hockey

2	C#	Cricket
2	Php	Hockey

As you can see in the table above, student with s_id **1** has opted for two courses, **Science** and **Maths**, and has two hobbies, **Cricket** and **Hockey**.
You must be thinking what problem this can lead to, right?

Well the two records for student with s_id **1**, will give rise to two more records, as shown below, because for one student, two hobbies exists, hence along with both the courses, these hobbies should be specified.

s_id	**Course**	**Hobby**
1	Science	Cricket
1	Maths	Hockey
1	Science	Hockey
1	Maths	Cricket

And, in the table above, there is no relationship between the columns course and hobby. They are independent of each other.
So there is multi-value dependency, which leads to un-necessary repetition of data and other anomalies as well.

How to satisfy 4th Normal Form?

To make the above relation satify the 4th normal form, we can decompose the table into 2 tables.

CourseOpted Table

s_id	**course**
1	Science
1	Maths
2	C#
2	Php

And, **Hobbies Table**,

s_id	**Hobby**
1	Cricket
1	Hockey
2	Cricket
2	Hockey

Now this relation satisfies the fourth normal form.

A table can also have functional dependency along with multi-valued dependency. In that case, the functionally dependent columns are moved in a separate table and the multi-valued dependent columns are moved to separate tables.

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

1. 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:

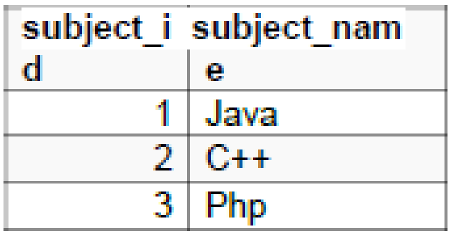
EMP_ID	EMP_NAME	EMP_PHONE	EMP_STATE
14	John	7272826385	UP

14	John	9064738238	UP
20	Harry	8574783832	Bihar
12	Sam	7390372389	Punjab
12	Sam	8589830302	Punjab

2. Second Normal Form (2NF)

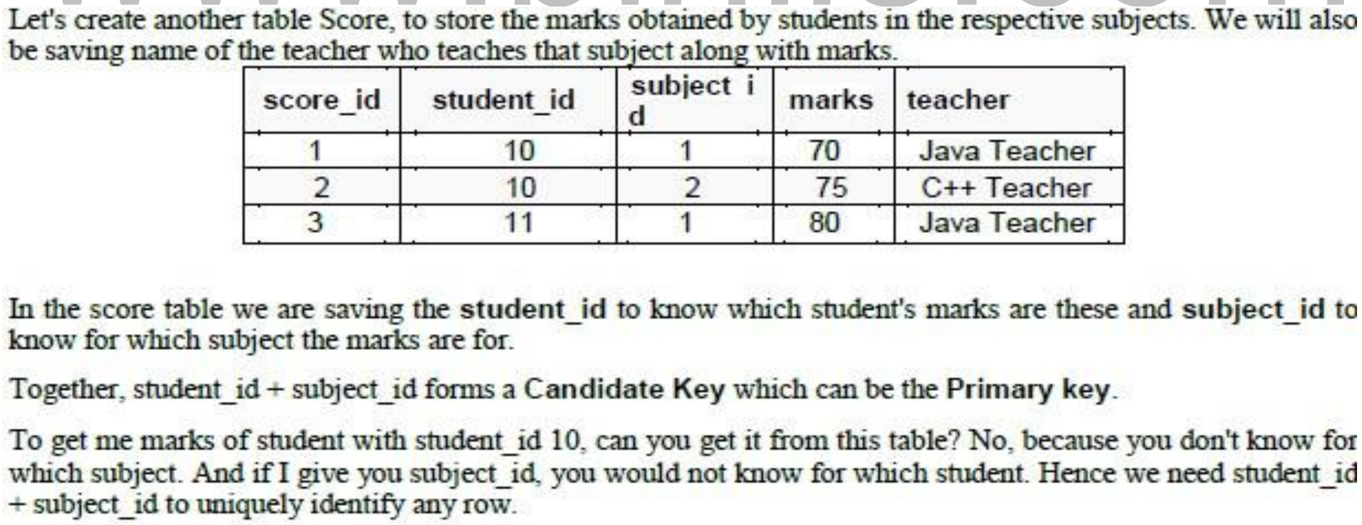
- In the 2NF, relational must be in 1NF.
- In the second normal form, all non-key attributes are fully functional dependent on the primary key

Example: Let us create the table for subject, which will have subject_id and subject_name fields



subject_id	subject_name
1	Java
2	C++
3	Php

and subject_id will be the primary key.



Let's create another table Score, to store the marks obtained by students in the respective subjects. We will also be saving name of the teacher who teaches that subject along with marks.

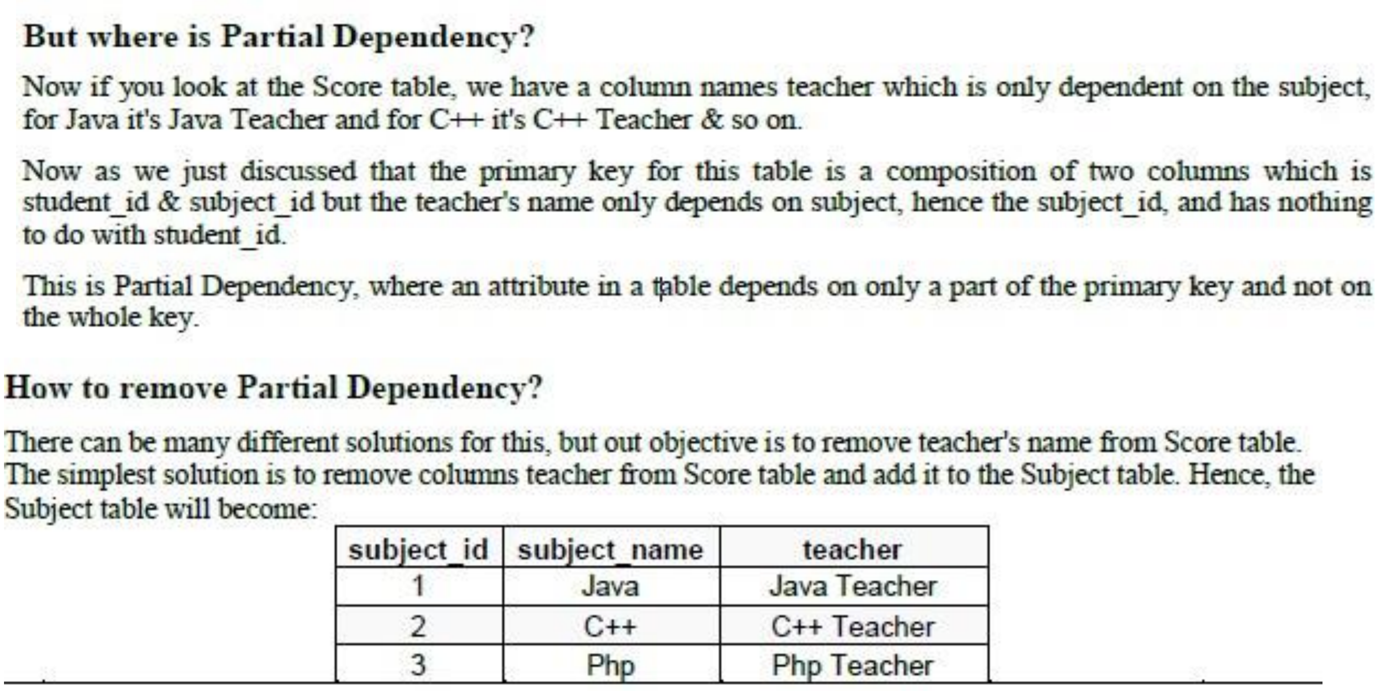
score_id	student_id	subject_id	marks	teacher
1	10	1	70	Java Teacher
2	10	2	75	C++ Teacher
3	11	1	80	Java Teacher

In the score table we are saving the **student_id** to know which student's marks are these and **subject_id** to know for which subject the marks are for.

Together, student_id + subject_id forms a **Candidate Key** which can be the **Primary key**.

To get me marks of student with student_id 10, can you get it from this table? No, because you don't know for which subject. And if I give you subject_id, you would not know for which student. Hence we need student_id + subject_id to uniquely identify any row.

Candidate Key: {student_id, subject_id} --- (Primary Key)



But where is Partial Dependency?

Now if you look at the Score table, we have a column names teacher which is only dependent on the subject, for Java it's Java Teacher and for C++ it's C++ Teacher & so on.

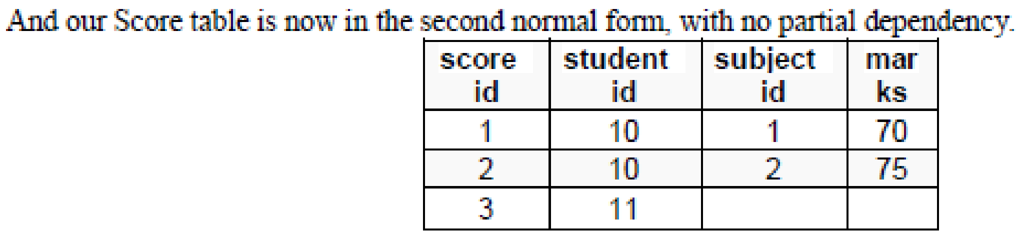
Now as we just discussed that the primary key for this table is a composition of two columns which is student_id & subject_id but the teacher's name only depends on subject, hence the subject_id, and has nothing to do with student_id.

This is Partial Dependency, where an attribute in a table depends on only a part of the primary key and not on the whole key.

How to remove Partial Dependency?

There can be many different solutions for this, but out objective is to remove teacher's name from Score table. The simplest solution is to remove columns teacher from Score table and add it to the Subject table. Hence, the Subject table will become:

subject_id	subject_name	teacher
1	Java	Java Teacher
2	C++	C++ Teacher
3	Php	Php Teacher



And our Score table is now in the second normal form, with no partial dependency.

score id	student id	subject id	marks
1	10	1	70
2	10	2	75
3	11		

3. 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.

A relation is in third normal form if it holds at least 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:

{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.

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

Dependency Preserving

- It is an important constraint of the database.
- In the dependency preservation, at least one decomposed table must satisfy every dependency.
- If a relation R is decomposed into relation R1 and R2, then the dependencies of R either must be a part of R1 or R2 or must be derivable from the combination of functional dependencies of R1 and R2.
- For example, suppose there is a relation R (A, B, C, D) with functional dependency set (A->BC). The relational R is decomposed into R1(ABC) and R2(AD) which is dependency preserving because FD A->BC is a part of relation R1(ABC).