



# Module 2

## Databases

### Enhanced Entity-Relationship (EER) Modeling

## Table of contents

- EER stands for Enhanced ER or Extended ER
- EER Model Concepts
  - Includes all modeling concepts of basic ER
  - Additional concepts:
    - subclasses/superclasses
    - specialization/generalization
    - categories (UNION types)
    - attribute and relationship inheritance
  - These are fundamental to conceptual modeling
- The additional EER concepts are used to model applications more completely and more accurately
  - EER includes some object-oriented concepts, such as inheritance

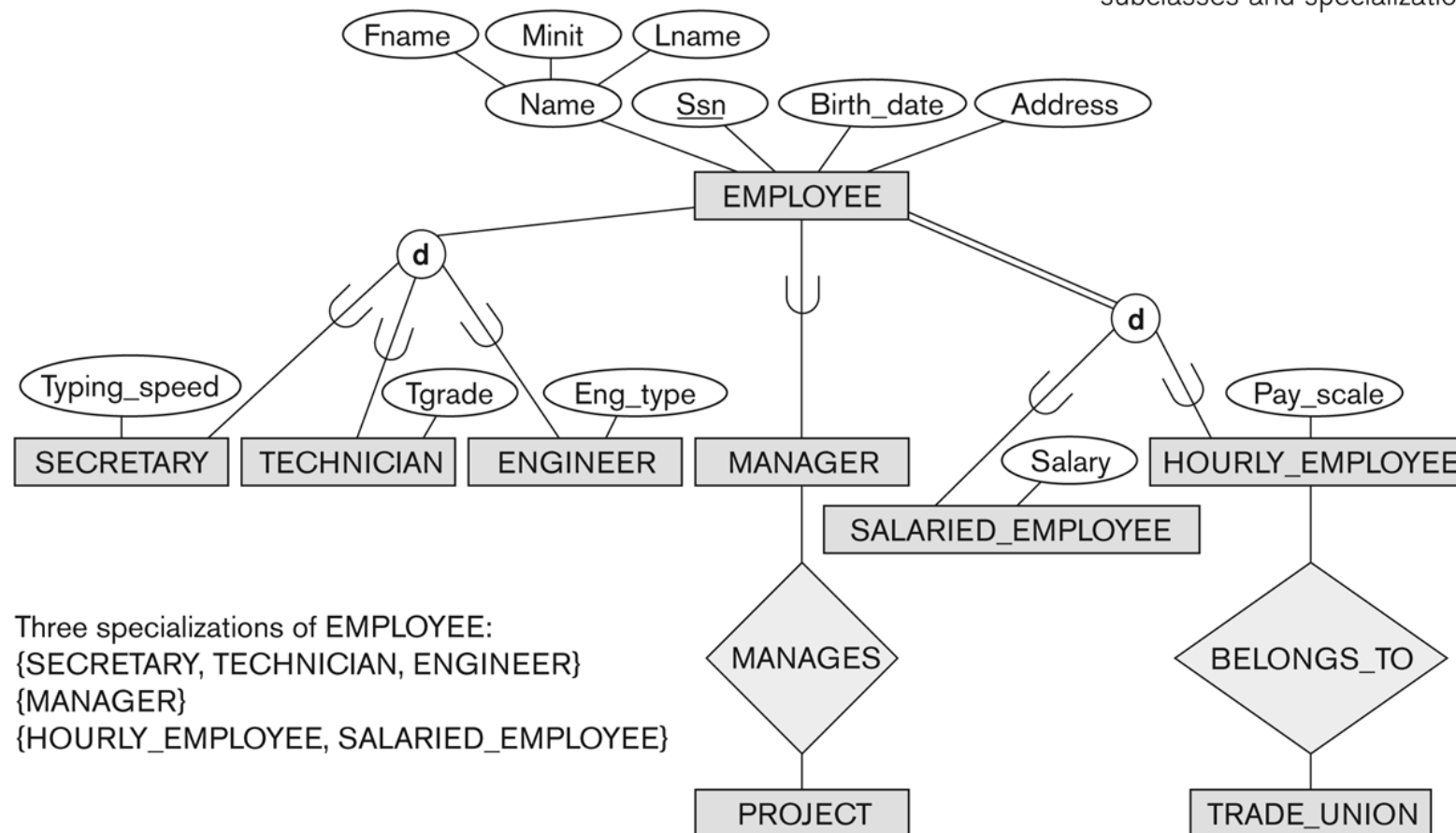
## Subclasses and Superclasses (1)

- An entity type may have additional meaningful subgroupings of its entities
  - Example: EMPLOYEE may be further grouped into:
    - SECRETARY, ENGINEER, TECHNICIAN, ...
      - Based on the EMPLOYEE's Job
    - MANAGER
      - EMPLOYEES who are managers
    - SALARIED\_EMPLOYEE, HOURLY\_EMPLOYEE
      - Based on the EMPLOYEE's method of pay
- EER diagrams extend ER diagrams to represent these additional subgroupings, called *subclasses* or *subtypes*

# Subclasses and Superclasses

**Figure 4.1**

EER diagram notation to represent subclasses and specialization.



## Subclasses and Superclasses (2)

- Each of these subgroupings is a subset of EMPLOYEE entities
- Each is called a subclass of EMPLOYEE
- EMPLOYEE is the superclass for each of these subclasses
- These are called superclass/subclass relationships:
  - EMPLOYEE/SECRETARY
  - EMPLOYEE/TECHNICIAN
  - EMPLOYEE/MANAGER
  - ...

## Subclasses and Superclasses (3)

- These are also called IS-A relationships
  - SECRETARY IS-A EMPLOYEE, TECHNICIAN IS-A EMPLOYEE, ....
- Note: An entity that is member of a subclass represents the same real-world entity as some member of the superclass:
  - The subclass member is the same entity in a *distinct specific role*
  - An entity cannot exist in the database merely by being a member of a subclass; it must also be a member of the superclass
  - A member of the superclass can be optionally included as a member of any number of its subclasses

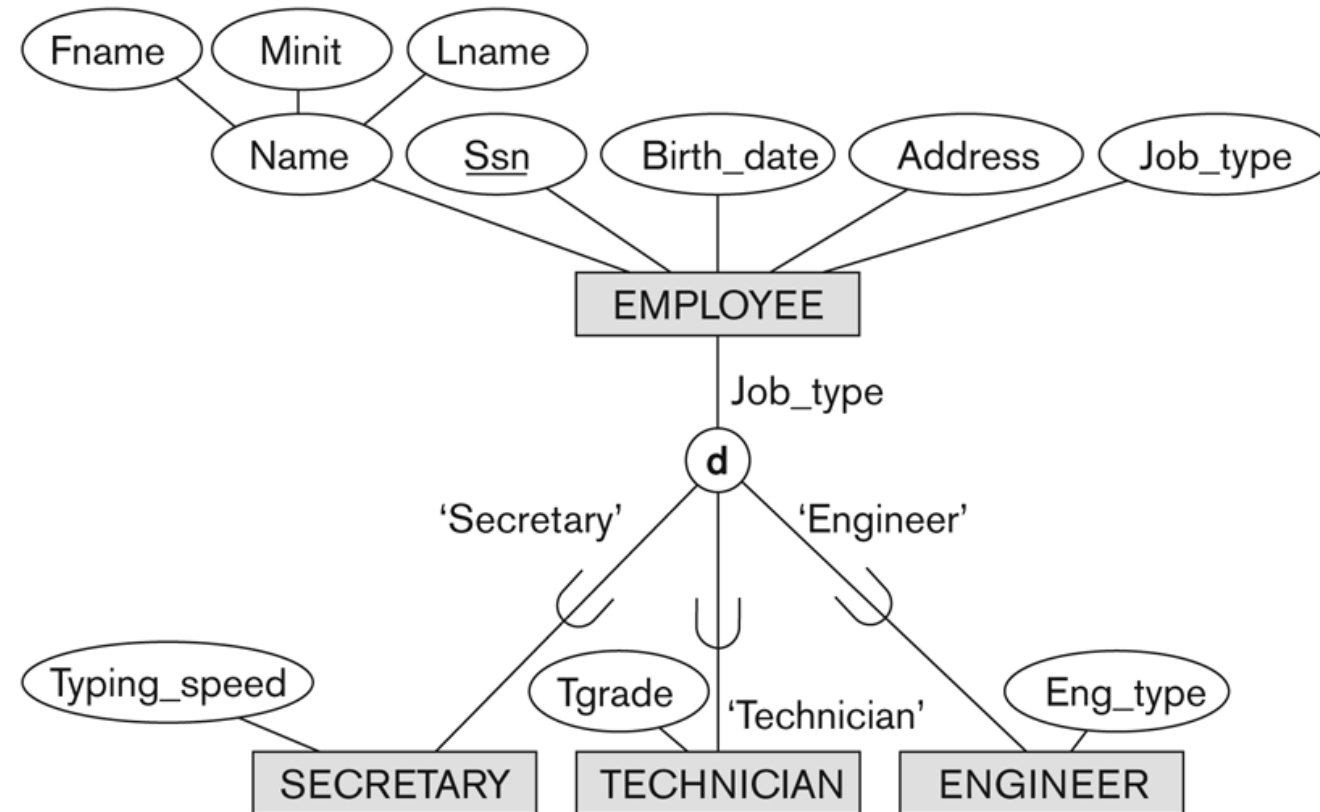
# Subclasses and Superclasses (4)

- Examples:
  - A salaried employee who is also an engineer belongs to the two subclasses:
    - ENGINEER, and
    - SALARIED\_EMPLOYEE
  - A salaried employee who is also an engineering manager belongs to the three subclasses:
    - MANAGER,
    - ENGINEER, and
    - SALARIED\_EMPLOYEE
- It is not necessary that every entity in a superclass be a member of some subclass

# Representing Specialization in EER Diagrams

**Figure 4.4**

EER diagram notation for an attribute-defined specialization on Job\_type.





## Attribute Inheritance in Superclass / Subclass Relationships

- An entity that is member of a subclass *inherits*
  - All attributes of the entity as a member of the superclass
  - All relationships of the entity as a member of the superclass
- Example:
  - In the previous slide, SECRETARY (as well as TECHNICIAN and ENGINEER) inherit the attributes Name, SSN, ..., from EMPLOYEE
  - Every SECRETARY entity will have values for the inherited attributes

## Specialization (1)

- Specialization is the process of defining a set of subclasses of a superclass
- The set of subclasses is based upon some distinguishing characteristics of the entities in the superclass
  - Example: {SECRETARY, ENGINEER, TECHNICIAN} is a specialization of EMPLOYEE based upon *job type*.
    - May have several specializations of the same superclass

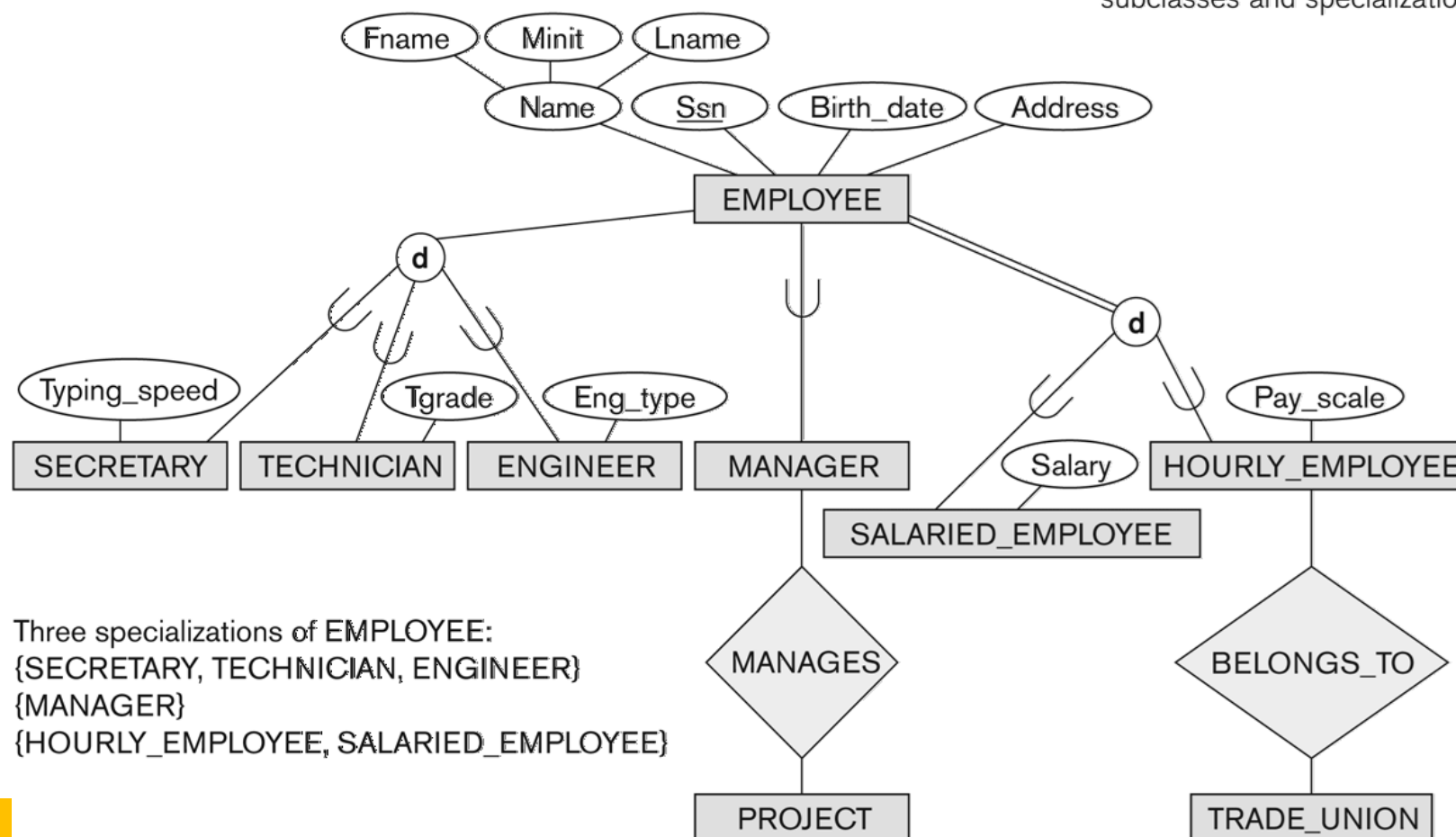
## Specialization (2)

- Example: Another specialization of EMPLOYEE based on *method of pay* is {SALARIED\_EMPLOYEE, HOURLY\_EMPLOYEE}.
  - Superclass/subclass relationships and specialization can be diagrammatically represented in EER diagrams
  - Attributes of a subclass are called *specific* or *local* attributes.
    - For example, the attribute TypingSpeed of SECRETARY
  - The subclass can also participate in specific relationship types.
    - For example, a relationship BELONGS\_TO of HOURLY\_EMPLOYEE

# Specialization (3)

**Figure 4.1**

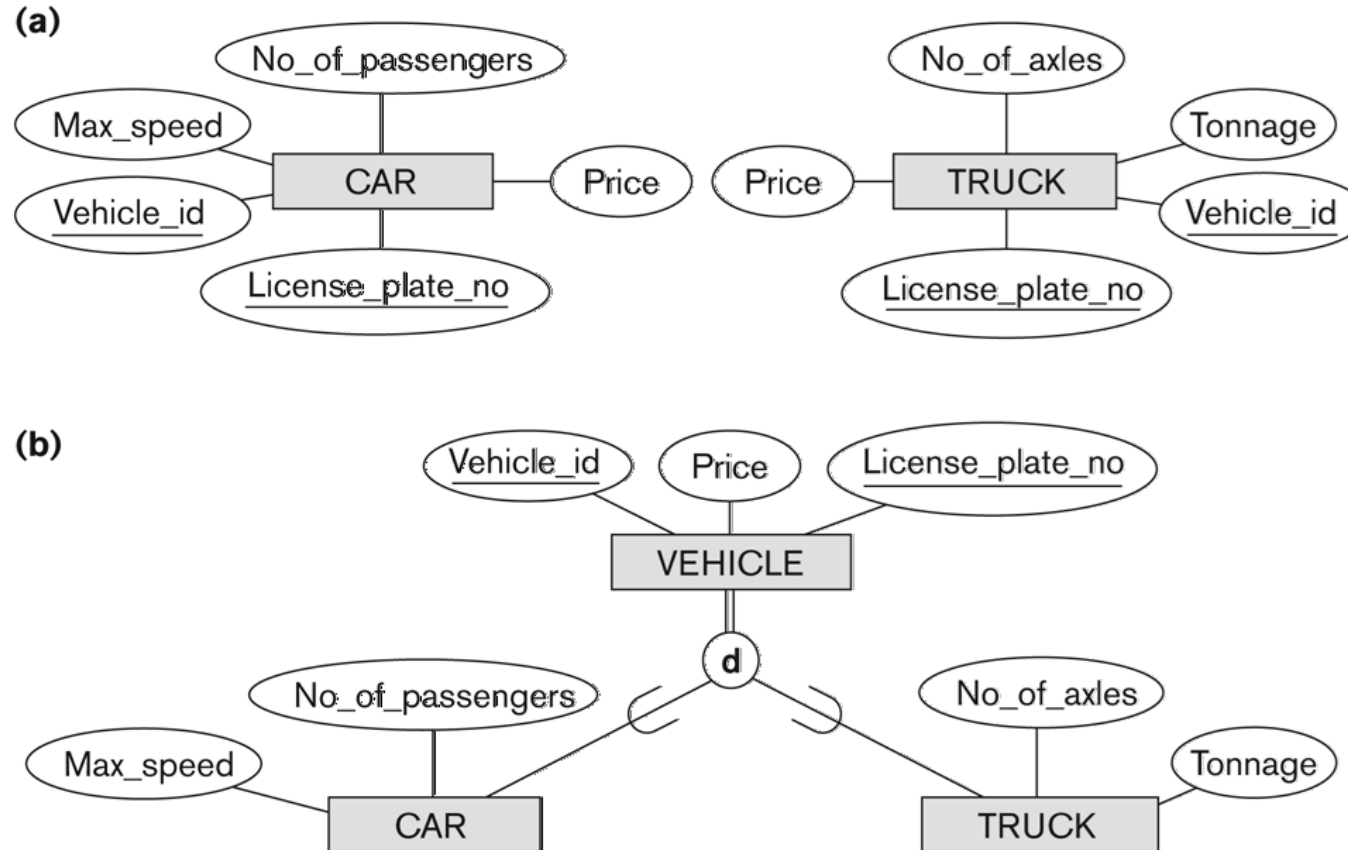
EER diagram notation to represent subclasses and specialization.



## Generalization

- Generalization is the reverse of the specialization process
- Several classes with common features are generalized into a superclass;
  - original classes become its subclasses
- Example: CAR, TRUCK generalized into VEHICLE;
  - both CAR, TRUCK become subclasses of the superclass VEHICLE.
  - We can view {CAR, TRUCK} as a specialization of VEHICLE
  - Alternatively, we can view VEHICLE as a generalization of CAR and TRUCK

# Generalization (2)



**Figure 4.3**

Generalization. (a) Two entity types, CAR and TRUCK.  
(b) Generalizing CAR and TRUCK into the superclass VEHICLE.

## Generalization and Specialization (1)

- Diagrammatic notation are sometimes used to distinguish between generalization and specialization
  - Arrow pointing to the generalized superclass represents a generalization
  - Arrows pointing to the specialized subclasses represent a specialization
  - We *do not use* this notation because it is often subjective as to which process is more appropriate for a particular situation
  - We advocate not drawing any arrows

## Generalization and Specialization (2)

- Data Modeling with Specialization and Generalization
  - A superclass or subclass represents a collection (or set or grouping) of entities
  - It also represents a particular *type of entity*
  - Shown in rectangles in EER diagrams (as are entity types)
  - We can call all entity types (and their corresponding collections) **classes**, whether they are entity types, superclasses, or subclasses



## Constraints on Specialization and Generalization (1)

- If we can determine exactly those entities that will become members of each subclass by a condition, the subclasses are called predicate-defined (or condition-defined) subclasses
  - Condition is a constraint that determines subclass members
  - Display a predicate-defined subclass by writing the predicate condition next to the line attaching the subclass to its superclass

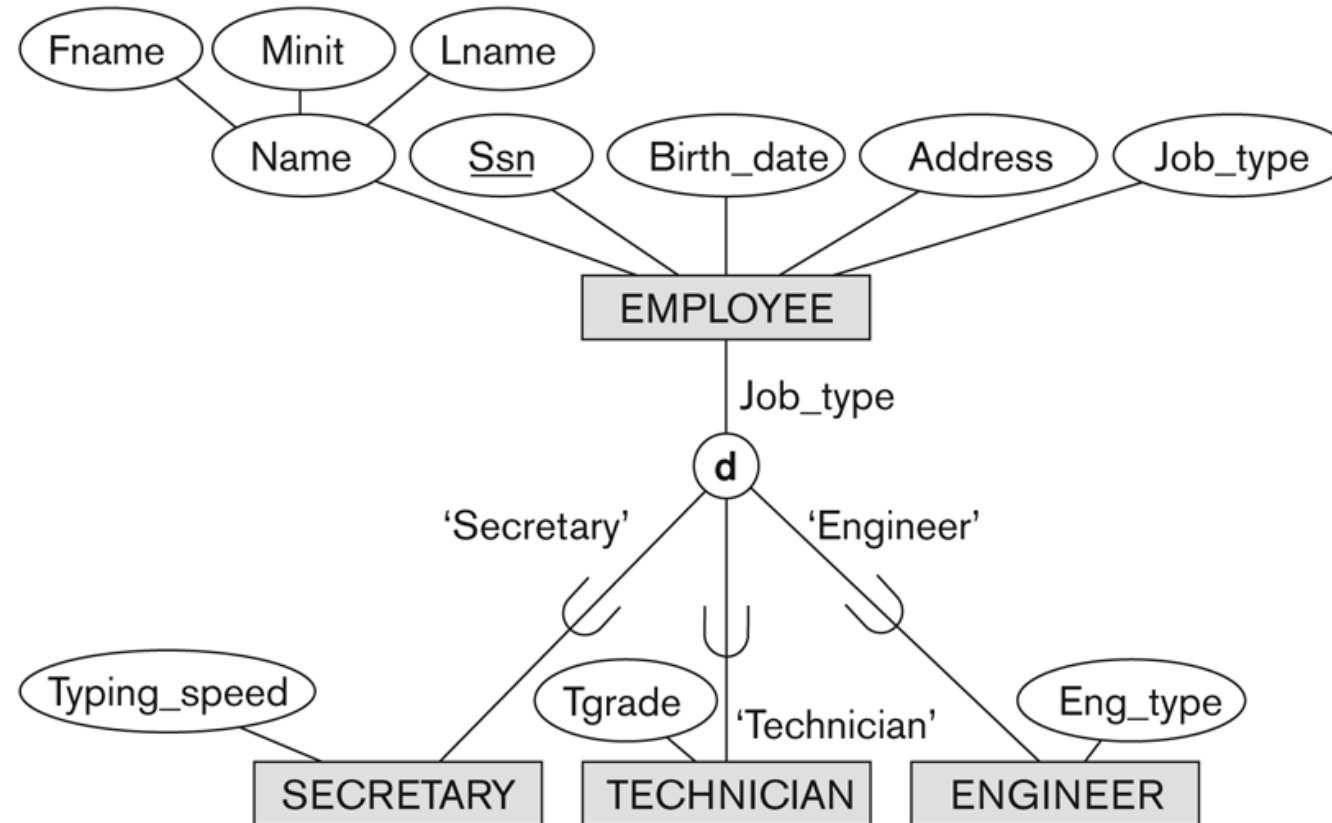
## Constraints on Specialization and Generalization (2)

- If all subclasses in a specialization have membership condition on same attribute of the superclass, specialization is called an attribute-defined specialization
  - Attribute is called the defining attribute of the specialization
  - Example: JobType is the defining attribute of the specialization {SECRETARY, TECHNICIAN, ENGINEER} of EMPLOYEE
- If no condition determines membership, the subclass is called user-defined
  - Membership in a subclass is determined by the database users by applying an operation to add an entity to the subclass
  - Membership in the subclass is specified individually for each entity in the superclass by the user

# Displaying an attribute-defined specialization in EER diagrams

**Figure 4.4**

EER diagram notation for an attribute-defined specialization on Job\_type.



## Constraints on Specialization and Generalization (3)

- Two basic constraints can apply to a specialization/generalization:
  - Disjointness Constraint:
  - Completeness Constraint:

## Constraints on Specialization and Generalization (4)

- Disjointness Constraint:
  - Specifies that the subclasses of the specialization must be *disjoint*:
    - an entity can be a member of at most one of the subclasses of the specialization
  - Specified by **d** in EER diagram
  - If not disjoint, specialization is *overlapping*:
    - that is the same entity may be a member of more than one subclass of the specialization
  - Specified by **o** in EER diagram

## Constraints on Specialization and Generalization (5)

- **Completeness Constraint:**

- *Total* specifies that every entity in the superclass must be a member of some subclass in the specialization/generalization
- Shown in EER diagrams by a **double line**
- *Partial* allows an entity not to belong to any of the subclasses
- Shown in EER diagrams by a single line

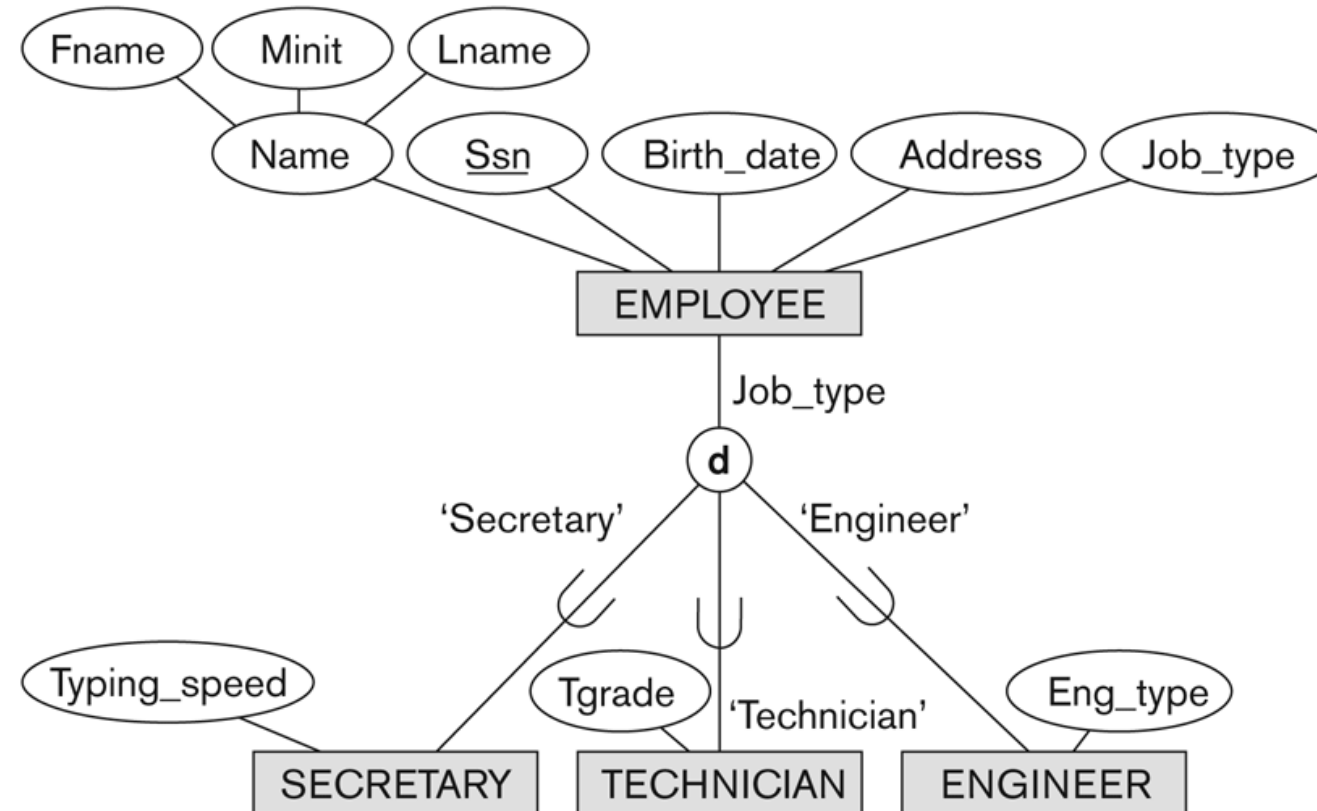
## Constraints on Specialization and Generalization (6)

- Hence, we have four types of specialization/generalization:
  - Disjoint, total
  - Disjoint, partial
  - Overlapping, total
  - Overlapping, partial
- Note: Generalization usually is total because the superclass is derived from the subclasses.

## Example of disjoint partial Specialization

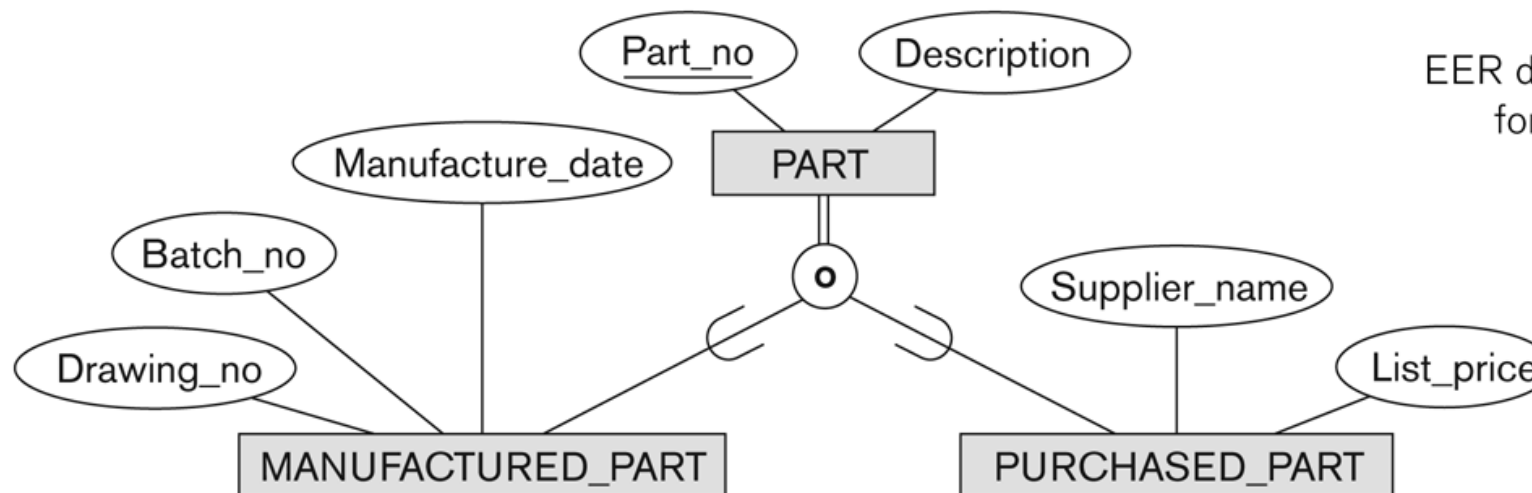
**Figure 4.4**

EER diagram notation for an attribute-defined specialization on Job\_type.





# Example of overlapping total Specialization

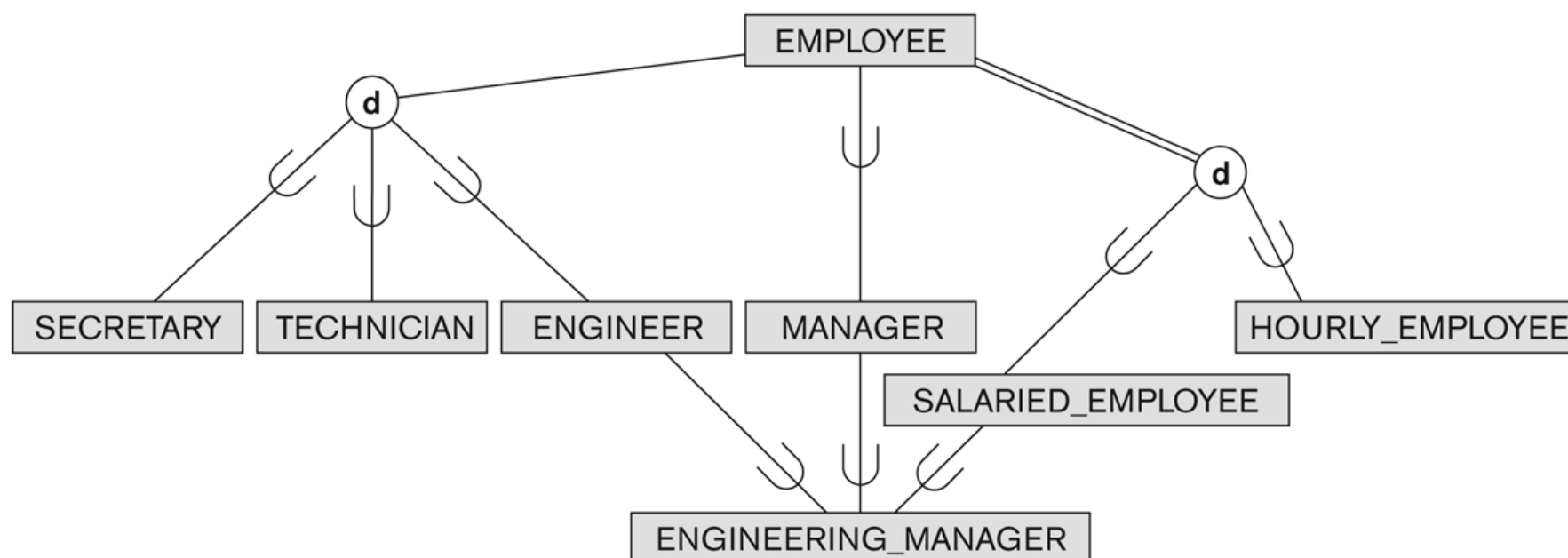


**Figure 4.5**  
EER diagram notation  
for an overlapping  
(nondisjoint)  
specialization.

## Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (1)

- A subclass may itself have further subclasses specified on it
  - forms a hierarchy or a lattice
- **Hierarchy** has a constraint that every subclass has only one superclass (called **single inheritance**); this is basically a **tree structure**
- In a **lattice**, a subclass can be subclass of more than one superclass (called **multiple inheritance**)

# Shared Subclass “Engineering\_Manager”



**Figure 4.6**

A specialization lattice with shared subclass ENGINEERING\_MANAGER.

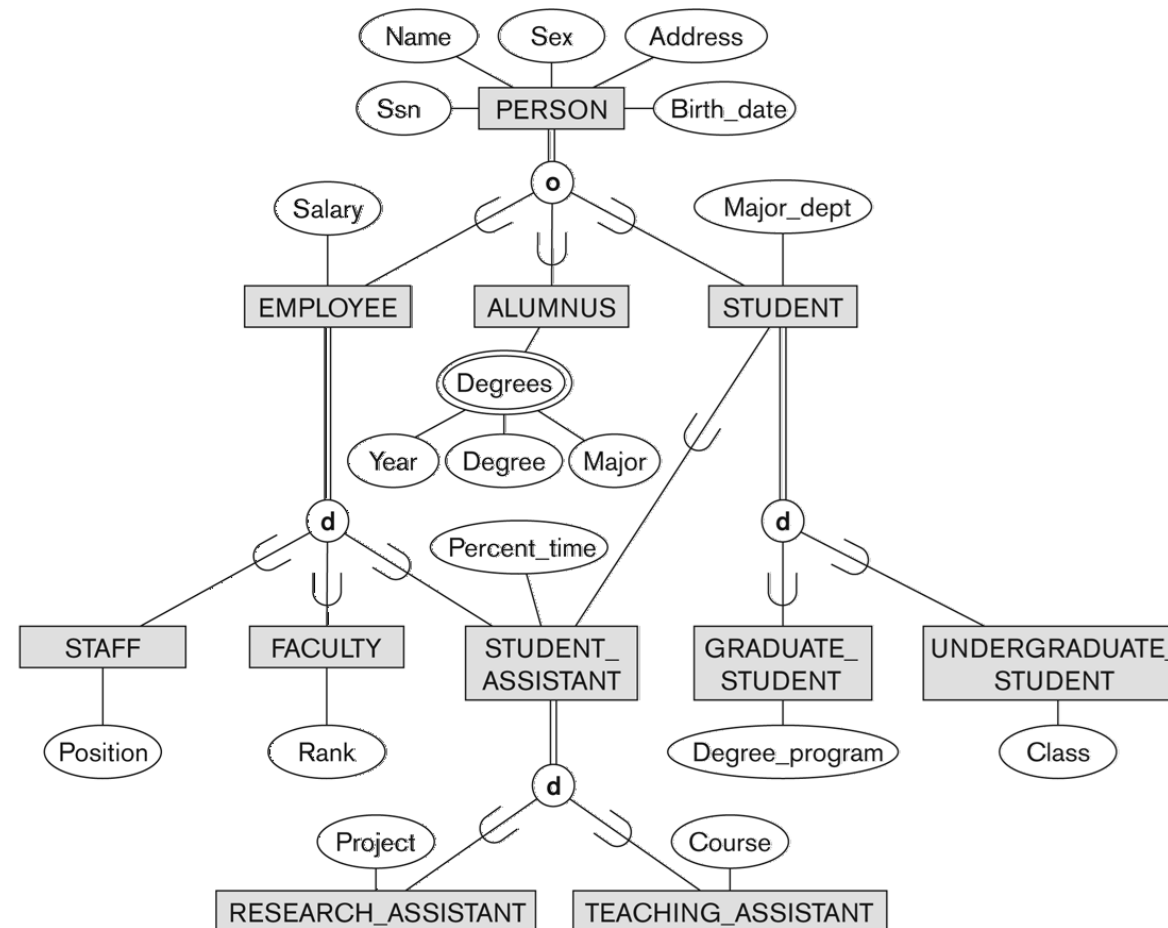
## Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (2)

- In a lattice or hierarchy, a subclass inherits attributes not only of its direct superclass, but also of all its predecessor superclasses
- A subclass with more than one superclass is called a shared subclass (multiple inheritance)
- Can have:
  - *specialization* hierarchies or lattices, or
  - *generalization* hierarchies or lattices,
  - depending on how they were *derived*
- We just use *specialization* (to stand for the end result of either specialization or generalization)

## Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (3)

- In *specialization*, start with an entity type and then define subclasses of the entity type by successive specialization
  - called a *top down* conceptual refinement process
- In *generalization*, start with many entity types and generalize those that have common properties
  - Called a *bottom up* conceptual synthesis process
- In practice, a *combination of both processes* is usually employed

## Specialization / Generalization Lattice Example (UNIVERSITY)



**Figure 4.7**

A specialization lattice with multiple inheritance for a UNIVERSITY database.

## Categories (UNION TYPES) (1)

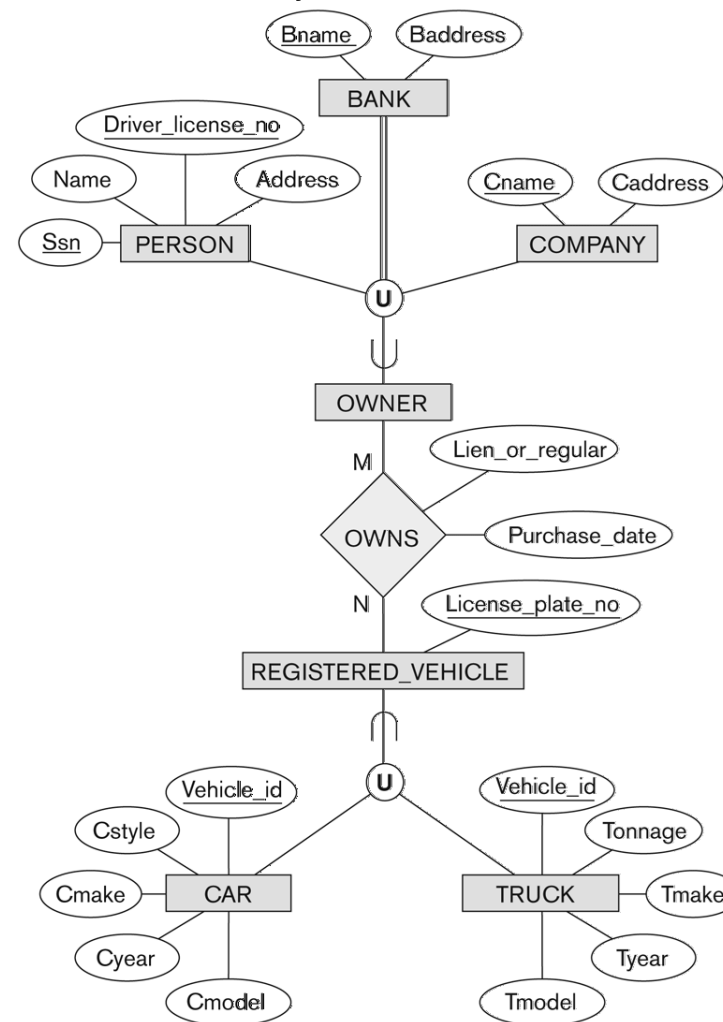
- All of the *superclass/subclass relationships* we have seen thus far have a single superclass
- A shared subclass is a subclass in:
  - *more than one* distinct superclass/subclass relationships
  - each relationships has a single superclass
  - shared subclass leads to multiple inheritance
- In some cases, we need to model a *single superclass/subclass relationship with more than one* superclass
- Superclasses can represent different entity types
- Such a subclass is called a category or UNION TYPE

## Categories (UNION TYPES) (2)

- Example: In a database for vehicle registration, a vehicle owner can be a PERSON, a BANK (holding a lien on a vehicle) or a COMPANY.
  - A *category* (UNION type) called OWNER is created to represent a subset of the *union* of the three superclasses COMPANY, BANK, and PERSON
  - A category member must exist in **at least one** of its superclasses
- Difference from *shared subclass*, which is a:
  - subset of the *intersection* of its superclasses
  - shared subclass member must exist in **all** of its superclasses



# Two categories (UNION types): OWNER, REGISTERED\_VEHICLE



**Figure 4.8**  
Two categories (union types): OWNER and REGISTERED\_VEHICLE.

# Formal Definitions of EER Model (1)

- Class C:
  - A type of entity with a corresponding set of entities:
    - could be entity type, subclass, superclass, or category
- Note: The definition of *relationship type* in ER/EER should have 'entity type' replaced with 'class' to allow relationships among classes in general
- Subclass S is a class whose:
  - Type inherits all the attributes and relationship of a class C
  - Set of entities must always be a subset of the set of entities of the other class C
    - $S \subseteq C$
  - C is called the superclass of S
  - A superclass/subclass relationship exists between S and C

## Formal Definitions of EER Model (2)

- Specialization Z:  $Z = \{S1, S2, \dots, Sn\}$  is a set of subclasses with same superclass G; hence, G/Si is a superclass relationship for  $i = 1, \dots, n$ .
  - G is called a generalization of the subclasses  $\{S1, S2, \dots, Sn\}$
  - Z is total if we always have:
    - $S1 \cup S2 \cup \dots \cup Sn = G$ ;
    - Otherwise, Z is partial.
  - Z is disjoint if we always have:
    - $S_i \cap S_j$  empty-set for  $i \neq j$ ;
  - Otherwise, Z is overlapping.

## Formal Definitions of EER Model (3)

- Subclass  $S$  of  $C$  is predicate defined if predicate (condition)  $p$  on attributes of  $C$  is used to specify membership in  $S$ ;
  - that is,  $S = C[p]$ , where  $C[p]$  is the set of entities in  $C$  that satisfy condition  $p$
- A subclass not defined by a predicate is called user-defined
- Attribute-defined specialization: if a predicate  $A = c_i$  (where  $A$  is an attribute of  $G$  and  $c_i$  is a constant value from the domain of  $A$ ) is used to specify membership in each subclass  $S_i$  in  $Z$ 
  - Note: If  $c_i \neq c_j$  for  $i \neq j$ , and  $A$  is single-valued, then the attribute-defined specialization will be disjoint.

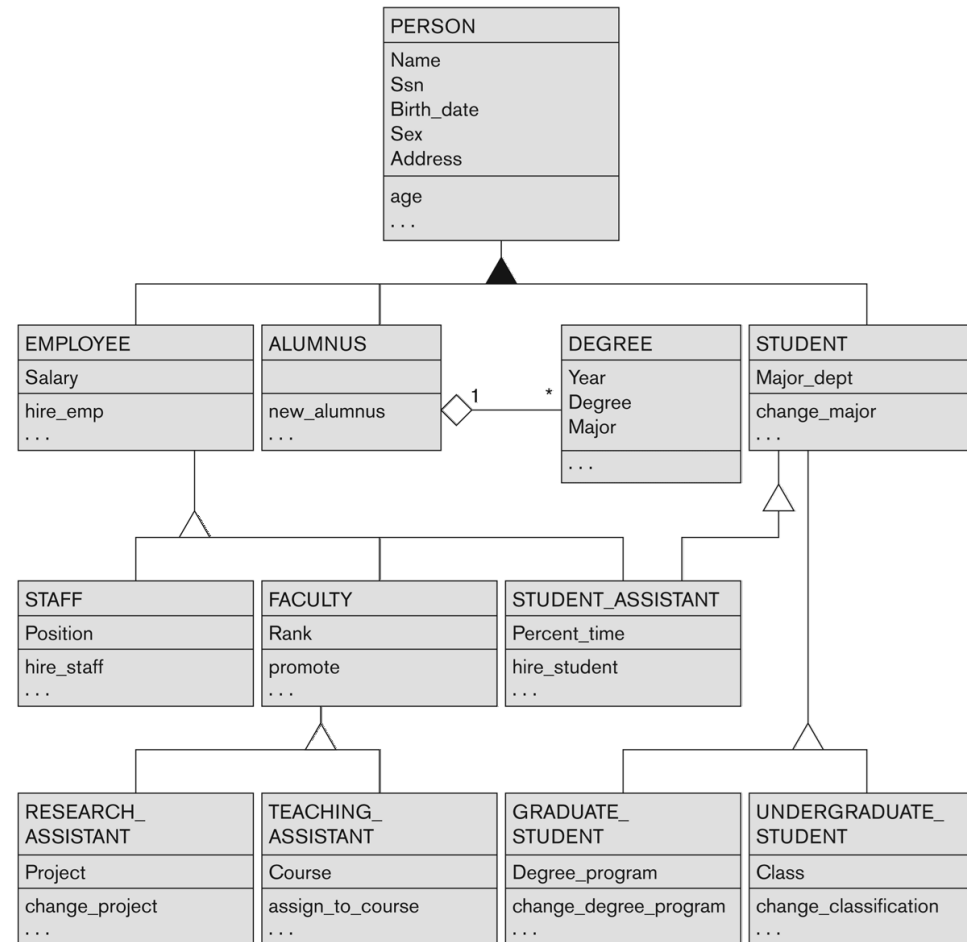
# Formal Definitions of EER Model (4)

- Category or UNION type T
  - A class that is a subset of the *union* of n defining superclasses  $D_1, D_2, \dots, D_n$ ,  $n > 1$ :
    - $T \subseteq (D_1 \cup D_2 \cup \dots \cup D_n)$
  - Can have a predicate  $p_i$  on the attributes of  $D_i$  to specify entities of  $D_i$  that are members of T.
  - If a predicate is specified on every  $D_i$ :  $T = (D_1[p_1] \cup D_2[p_2] \cup \dots \cup D_n[p_n])$

# Alternative diagrammatic notations

- ER/EER diagrams are a specific notation for displaying the concepts of the model diagrammatically
- DB design tools use many alternative notations for the same or similar concepts
- One popular alternative notation uses *UML class diagrams*
- see next slides for UML class diagrams and other alternative notations

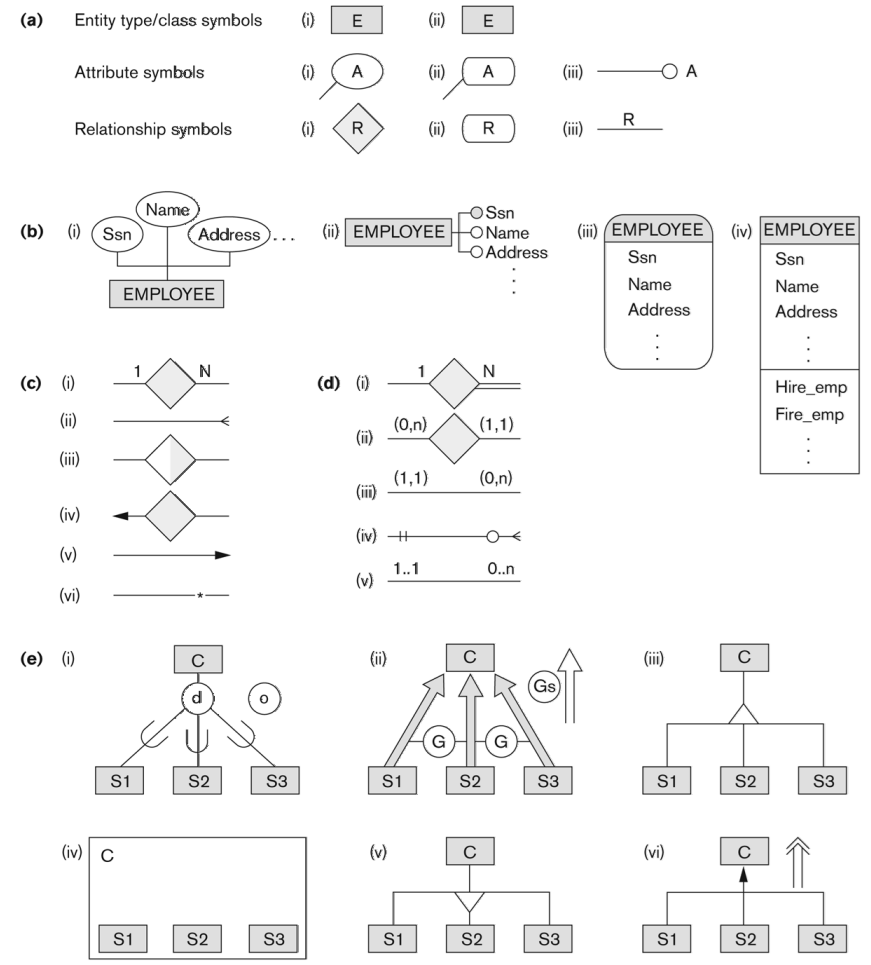
# UML Example for Displaying Specialization / Generalization



**Figure 4.10**

A UML class diagram corresponding to the EER diagram in Figure 4.7, illustrating UML notation for specialization/generalization.

# Alternative Diagrammatic Notations



**Figure A.1**  
 Alternative notations. (a) Symbols for entity type/class, attribute, and relationship. (b) Displaying attributes. (c) Displaying cardinality ratios. (d) Various (min, max) notations. (e) Notations for displaying specialization/generalization.



## General Conceptual Modeling Concepts

- **GENERAL DATA ABSTRACTIONS**
  - CLASSIFICATION and INSTANTIATION
  - AGGREGATION and ASSOCIATION (relationships)
  - GENERALIZATION and SPECIALIZATION
  - IDENTIFICATION
- **CONSTRAINTS**
  - CARDINALITY (Min and Max)
  - COVERAGE (Total vs. Partial, and Exclusive (disjoint) vs. Overlapping)

# Ontologies

- Use conceptual modeling and other tools to develop “a specification of a conceptualization”
  - **Specification** refers to the language and vocabulary (data model concepts) used
  - **Conceptualization** refers to the description (schema) of the concepts of a particular field of knowledge and the relationships among these concepts
- Many medical, scientific, and engineering ontologies are being developed as a means of standardizing concepts and terminology

## Summary

- Introduced the EER model concepts
  - Class/subclass relationships
  - Specialization and generalization
  - Inheritance
- These augment the basic ER model concepts introduced in Chapter 3
- EER diagrams and alternative notations were presented