COMPUTER SCIENCE & INFORMATION TECHNOLOGY

Databases

Comprehensive Theory
with Solved Examples *and* Practice Questions

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Databases

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Databases

Goal of the Subject

The main goal of Data Base management System is to make it possible for users to create, edit and update data in database files. Once created, the DBMS makes it possible to store and retrieve data from those database files.

More specifically, a DBMS provides the following functions:

- Concurrency: concurrent access (meaning ‘at the same time’) to the same database by multiple users
- Security: security rules to determine access rights of users
- Backup and recovery: processes to back-up the data regularly and recover data if a problem occurs
- Integrity: database structure and rules improve the integrity of the data
- Data descriptions: a data dictionary provides a description of the data

Databases

INTRODUCTION

Very often the subject *Data Base management System* is discussed vastly. But in this book we tried to keep it around the GATE syllabus. Each topic required for GATE is crisply covered with illustrative examples and each chapter is provided with Student Assignment at the end of each chapter so that the students get the thorough revision of the topics that he/she had studied. This subject is carefully divided into seven chapters as described below.

1. **The Relational Model**: In this chapter we discuss ER model and its constraints, types of relationships and we also the minimization of ER diagrams.
2. **Database design and Normalization: In** this chapter we discuss the types of keys in relational model , integrity constraints , functional dependencies of attributes and their properties, decomposition of relationship into 2NF, 3NF, BCNF etc.
3. **Relational Algebra**: In this chapter we discuss the Operators of relational algebra, operations on the set of records and finally we discuss the Tuple Relational Calculus (TRC).
4. **SQL**: In this chapter we discuss the basic form of SQL Query, operator, types of queries, group by and having clauses and finally we discuss the special properties of NULL value.
5. **Transaction**: In this chapter we discuss the ACID properties of a transaction, problem of concurrent execution, serializability etc.
6. **Concurrency Control Techniques**: In this chapter we discuss the various protocols used to achieve concurrent execution with any of the problem discussed in the previous chapter.
7. **File Organization and Indexing:** in this chapter we discuss concept of file organization, indexing techniques and B, B+ trees which form backbone of indexing techniques.

■■■■

CHAPTER

1

The Relational Model

1.1 Introduction

Entity relationships (ER) model is high level database design allows us to describe the data involved in real-world enterprise in terms of objects and their relationships and is widely used to develop initial database design. In overall design process, the ER model is used in a phase called conceptual database design.

1.2 Database Design and ER Diagrams

The database design process can be divided into six steps. The ER model is most relevant to the first three steps.

Requirements Analysis

The very first step in designing a database application is to understand what data is to be stored in the database, what applications must be built on top of it, and what operations are most frequent and subject to performance requirements. In other words, we must find out what the users want from the database. This is usually an informal process that involves discussions with user groups, a study of the current operating environment and how it is expected to change, analysis of any available documentation on existing applications that are expected to be replaced or complemented by the database, and so on.

Conceptual Database Design

The information gathered in the requirements analysis step is used to develop a high-level description of the data to be stored in the database, along with the constraints known to hold over this data. This step is often carried out using the ER model and is discussed in the rest of this chapter. The ER model is one of several high-level, or semantic, data models used in database design. The goal is to create a simple description of the data that closely matches how users and developers think of the data

Logical Database Design

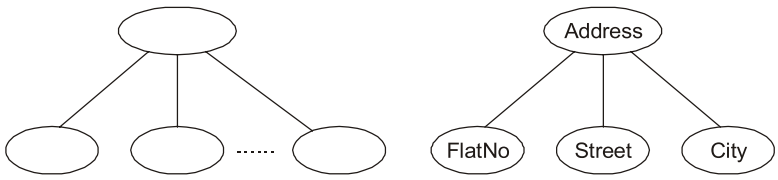
We must choose a DBMS to implement our database design, and convert the conceptual database design into a database schema in the data model of the chosen DBMS. We will consider only relational DBMSs, and therefore, the task in the logical design step is to convert an ER schema into a relational database schema.

1.3 Entity, Attributes, Entity Set

- Entity is an object that exist and is distinguishable from other objects. For example a person with give UID is an entity as he can be uniquely identified as one particular person.
- An entity may be concrete (person) or abstract (job). It is represented by rechange.
- An entity set is a collection of similar entities. (All persons having an account at a bank)
- Entity sets need not be disjoint. For example, the entity set employee (all employees of a bank) and entity set customer (all customers of the bank) may have members (Entity) in common.
- An entity is described using a set of attributes, all entities in a given entity set have same attributes, this is what we mean by similar.
- For each attribute associated with an entity set, we must identify domain of attribute which is the set of permitted values (e.g. if a company rates employees on a scale of 1 to 10 and stores rating in a field called rating, the associated domain consist of integers 1 through 10)
- Attribute is represented by an oval.
- Types of attributes and their representations:
  1. **Key attribute:** The attribute which uniquely identifies each entity in the entity set is called key attribute. For example, account number of customer.

     Represented as 

  2. **Composite attribute:** An attribute composed of many other attributes is called as composite attribute. For example, address of employee.

     Represented as 

  3. **Multivalued attributed:** An attribute consisting more than one value for a given entity. For example, phone number of bank employee.

     Represented as 

  4. **Derived attribute:** An attribute which can be derived from other attributes of the entity type is known as derived attribute. For example, age of employee (as it can be derived from date of birth).

     Represented as 

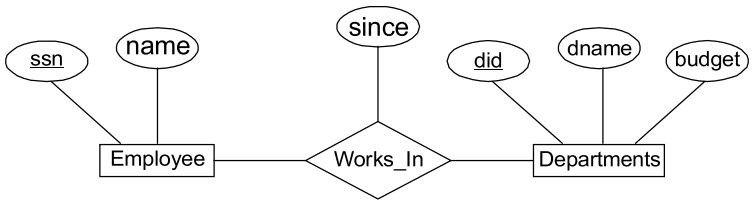
1.4 Relationship and Relationship Sets

- Relationship is association between two or more entities.
- Relationship set is a set of relationships of same type i.e. relate two or more entity sets.

A relationship set can be thought of as a set of n-tuples: $\{(e_1,...,e_n) \mid e_1 \in E_1,..., e_n \in E_n\}$

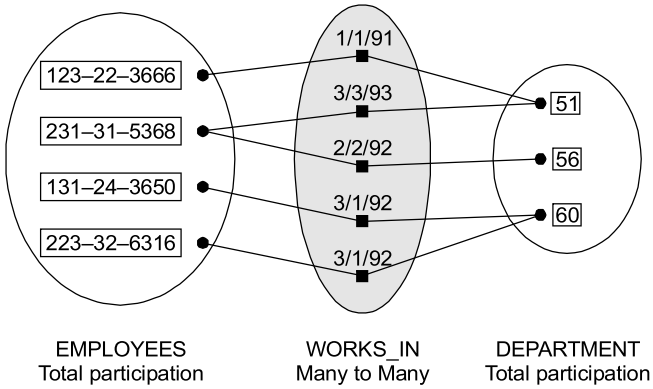
Each n-tuple denotes a relationship involving n entities e_1 through e_n, where entity e_i is in entity set E_i. In figure, we show the relationship set Works_In, in which each relationship indicates a department in which an

employee works. Note that several relationship sets might involve the same entity sets. For example, we could also have a Manages relationship set involving Employees and Departments.



A relationship can also have **descriptive attributes.** Descriptive attributes are used to record information about the relationship, rather than about any one of the participating entities; for example, we may wish to record that XYZ works in the pharmacy department as of January 1991. This information is captured in Figure by adding an attribute, *since,* to works_In. A relationship must be uniquely identified by the participating entities, without reference to the descriptive attributes. In the works_In relationship set, for example, each Works_In relationship must be uniquely identified by the combination of employee *ssn* and department did. Thus, for a given Employee-Department pair, we cannot have more than one associated *since* value.

An **instance** of a relationship set is a set of relationships. Intuitively, an instance can be thought of as a 'snapshot' of the relationship set at some instant in time. An instance of the Works_In relationship set is shown in Figure. Each Employees entity is denoted by its *ssn,* and each Departments entity is denoted by its did, for simplicity. The *since* value is shown beside each relationship.

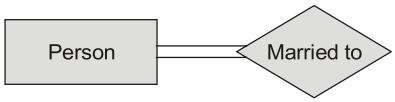


An Instance of the Works_In Relationship Set

Degree of a Relationship Set

The number of different entity sets participating in a relationship set is called as degree of relationship set.

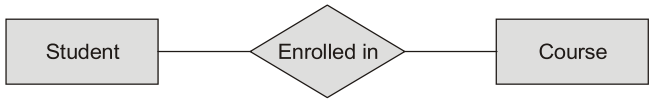
(*i*) **Unary relationship:** When there is only one entity set participating in a relation.



One person is married by other person.

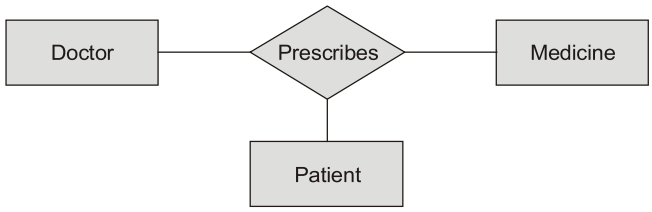
(*ii*) **Binary relationship:** When there are two entities set participating in a relation.

Eg: Student enroll in course



(iii) Ternary relationship: When there are three entity sets participating in a relation.

Eg: Patient visit doctor and doctor prescribes medicine



(iv) *n*-ary: When there are *n* number of entity sets participating in a relation.

1.5 Relationship Constraints

There are two types of relationship constraints

- Participation constraints
- Cardinality ratio

There are two types of participation constraints:

(i) Total participation constraints (existence dependency): The participation of an entity set *E* in a relationship set *R* is said to be total if every entity in *E* participates in at least one relationship in *R*. This participation is displayed as a double line connecting.

Example: If a company policy states that every employee must work for a department, then an employee entity can exist only if it participates in at least one "worksfor" relationship instance.

(ii) Partial Dependency: If only some entities in *E* participate in relationship in *R*, the participation of entity set *E* in relationship *R* is said to be partial. This participation is displayed as a single line connecting.

Example: Not every employee "Manages" a department.

Mapping Constraints: The possible cardinality ratio for binary relationship are:

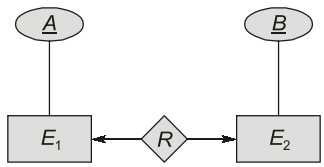
- One to one (1 : 1)
- One to many (1 : *M*)
- Many to one (*M* : 1)
- Many to many (*M* : *M*)

One is represented by '→'

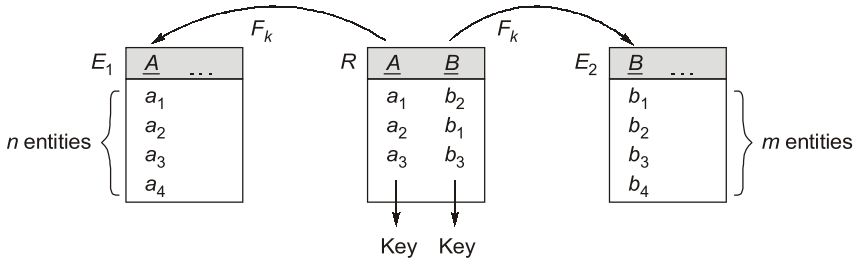
Many is represented by '—'

One to One (1 : 1): An entity (tuple) in E_1 is associated with atmost one Entity (tuple) in E_2, and an entity in E_2 is associated with atmost one entity in *A*

Example:



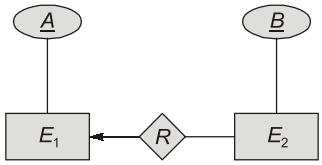
Candidate keys of relation *R* (*A*, *B*) = $\underline{A}$, $\underline{B}$



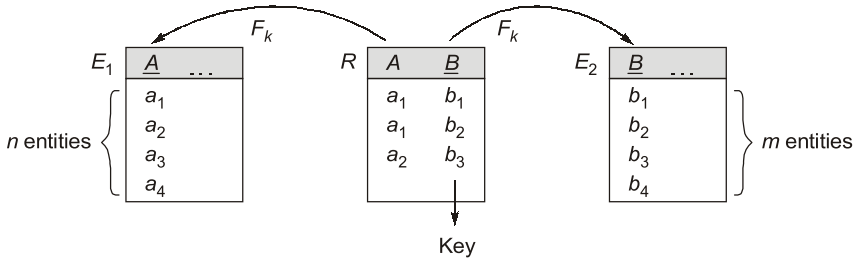
- Maximum possible records in relationship set R is min(m, n).

One to Many (1 : *M*): An entity (tuple) in E_1 is associated with zero or more entities in E_2 but an entity in E_2 can be associated with at most one entity in E_1

Example :



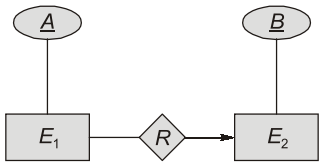
Candidate key of $R(A, B) = \underline{B}$



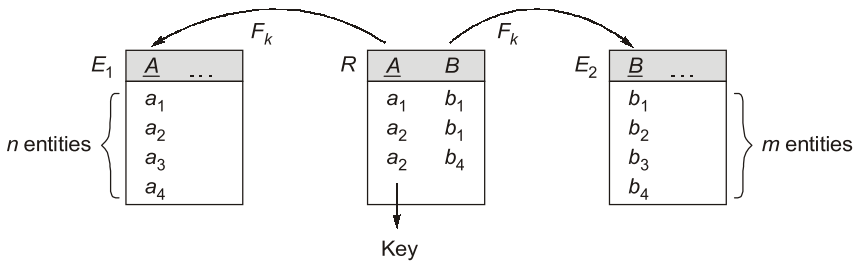
- Maximum possible records in relationship set R is m entities (or tuples).
- The relationship set R is same as right side they mapping.

Many to one (*M* : 1): An entity (tuple) in E_2 is associated with zero or more entities in E_1 but an entity in E_1 can be associated with at most one entity in E_2.

Example :



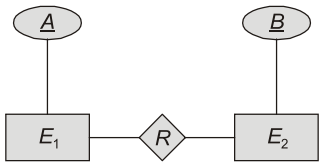
Candidate key of $R(A, B) = \underline{A}$



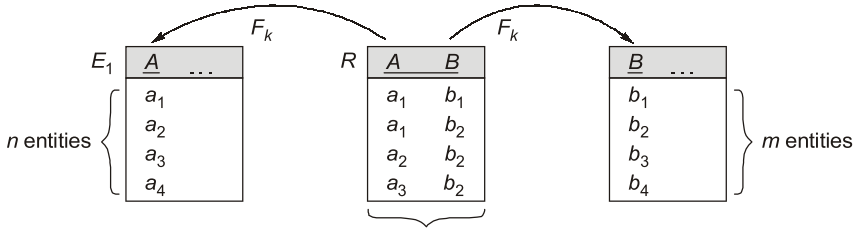
- Maximum possible records in relationship set R is n tuples.

Many to many (*M* : *M*): An entity (tuple) in E_2 is associated with zero or more entities in E_1 and An entity (tuple) in E_1 is associated with zero or more entities in E_2.

Example :



Candidate key of $R(A, B) = \underline{AB}$



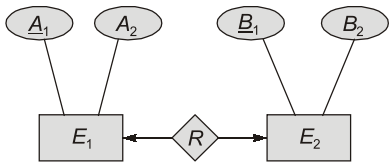
It can have null or duplicate values of A or B or both, so A or B can't be key individually.

- Maximum possible records in relationship set R is $n \times m$ tuples.

1.6 Minimization of ER Diagram

1. **1 : 1 cardinality** with partial participation at both end

   Example:



Consider the relation instances of relation E_1, E_2 and R.

E_1:

A_1	A_2
1	P
2	P
3	q

E_2:

B_1	B_2
11	P
21	q
31	R

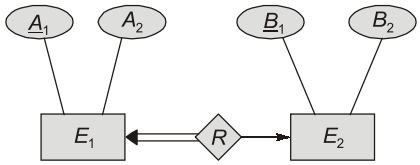
R:

A_1	B_1
1	11
3	21

E_1 and R can be combined to form a single table with A_1 is primary key (Unique and not NULL) and B_1 as alternate key as well as foreign key. Similarly R can be combined with E_2. But can't be combined to both E_1 and E_2 i.e. a single table E_1RE_2 can't be formed.

- If R is combined with both E_1 and E_2 i.e. a single relation E_1RE_2 then it has no primary key
- **Minimum number of tables** = 2
  (E_1R) and E_2 or E_1 and (E_2R)

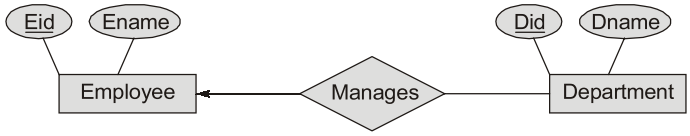
2. **1 : 1 cardinality** with total participation atleast one side. The relationship set E_1RE_2 (A_1, A_2, $\underline{B_1}$, B_2) has B_1 as primary key and A_1 as alternate key.



Note that A_1 can be null because there may be an entity in E_2 which is not related to any entity of E_1.

- **Minimum number of tables** = 1 i.e. E_1RE_2

3. **1 : *M* Cardinality:** Consider relationship set called manages between the Employees and Departments entity sets such that each department has at most one manager, although a single employee is allowed to manage more than one department. The restriction implies that each departments entity appears in at most one manages relationship in any allowable instance of Manages. This restriction is indicated in the ER diagram of figure.



Employee (Eid, Ename)

E_1	A
E_2	B
E_3	B

Manages (Eid, Did)

E_1	D_1
E_1	D_2
E_2	D_3

key

Department (Did, Dname)

D_1	X
D_2	Y
D_3	Y
D_4	Z

For 1 : *M* mapping, minimization is performed by combining the relationship set towards many side. Hence the resulting relations after minimization = 2.

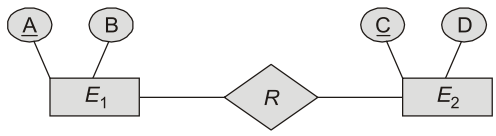
Employee (Eid, Ename) & Dept_manages (Did, Dname Eid)

E_1	A	D_1	X	E_1
E_2	B	D_2	Y	E_1
E_3	B	D_3	Y	E_2
		D_4	Z	Null

Here Eid of Dept_manages foreign key refers to Eid of Employee.

- If foreign key attribute Eid allows null, that implies partial participation from Employee relation.
- If foreign key attribute Eid does not allow null values, that implies total participation from Employee entity.
- Minimum number of tables in 1 : *M* or *M* : 1 = 2.

4. ***M* : *M* Cardinality:** Consider the following ER model:



E_1(A, B)

1	X
2	Y
3	Y

R(A C)

1	4
1	5
2	4

E_2(C D)

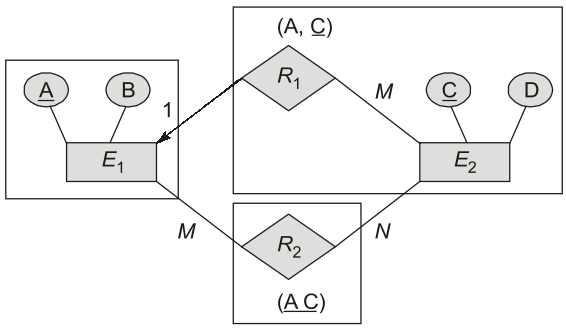
4	A
5	C
6	B

For $M : M$ mapping, minimization is performed by maintaining separates tables for E_1, E_2, R. R can't be combined with E_1 or E_2 as it has key AC.
Minimum number of tables for $M : M$ mapping = 3.

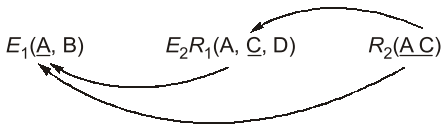
Example - 1.1 E_1 and E_2 are entity sets and R_1 and R_2 are relationship sets related between E_1 and E_2 with $1 : M$ and $M : N$ mapping respectively. How many minimum relations are required to represent this database instance?

(a) 2 (b) 3
(c) 4 (d) 5

Solution: b)



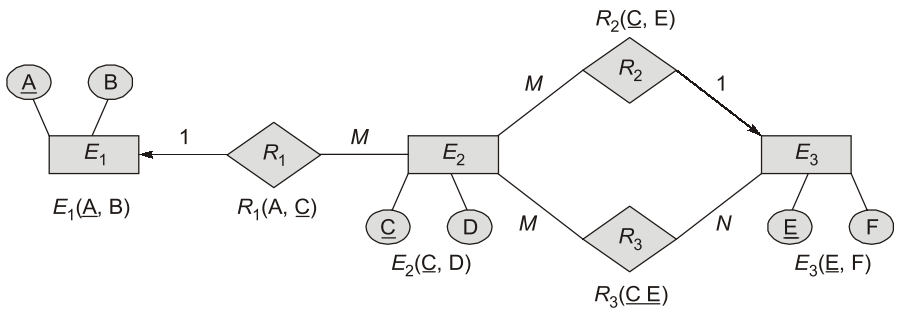
Since R_1 has $1 : M$ mapping, R_1 can be combined to E_2, so we get



Hence, we have 3 relation and 3 foreign key.

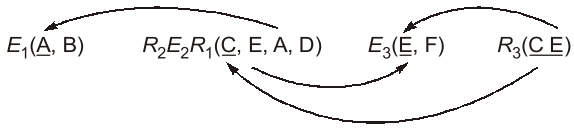
Example - 1.2 E_1, E_2, E_3, entity set. R_1 relationship set between E_1 and E_2 with $1 : M$ mapping R_2, R_3 relationship set between E_2, E_3 with $M : 1$ and $M : M$ mapping respectively. How many minimum relational table for given ERD?

Solution:



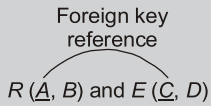
R_1 is in $1 : M$ mapping, hence R_1 and E_2 can be combined.
E_1(A, B) and R_1 E_2(A, C, D)
also R_2 has $M : 1$ mapping, hence R_2 and E_2R, can be combined
E_3(E, F) and R_2 E_2 R_1(C, E, A, D)

R_3 has $M : M$ mapping, hence it will be a separate table.
R_3 (CE)
$\therefore$ final relations are:



4 relations and 4 foreign key.

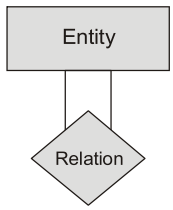
When to minimize?
If relationship set R is having a key as A which is also foreign key referencing to entity set E, then R and E combined to a single entity set e.g.



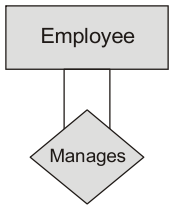
R and E combined to a single table = RE (C, B, D)

1.7 Self Referential Relationship

Relationship set relates to same entity sets i.e. pair of entities relating to each other.

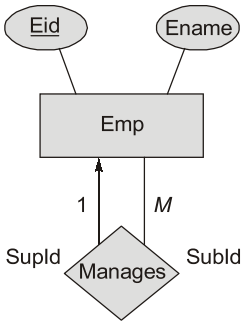


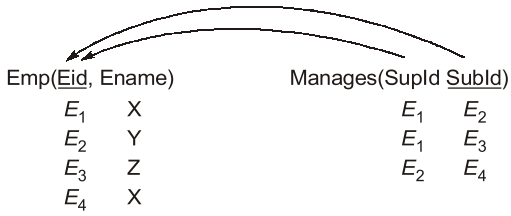
Example: Consider the relationship between manages and employees.



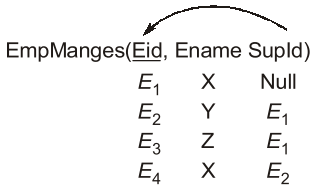
All people working in an organization are employees and few of the employees take the role of manager.

1. Each employee manages more than one employee but a employee has only one manager, i.e. 1 : M relation exist.



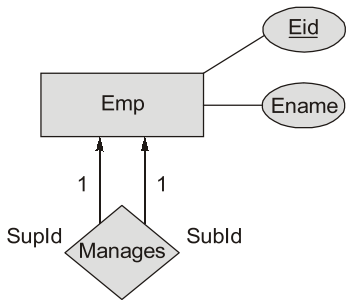


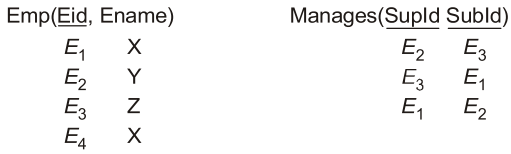
After minimization:



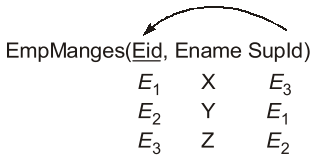
Minimum number of table = 1.

2. Each employee manages one employee and one employee has only manager.





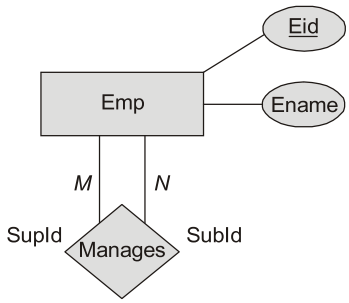
Resulting relation:



This EmpManages(Eid Ename SupId) is also possible.

Minimum number of table = 1.

3. M : N mapping



Summary

In this chapter we presented the modeling concepts of a high-level conceptual data model, the Entity-Relationship (ER) model. We started by discussing the role that a high-level data model plays in the database design process, we defined the basic ER model concepts of entities and their attributes. Which can be nested arbitrarily to produce complex attributes:

- Simple or atomic
- Composite
- Multivalued
- Derived

We also briefly discussed stored versus derived attributes. Then we discussed the ER model concepts at the schema or "intension" level:

- Entity types and their corresponding entity sets
- Key attributes of entity types
- Value sets (domains) of attributes
- Relationship types and their corresponding relationship sets
- Participation roles of entity types in relationship types

We presented two methods for specifying the structural constraints on relationship types. The first method distinguished two types of structural constraints:

- Cardinality ratios (1:1, 1:N, M:N for binary relationships)
- Participation constraints (total, partial)

We discussed weak entity types and the related concepts of owner entity types, identifying relationship types, and partial key attributes.

The ER modeling concepts we have presented thus far—entity types, relationship types, attributes, keys, and structural constraints—can model many database applications. However, more complex applications—such as engineering design, medical information systems, and telecommunications—require additional concepts if we want to model them with greater accuracy.

Student's Assignment

Q.1 Which of the following statement above ER models is/are correct?

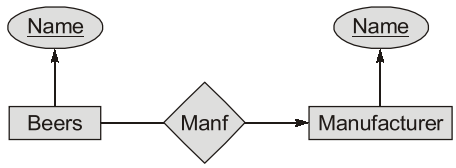
I. Many-many relationships cannot be representation ERD.

II. Relationship sets can have attributes of their own.

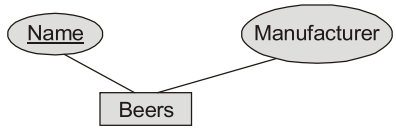
III. All many to one relationships are represented by the relationships between a weak and a non weak entity set.

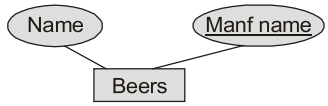
(a) II only (b) III only
(c) II and III only (d) I and II only

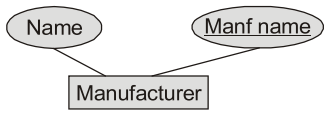
Q.2 Figure shows an ER diagram:

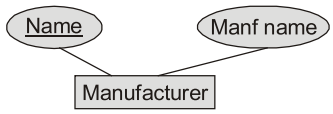


Which of the following best describes the above ER diagram?

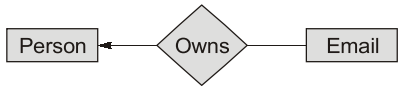
(a)


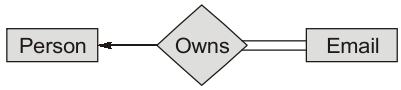
(b)


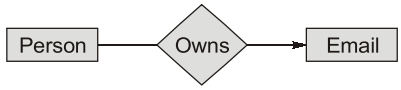
(c)


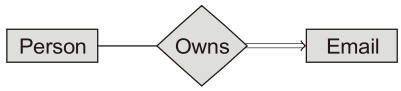
(d)


Q.3 Suppose we have two entity sets person, E-mail and use a relationship Owns. A person own atmost one E-mail account but an email account can be owned by multiple persons. Which of the following is an ER diagram based on above description.

(a)


(b)


(c)


(d)


Q.4 A student can take one or more courses and courses can be offered to any number of students. Which of the following represents given scenario in ER-model

(a)


(b)


(c)


(d)


Q.5 R is relationship, with 1 : 1 cardinality 30% participation at E_1 end 70% participation at E_2 end which is the best possible design?

(a) E_1 and E_2 kept separate with foreign key at E_1 end

(b) E_1 and E_2 kept separate with foreign key at E_2 end

(c) E_1 and E_2 kept separate with foreign key at E_1 as well as E_2

(d) E_1 and E_2 merges into a single table with no foreign key

Q.6 For weak entity set to be meaningful it must be part of

(a) one to one relationship

(b) one to many relationship

(c) many to one relationship

(d) All of the above

Q.7 In an E-R diagram, Y is the dominant entity and X is a subordinate entity. Then which of the following is incorrect:

(a) Operationally, if Y is deleted, so X is also deleted

(b) X existence is dependent on Y

(c) Operationally, if X is deleted, so Y is also deleted

(d) Operationally, if X is deleted, Y remains the same

Q.8 Map the following statements with True (T)/ False (F)

S_1: Participation of the weak entity set in identifying relationship must be total.

S_2: Multivalued attributes in E-R diagram require separate tables when converted into relational model with satisfy 2NF.

(a) F T (b) T F

(c) F F (d) T T

Answers Key:

1. (a) **2.** (a) **3.** (c) **4.** (b) **5.** (b)

6. (b) **7.** (c) **8.** (d)

Student's Assignments Explanations

2. (a)
Manufacturer is a name and it is at the 'one' end of any relationship. Hence it should not be an entity set it can be a attribute of Beer entity option (a) is correct.

3. (c)
The relationship is many to one and the partial participation from both entity set.

4. (b)
Student entity will have total participation with offered relation because each student takes atleast one course (i.e. 1 or more).

6. (b)
Weak entity set always have total participation in the relationship. It must be merged with the relationship entity. So the relation must be 1 : *M*.

7. (c)
X foreign key references to Y if "X" deleted then "Y" need not deleted.

8. (d)
Both the given statements are true.
S_1: Participation of the weak entity set in identifying relationship should be total because primary key of weak entity set gets defined only by relating it to strong entity and its primary key value.
S_2: Multivalued attributes in E-R diagram require separate tables along with key attribute when converted into relational model.