Enhanced Entity-Relationship Model

Chapter 3

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Introduction to Enhanced-ER Model

- Enhanced ER or Extended ER (EER) model
  - Created to design more accurate database schemas
  - More complex requirements than traditional applications
- EER model includes all modeling concepts of the ER model. In addition, EER includes:
  - **Subclasses** and **superclasses**
  - **Specialization** and **generalization**
  - **Category** or **union type**
  - **Attribute** and **relationship inheritance**
- EER diagrams
  - Diagrammatic technique for displaying these concepts in an EER schema

Contents

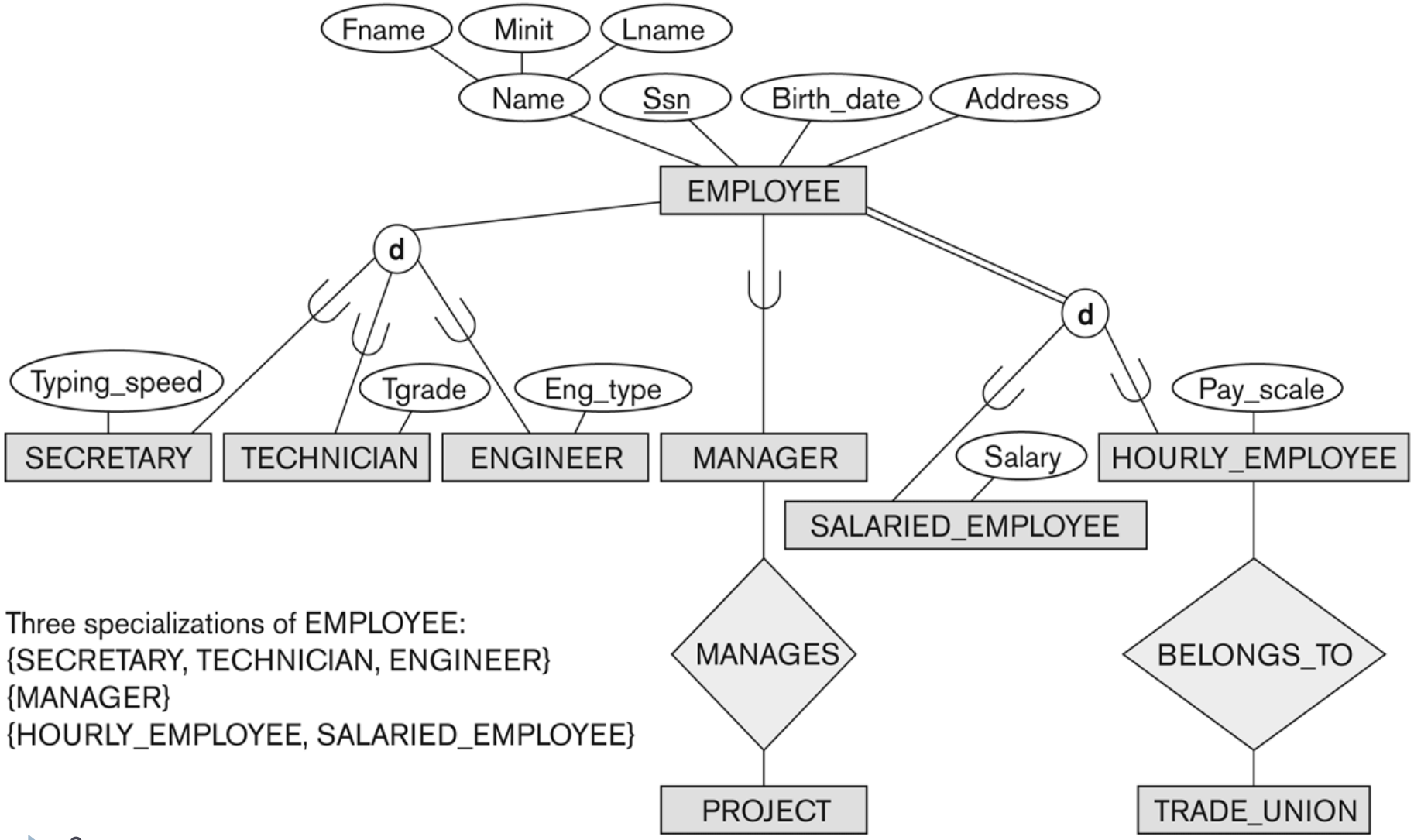
Subclasses, Superclasses & Inheritance

- **Subtype or subclass** of an entity type
  - Subgroupings of entities that are meaningful
  - Represented explicitly because of their significance to the database application
- Terms for relationship between a superclass and any one of its subclasses
  - Superclass/subclass
  - Supertype/subtype
  - Class/subclass
- A class/subclass relationship is often called an **IS-A** (IS-AN) relationship.

Subclasses, Superclasses & Inheritance

- Ex: EMPLOYEE may be further grouped into SECRETARY, ENGINEER, MANAGER, TECHNICIAN, SALARIED_EMPLOYEE, HOURLY_EMPLOYEE, and so on.
  - Set of entities in each subgroups is a subset of the EMPLOYEE entity set.
  - Each is called a subclass of EMPLOYEE
  - EMPLOYEE is the superclass for each of these subclasses

EER diagram notation to represent subclasses & specialization



Three specializations of EMPLOYEE:
{SECRETARY, TECHNICIAN, ENGINEER}
{MANAGER}
{HOURLY_EMPLOYEE, SALARIED_EMPLOYEE}

Subclasses, Superclasses & Inheritance

- A subclass member is the same as the entity in the superclass, but 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 a superclass can be optionally included as a member of some of its subclasses
- It is not necessary that every entity in a superclass be a member of some subclass
- Superclass/subclass relationship is one-to-one (1:1)

Subclasses, Superclasses & Inheritance

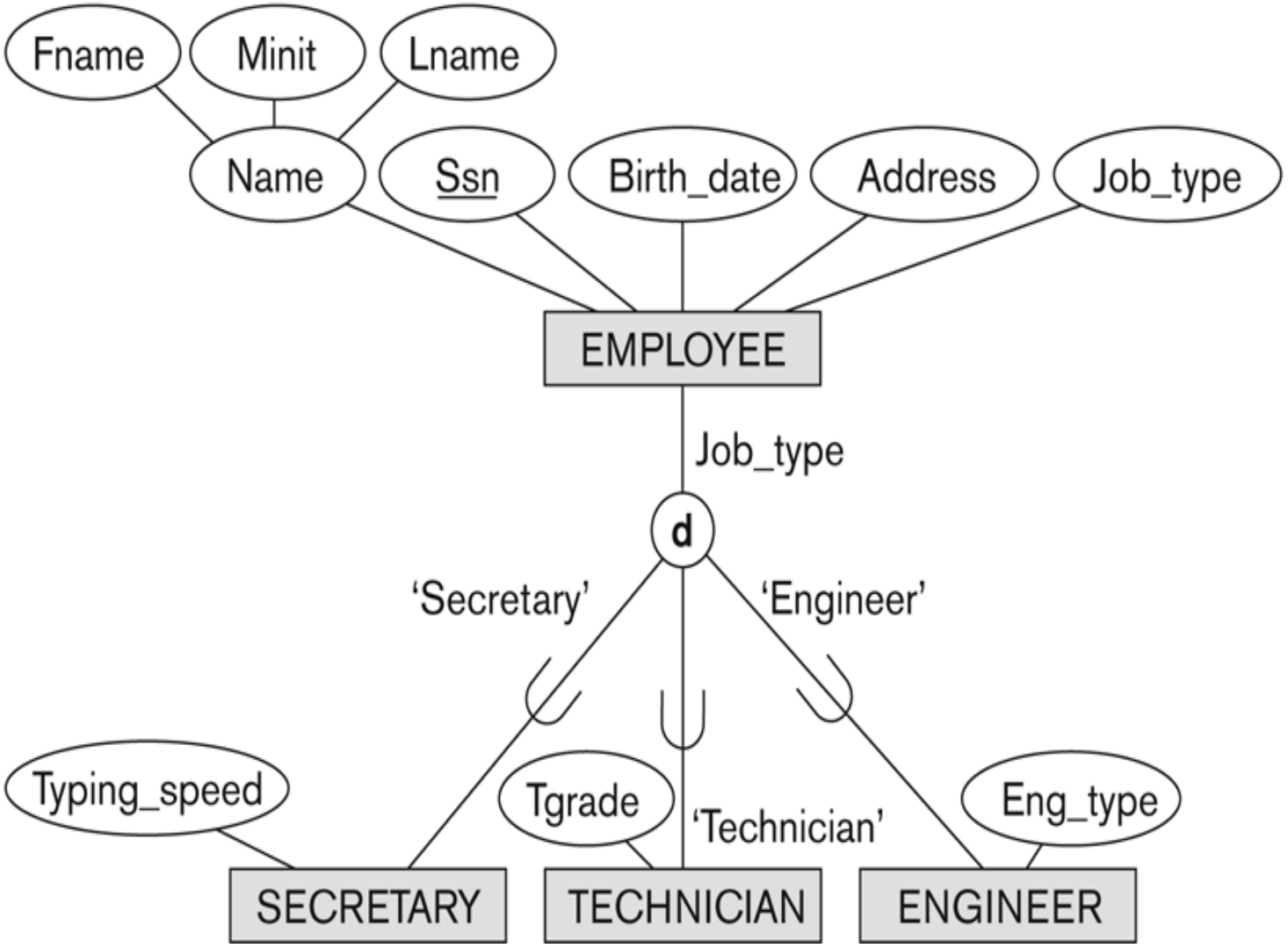
- Subclass entity **inherits all attributes and relationships** of superclass
- Notice that a subclass, with its own specific (or local) attributes and relationships together with all the attributes and relationships it inherits from the superclass, can be considered an entity type in its own right.

Contents

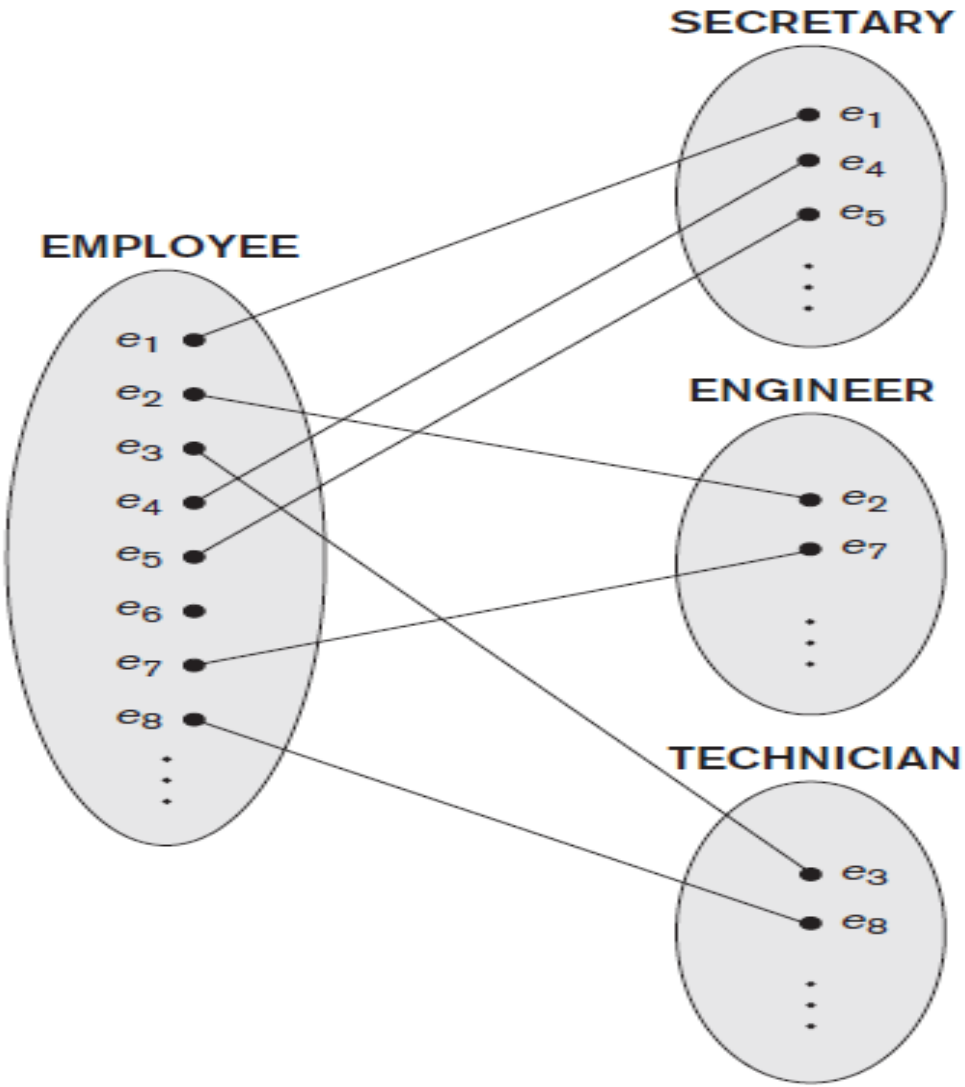
Specialization and Generalization

- **Specialization**
  - Process of defining a set of subclasses of an entity type, called superclass
  - Defined on the basis of some distinguishing characteristic of the entities in the superclass
  - May have several specializations of the same entity type based on different distinguishing characteristics
- Subclass can have its own:
  - Specific attributes (local attributes)
  - Specific relationship types

Example of a Specialization



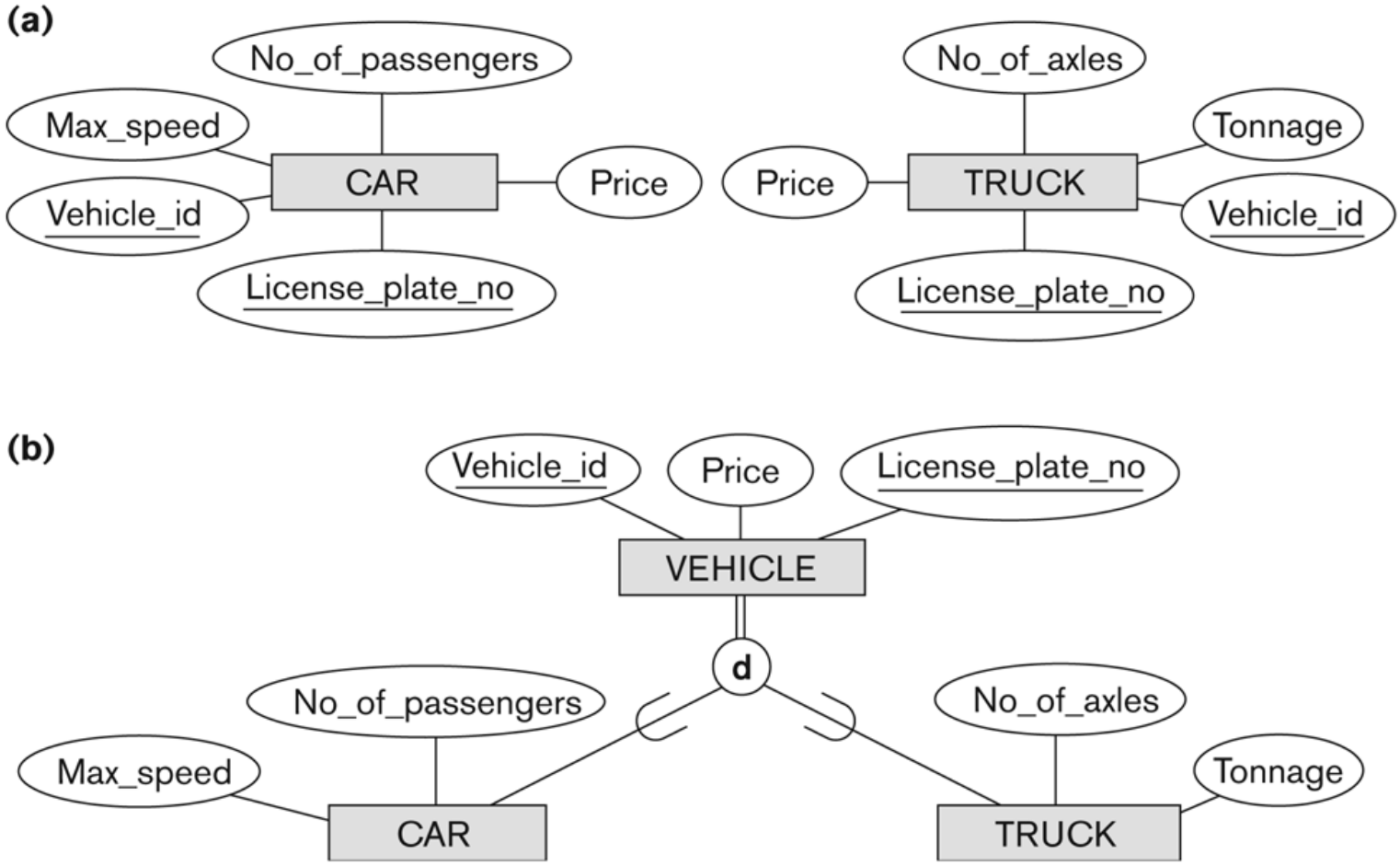
Instances of a specialization



Generalization

- Reverse process of Specialization
- **Generalize** several entity types which have some common features into a single **superclass**
  - Original entity types are special subclasses
- **Generalization**
  - Process of defining a generalized entity type from the given entity types

Example of a Generalization



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

Specialization and Generalization

- Diagrammatic notation 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 in these situations

Specialization and Generalization

- Data Modeling with Specialization and Generalization
  - A superclass or subclass represents a set of entities
  - Shown in rectangles in EER diagrams (as are entity types)
  - Sometimes, all entity sets are simply called classes, whether they are entity types, superclasses, or subclasses

Contents

Constraints and Characteristics of Specialization and Generalization Hierarchies

- Constraints that apply to a single specialization or a single generalization
- Differences between specialization/ generalization lattices and hierarchies

Constraints on Specialization & Generalization

- Determine subclass:
  - Predicate-defined (or condition-defined) subclasses
  - Attribute-defined specialization
  - User-defined

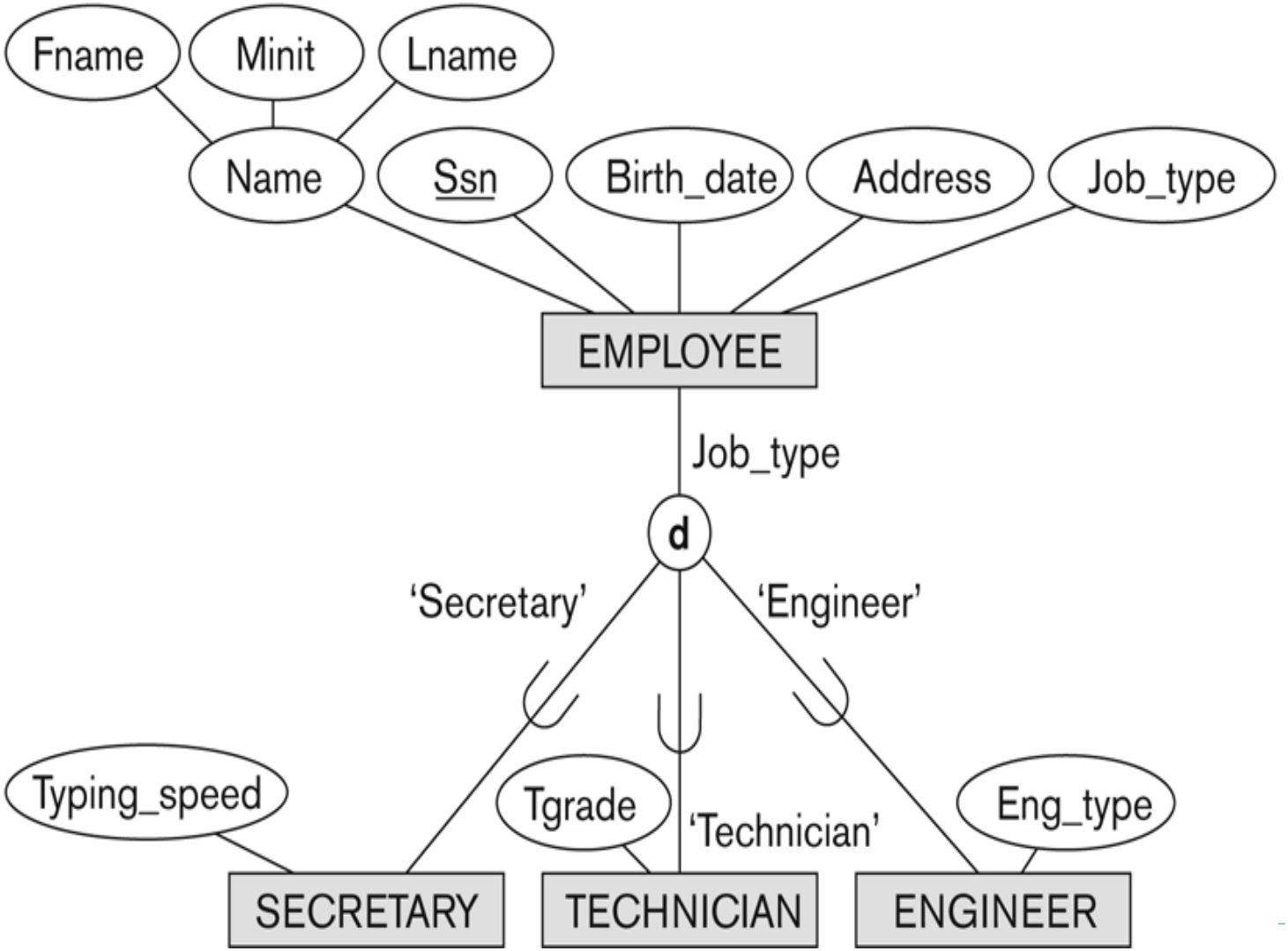
Constraints on Specialization & Generalization

- 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 & Generalization

- 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
  - Ex: JobType is the defining attribute of the specialization {SECRETARY, TECHNICIAN, ENGINEER} of EMPLOYEE

EER diagram notation for an attribute-defined specialization on JobType



Constraints on Specialization & Generalization

- 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

Constraints on Specialization & Generalization

- Two basic conditions apply to a specialization/ generalization: **disjointness** and **completeness** constraints
- **Disjointness constraint**
  - May be **disjointed** or **overlap**
- **Completeness** (or **totalness**) **constraint**
  - May be **total** or **partial**
- Disjointness and completeness constraints are independent

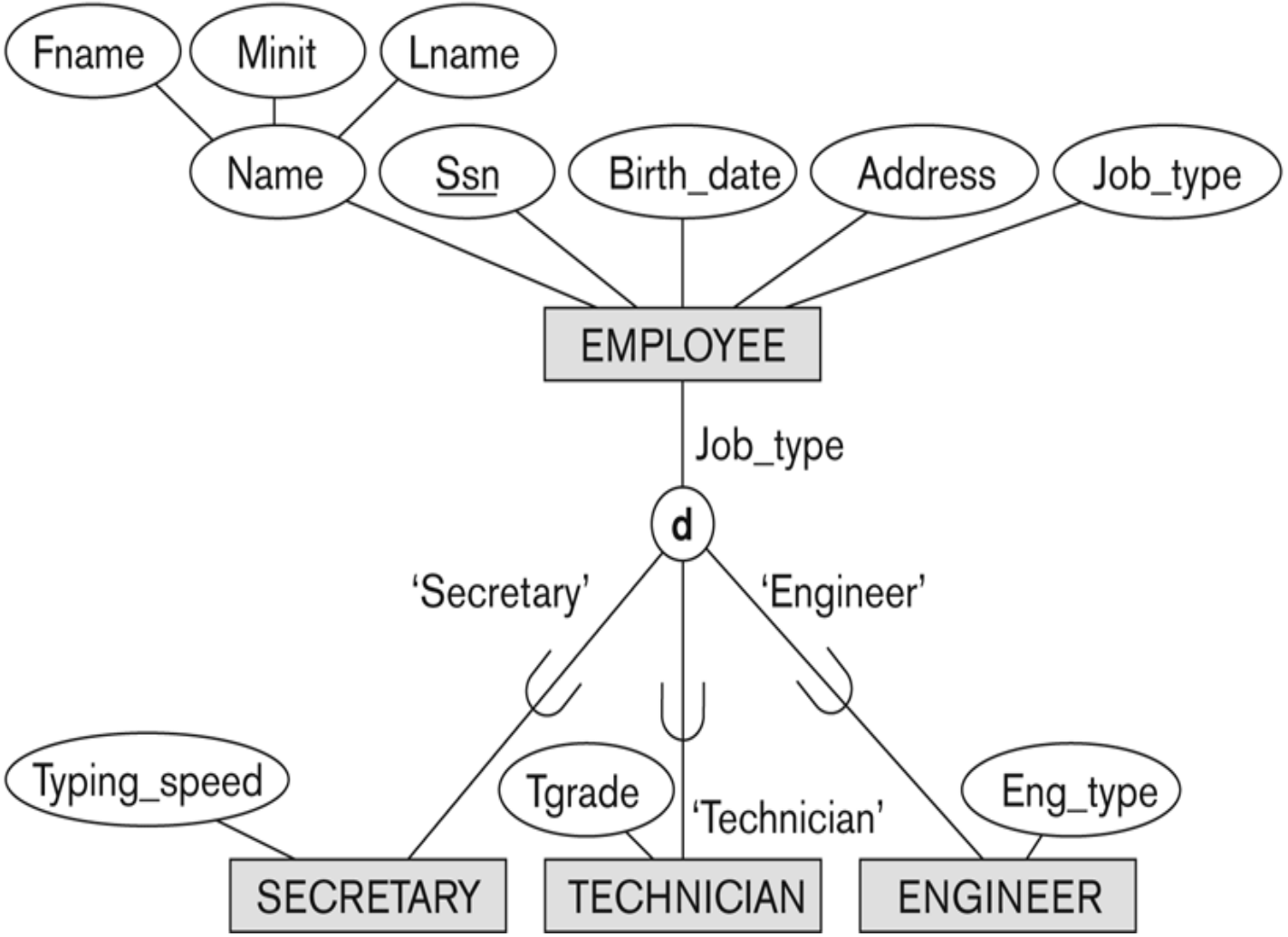
Constraints on Specialization & Generalization

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

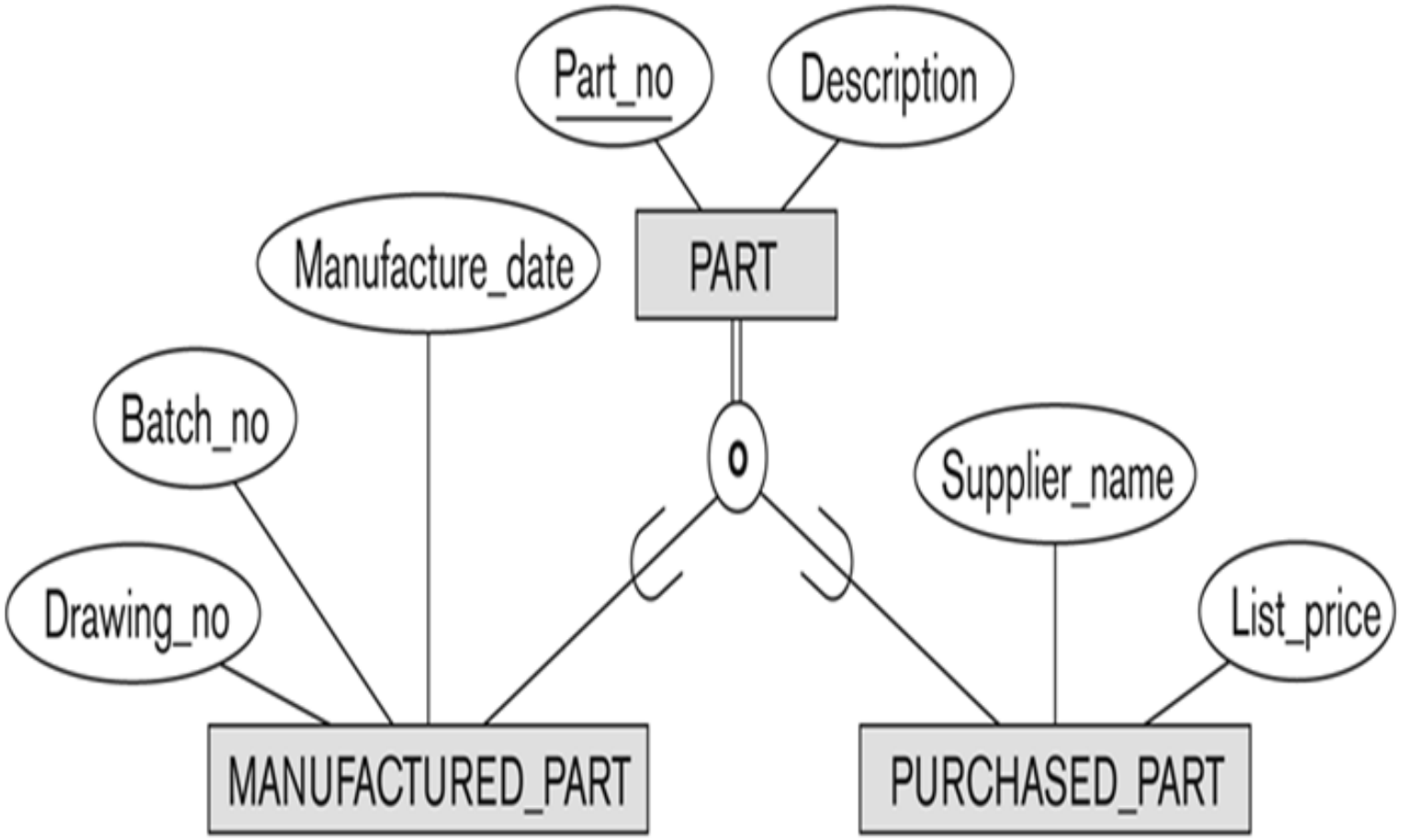
Constraints on Specialization & Generalization

- **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**

Example of Disjoint Partial Specialization



Example of Overlapping Total Specialization



Constraints on Specialization & Generalization

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

Case study: Identify superclass-subclass

GROUP A	GROUP B
A system for course registration of Bach Khoa University *Hints:* ***Students*** *(Grad-Student, undergrad-student),* ***Modules*** *(for grad-student, for undergrad-students)*	A system for a Library of a University  *Hints:* ***Materials*** *(Book, Journal, ...),* ***Borrowers*** *(Guest, Member)*

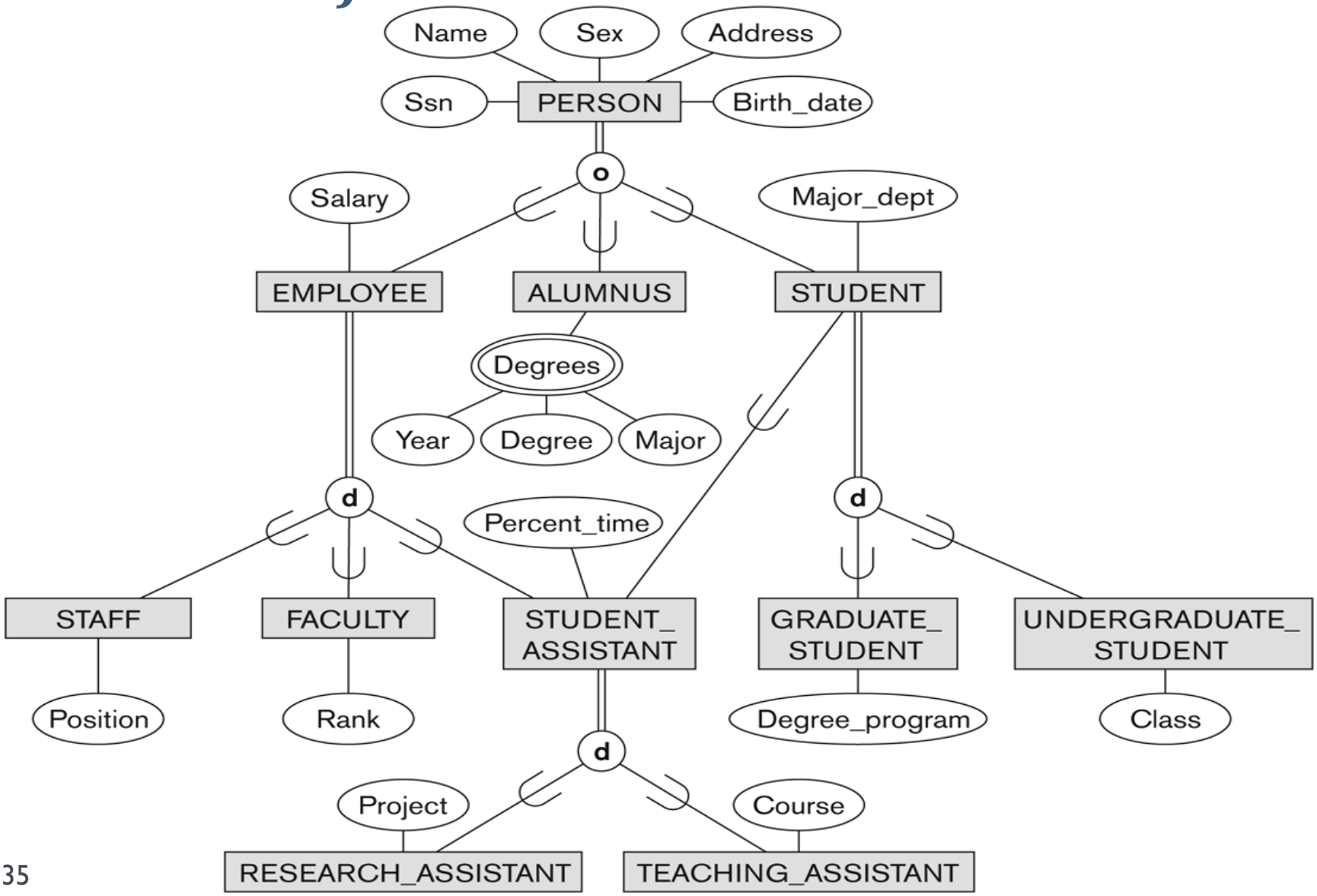
Specialization and Generalization Hierarchies and Lattices

- A subclass may itself have further subclasses specified on it, forming a hierarchy or a lattice.
- **Specialization hierarchy**
  - Every subclass participates as a subclass in **only one** class/subclas**s** relationship
  - Results in a **tree** structure or strict hierarchy
  - **Single inheritance**
- **Specialization lattice**
  - Subclass can be a subclass in **more than one** class/subclass relationship
  - **Multiple inheritance**

Specialization and Generalization Hierarchies and Lattices

- 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**
- In case of multiple inheritance, if attribute (or relationship) originating in the same superclass inherited more than once via different paths in lattice
  - Included only **once** in shared subclass

Specialization / Generalization Lattice Example (UNIVERSITY)



Utilizing Specialization and Generalization in Refining Conceptual Schemas

- Specialization process
  - Start with entity type then define subclasses by successive specialization
  - **Top-down** conceptual refinement process
- **Bottom-up** conceptual synthesis
  - Involves generalization rather than specialization

Contents

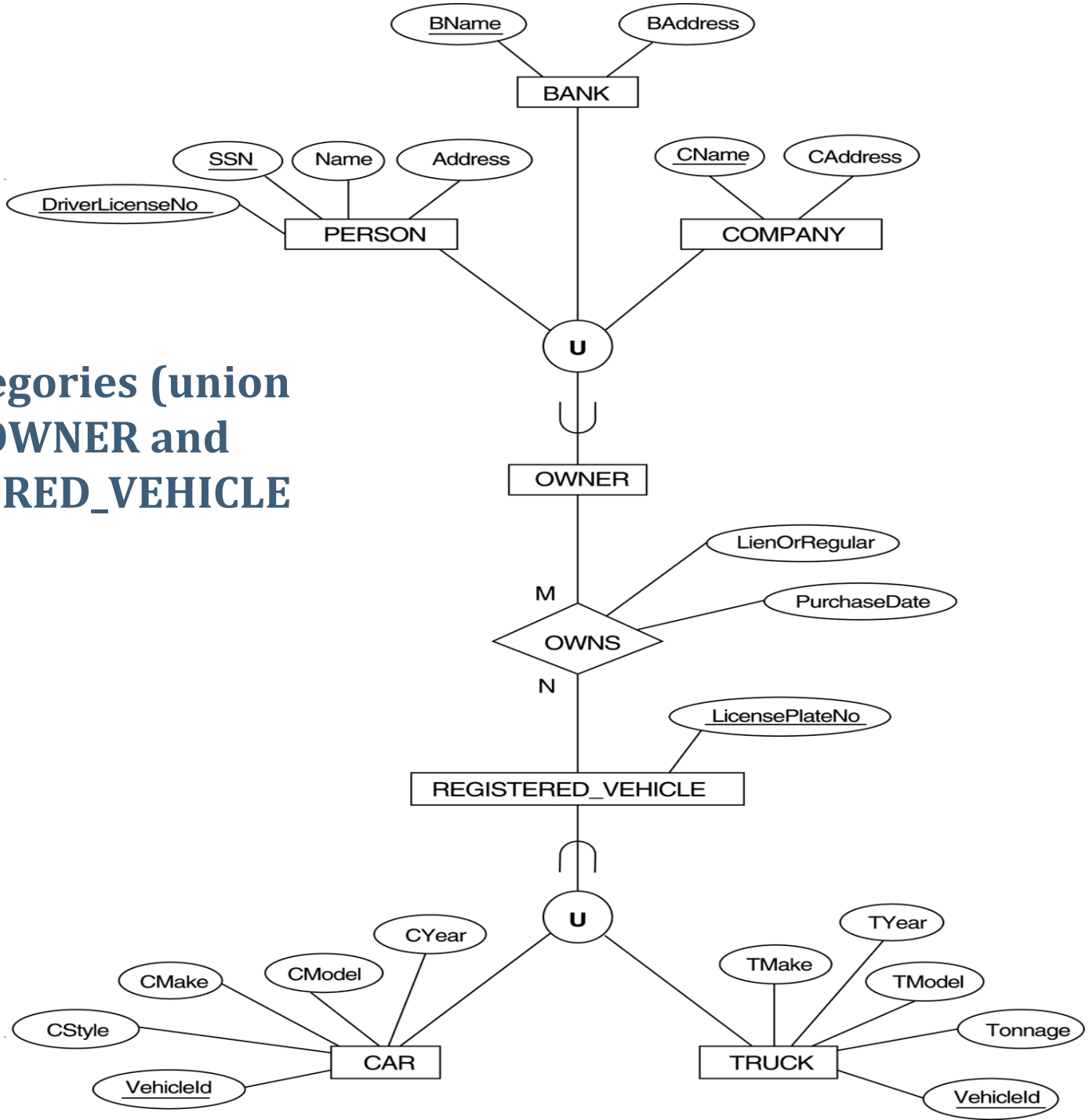
Categories

- **Category** or **Union type**
  - Represents a single superclass/subclass relationship with more than one superclass
  - Subclass represents a collection of objects that is a subset of the UNION of distinct entity types
  - Attribute inheritance works more selectively
  - Category can be **total** or **partial**
- Some modeling methodologies do not have union types

Categories

- Example: Database for vehicle registration, vehicle owner can be a person, a bank (holding a lien on a vehicle) or a company.
  - Category (subclass) OWNER is 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
- Note: The difference from shared subclass, which is a subset of the intersection of its superclasses (shared subclass member must exist in all of its superclasses)

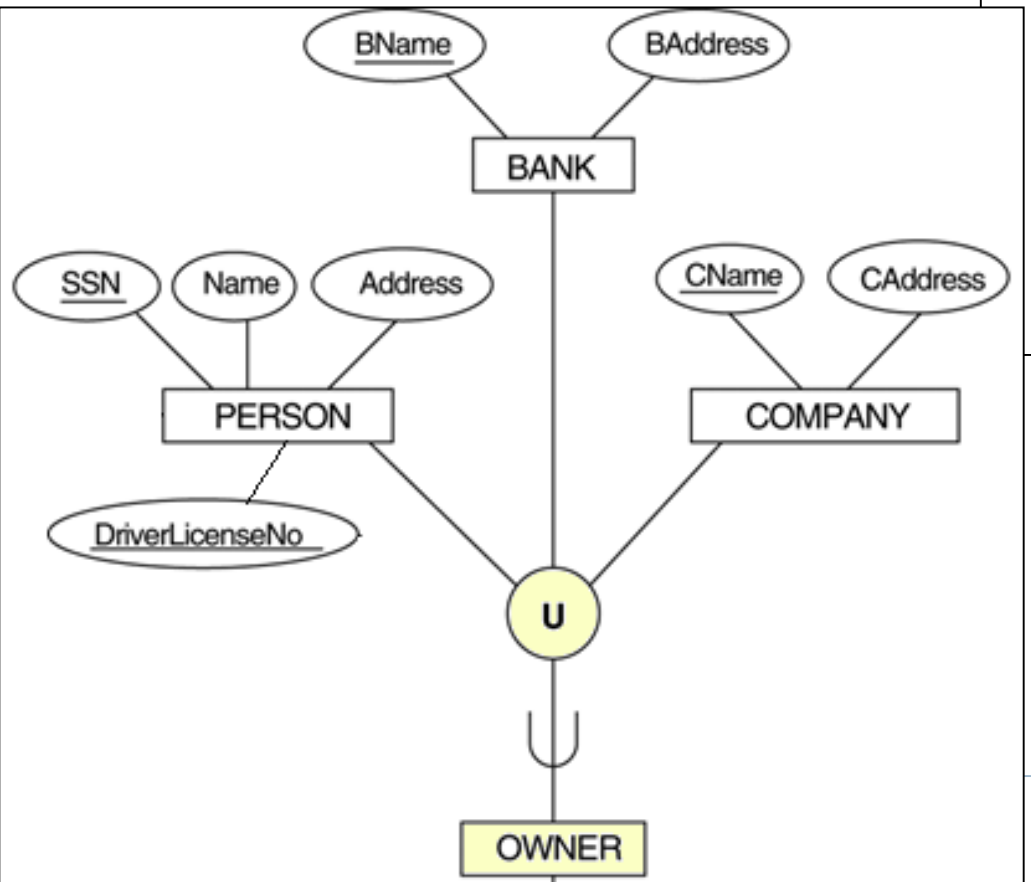
Two categories (union types): OWNER and REGISTERED_VEHICLE

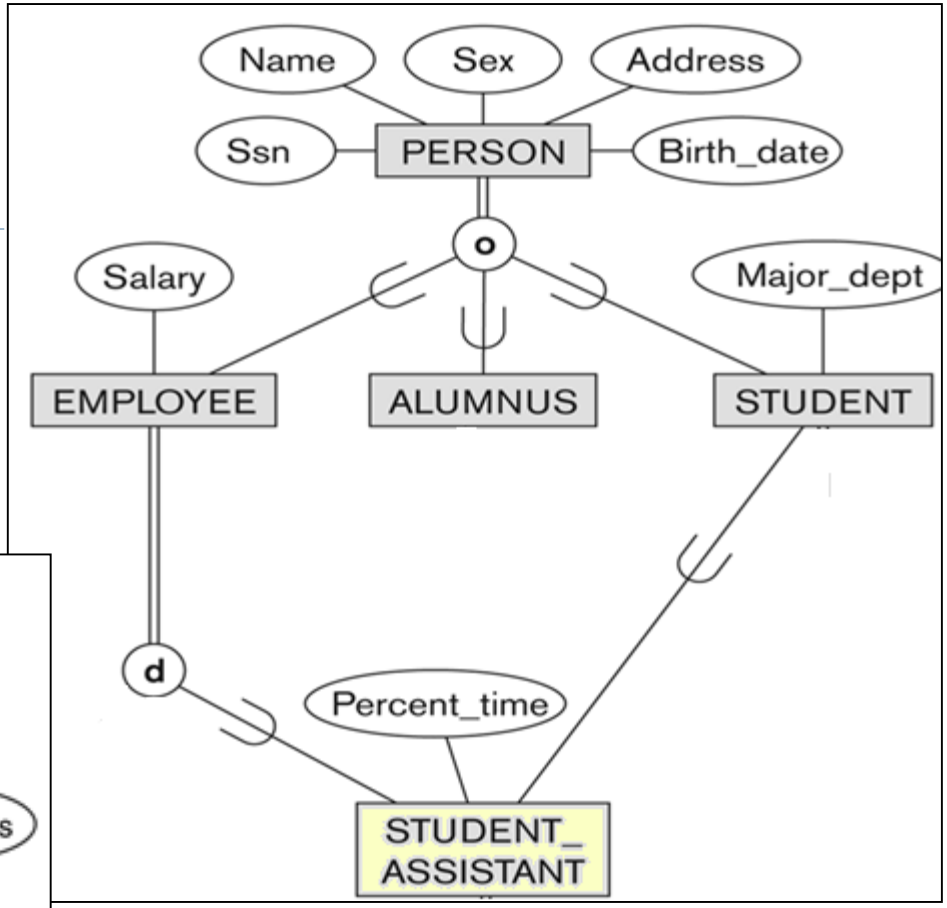


Categories

- A category can be total or partial
  - **Total**
    - Hold the union of all entities in its superclasses.
    - Represented diagrammatically by a *double line* connecting the category and the circle.
  - **Partial**
    - Can hold a subset of the union.
    - Represented diagrammatically by a *single line* connecting the category and the circle.
- The superclasses of a category may have different key attributes or the same key attribute.
  - E.g.:
    - Different key attributes: OWNER category.
    - The same key attribute: REGISTERED_VEHICLE category.

Category





vs. Shared Subclass

Category

A category is the subclass in one single relationship.

This relationship has more than one superclass representing different entity types.

Shared Subclass

A shared subclass is the subclass in more than one distinct relationship (multiple inheritance).

Each of these relationships has a single superclass.

Category

A member entity of a category must exist in only one of its superclasses (**OR**).

- E.g.: An OWNER may be a COMPANY, a BANK, or a PERSON.

A category is a subset of the union of its superclasses.

- E.g.: OWNER is a subset of the union of the three superclasses.

Shared Subclass

An member entity of a shared subclass must exist in all its superclasses (**AND**).

- E.g.: An engineering manager must be an ENGINEER, a MANAGER, and a SALARIED_EMPLOYEE.

A shared subclass is a subset of the intersection of its superclasses.

- E.g.: ENGINEERING_MANAGER is a subset of the intersection of the three superclasses.

Category

A member of a category inherits attributes and relationships of only one of its superclasses.

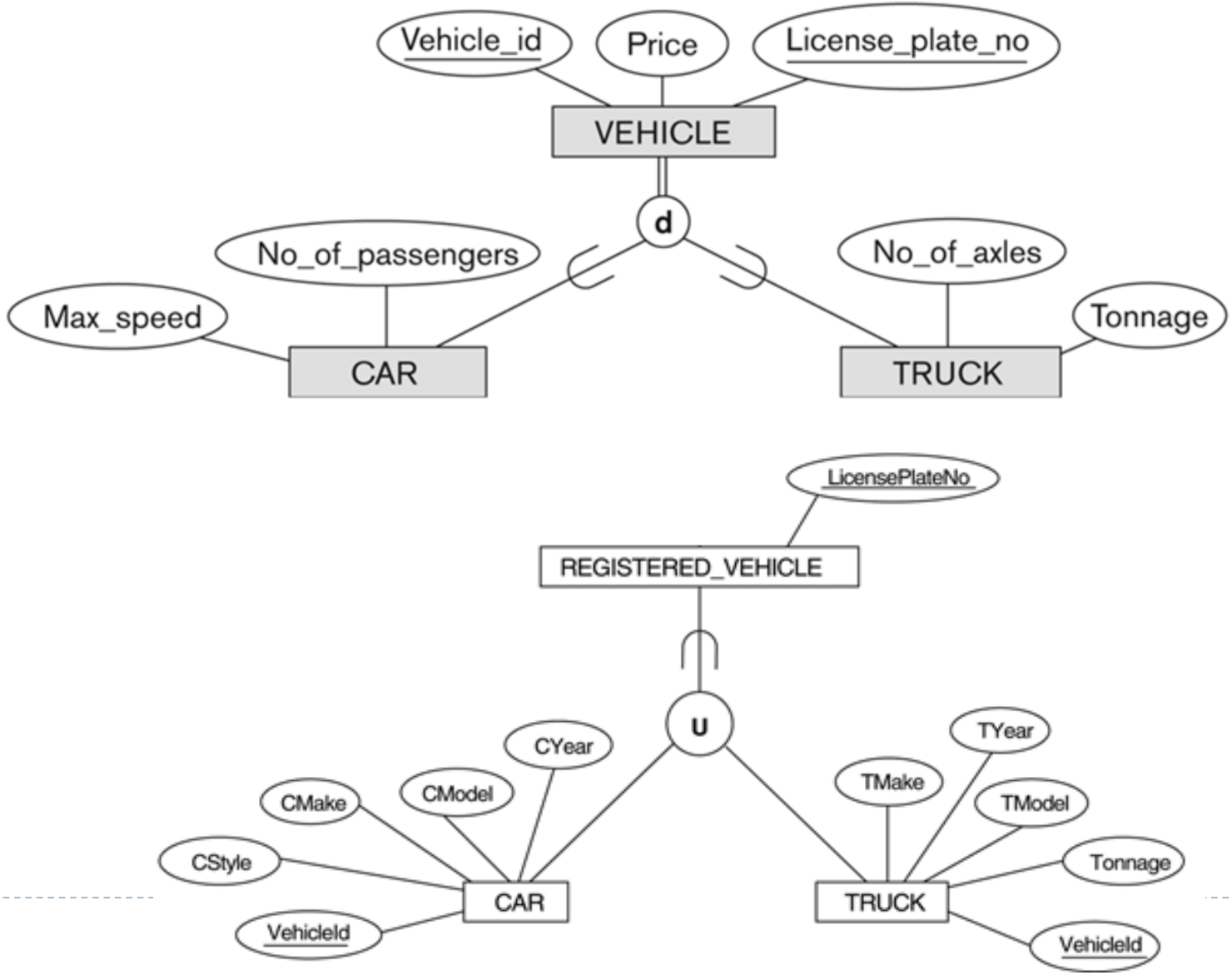
- E.g.: Each OWNER entity inherits the attributes of a COMPANY, a PERSON, or a BANK, depending on the superclass to which the entity belongs.

Shared Subclass

A member of a shared subclass inherits all the attributes and relationships of all its superclasses.

- E.g.: ENGINEERING_MANAGER inherits all the attributes of its superclasses SALARIED_EMPLOYEE, ENGINEER, and MANAGER.

Specialization/Generalization vs. Union Type



Specialization/Generalization vs. Union Type

Category REGISTERED_VEHICLE

REGISTERED_VEHICLE category includes some cars and some trucks but not necessarily all of them

- E.g.: some cars or trucks may not be registered.

A category such as REGISTERED_VEHICLE implies that only cars and trucks, but not other types of entities, can be members of REGISTERED_VEHICLE.

Superclass VEHICLE

Every car and every truck is a VEHICLE.

If the specialization of VEHICLE were partial, it would not preclude VEHICLE from containing other types of entities, such as motorcycles.

Contents

Design Choices for Specialization/Generalization

- Many specializations and subclasses can be defined to make the conceptual model accurate
- If subclass has few specific attributes and no specific relationships
  - Can be merged into the superclass

Design Choices for Specialization/Generalization

- If all the subclasses of a specialization/ generalization have few specific attributes and no specific relationships
  - Can be merged into the superclass
  - Replace with one or more type attributes that specify the subclass or subclasses that each entity belongs to

Design Choices for Specialization/Generalization

- Union types and categories should generally be avoided
- Choice of disjoint/overlapping and total/partial constraints on specialization/generalization
  - Driven by rules in miniworld being modeled

Formal Definitions for the EER Model Concepts

- **Class *C***
  - Set or collection of entities
  - Includes any of the EER schema constructs of group entities
  - Can 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

Formal Definitions for the EER Model Concepts

- **Subclass S :**
  - 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 for the EER Model Concepts

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

Formal Definitions for the EER Model Concepts

- **Generalization:**
  - Generalized entity type or superclass
- 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**

Formal Definitions for the EER Model Concepts

- **Category or UNION type T**
  - Class that is a subset of the union of n defining superclasses
    D1, D2,…Dn, n>1: $T \subseteq (D1 \cup D2 \cup \ldots \cup Dn)$
  - Can have a predicate pi on the attributes of Di to specify entities of Di that are members of T.
  - If a predicate is specified on every Di: T = (D1[p1] ∪ D2[p2] ∪…∪ Dn[pn])
- **Relationship type**
  - Any class can participate in a relationship

Contents


Q
A

Exercise 1

A non-profit organization depends on a number of different types of persons for its successful operation. The organization is interested in the following attributes for all of these persons: Social Security Number, Name, Address, City, State and Telephone. Three types of persons are of interest: employees, volunteers and donors. Employees have only a Date_Hired attribute, and volunteers have only a Skill attribute. Donors have a relationship (named Donates) with an Item. A donor must have donated one or more Items, and an Item can only be donated by one donor. Attributes of item includes an identity and a description. There are persons other than employees, volunteers and donors who are of interest to the organization, so a person does not have to belong to one of these groups. A person may also belong to one or more of these groups, at any one time.

Exercise 2

WV Bank has three different types of bank accounts available for their customers. Each customer may have any number of bank accounts, and all accounts have a unique account number. For Savings Accounts, WV Bank must keep track of the account's balance, interest rate, and the date the account was opened. Checking Accounts pay no interest, so the bank keeps track of just the balance and date opened. The third type of account, Loans, requires tracking the date the loan was taken, the balance due, and the interest rate of the loan. Loan Accounts are also assigned to a Loan Officer, who keeps track of the account and ensures that the client is making their payments on-time.