Chapter 7: Entity-Relationship Model

Database System Concepts, 6th Ed.

Chapter 7: Entity-Relationship Model

Design Process

- Creating a database application
  - Design of the database schema
  - Design of the programs that access and update the data
  - Design of a security scheme to control access to data
- The phases of the database design
  - Understanding the needs of users and enterprises
  - Conceptual design using the abstract model like ER Model
  - Specification of functional requirements (operations & transactions)
  - Converting the abstract model to implementation details
    - Logical design phase: convert ER to Tables
    - Physical design phase: file organization, storage structure, index creation
- Design alternatives for avoiding two major pitfalls
  - Redundancy
  - Incompleteness

Chapter 7: Entity-Relationship Model

- 7.1 Overview of the Design Process
- 7.2 The Entity-Relationship Model
- 7.3 Constraints
- 7.4 Removing Redundant Attributes in Entity Sets
- 7.5 Entity-Relationship Diagrams
- 7.6 Reduction to Relational Schemas
- 7.7 Entity-Relationship Design Issues
- 7.8 Extended E-R Features
- 7.9 Alternative Notation for Modeling Data
- 7.10 Other Aspects of Database Design

ER Modeling

- Peter Chen, 1976, "The ER Model: Toward a Unified View of Data", ACM Transactions of Database Systems (TODS)
- A *database* can be modeled as a collection of entities and relationship among entities
- An **entity** is an object that exists and is distinguishable from other objects.
  - Example: specific person, company, event, plant
- Entities have **attributes**
  - Example: Entity "people" have attributes "*name*" and "*address*"
- An **entity set** is a set of entities of the same type that share the same properties.
  - Example: set of all persons, companies, trees, holidays

instructor entity set

instructor_ID	instructor_name
76766	Crick
45565	Katz
10101	Srinivasan
98345	Kim
76543	Singh
22222	Einstein

instructor

student-ID	student_name
98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

student

instructor entity set

Relationship Sets [1/2]

- A **relationship** is an association among several entities

  Example: 44553 (Peltier) *advisor* 22222 (Einstein)

  student entity — relationship set — *instructor* entity

- A **relationship set** is a mathematical relation among $n \geq 2$ entities, each taken from entity sets $\{(e_1, e_2, \ldots e_n) \mid e_1 \in E_1, e_2 \in E_2, \ldots, e_n \in E_n\}$ where $(e_1, e_2, \ldots, e_n)$ is a relationship
  - Example: (44553,22222) $\in$ *advisor*

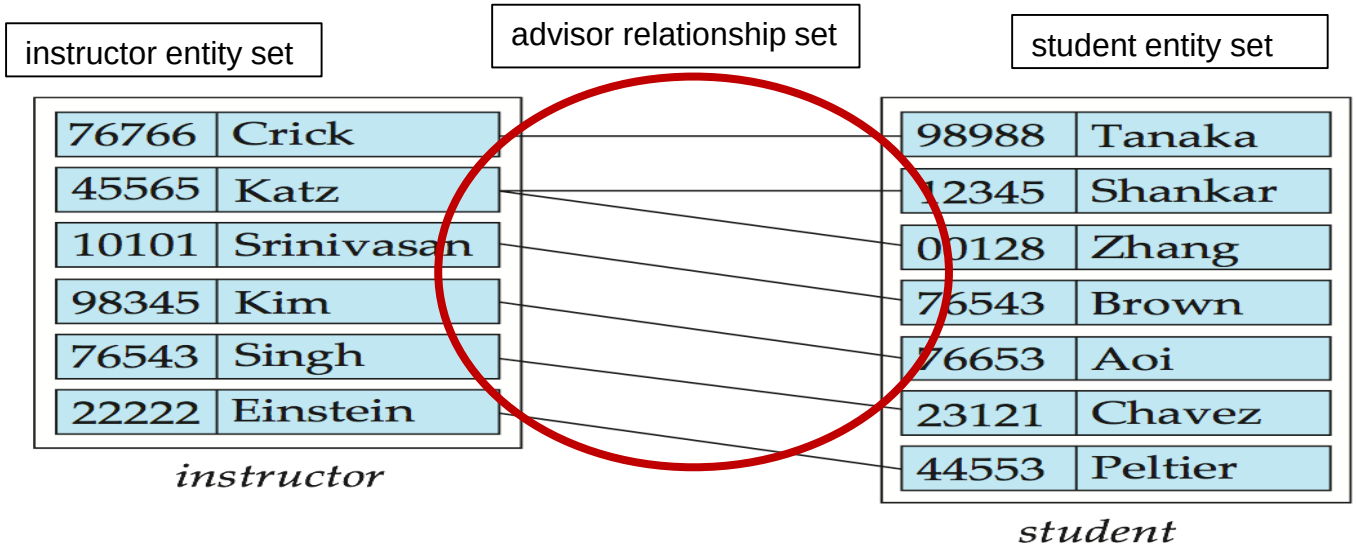
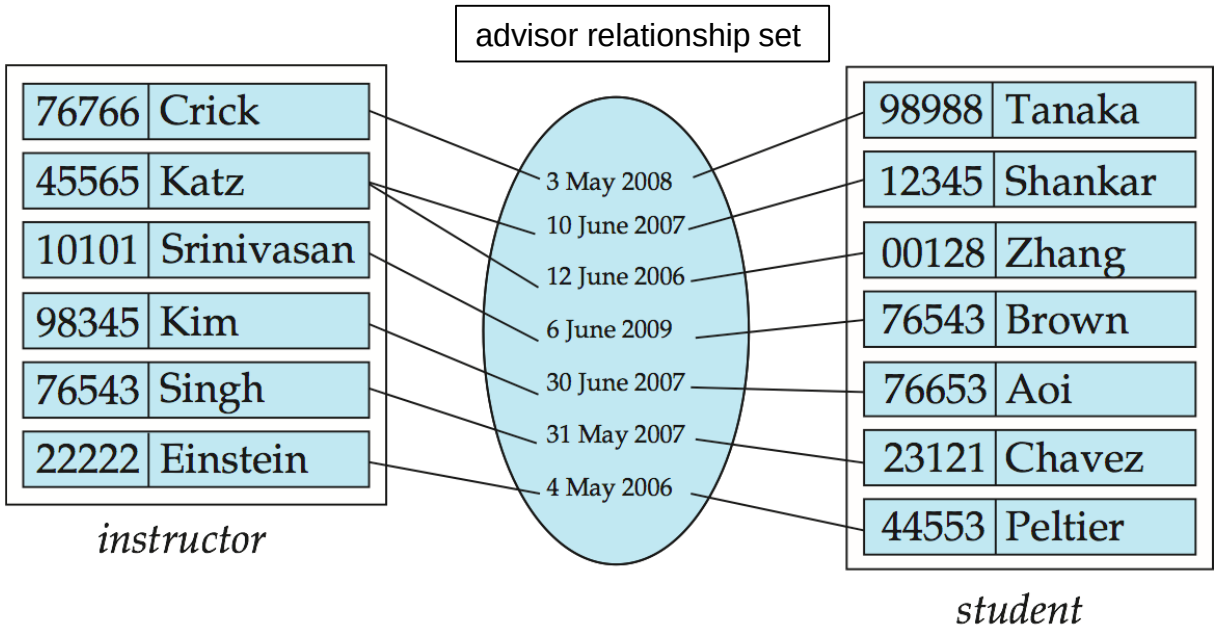


Fig 7.03: Relationship Sets [2/2]

- An **attribute** can also be property of a relationship set.
- For instance, the *advisor* relationship set between entity sets *instructor* and *student* may have the attribute *date* which tracks when the student started being associated with the advisor

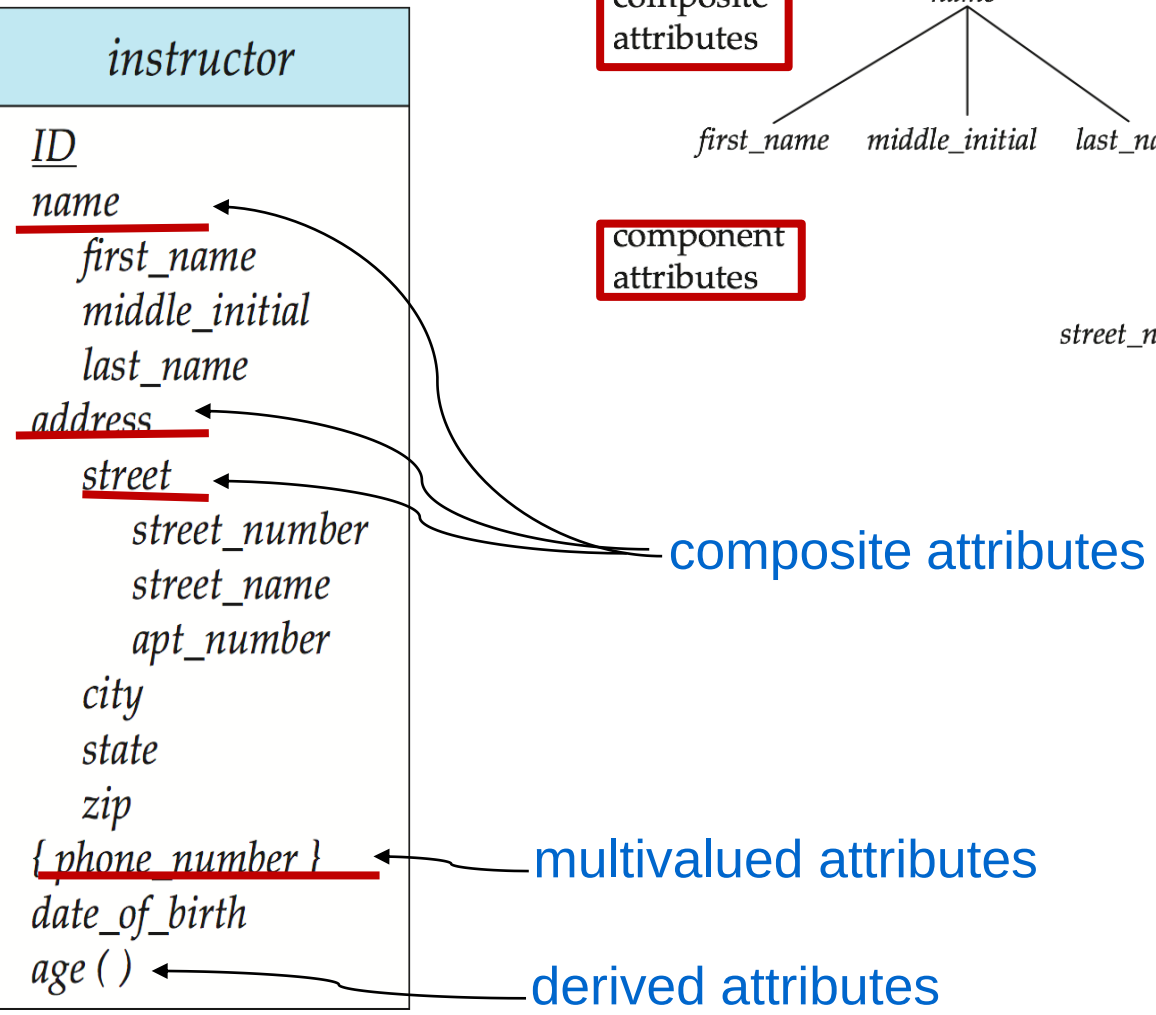


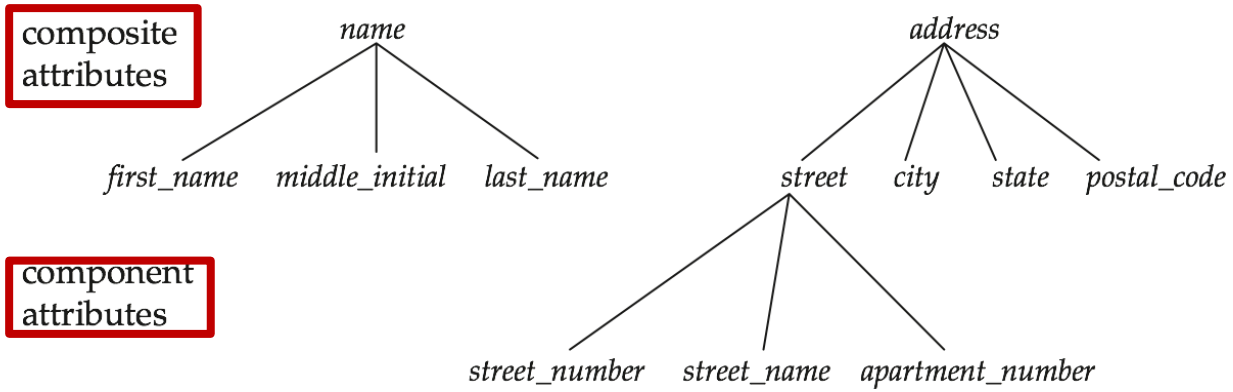
Attributes

- An entity is represented by a set of attributes, that is descriptive properties possessed by all members of an entity set.
  - Example:

    instructor = (*ID, name, street, city, salary*)
    course= (*course_id, title, credits*)
- **Domain** – the set of permitted values for each attribute
- Attribute types:
  - **Simple** and **composite** attributes.
  - **Single-valued** and **multivalued** attributes
    - Example: multivalued attribute: *phone_numbers*
  - **Derived** attributes
    - Can be computed from other attributes
    - Example: age, given date_of_birth

Composite and Multivalued Attributes





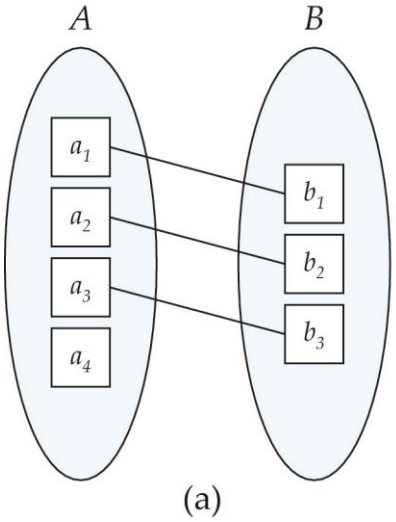
Chapter 7: Entity-Relationship Model

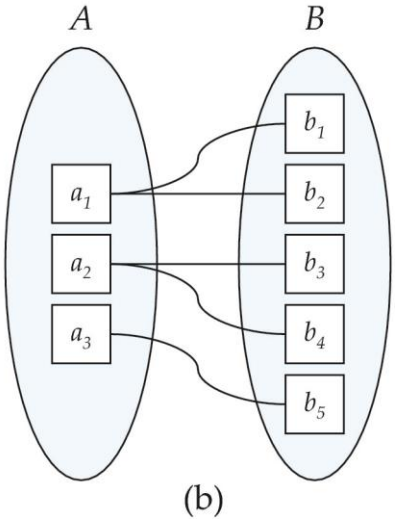
Mapping Cardinality Constraints

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
  - One to one
  - One to many
  - Many to one
  - Many to many

Fig 7.05 & 7.06: Mapping Cardinalities

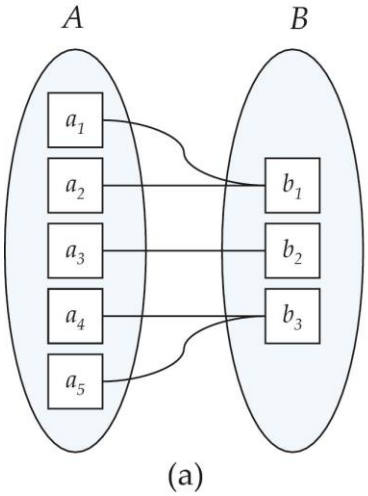
One to one

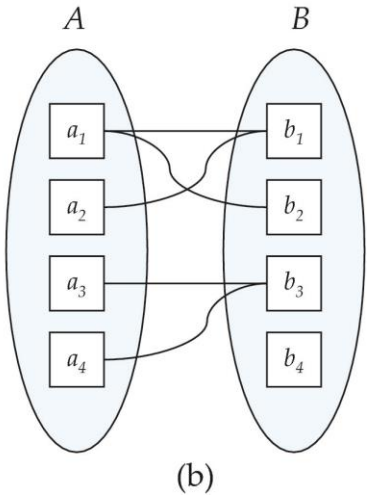




One to many

Many to one





Many to many

Note: Some elements in *A* and *B* may not be mapped to any elements in the other set

Keys of Entity Sets

- A **super key** of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A **candidate key** of an entity set is a minimal super key

instructor = (*ID, name, street, city, salary*)
course= (*course_id, title, credits*)

- *ID* is candidate key of *instructor*
- *course_id* is candidate key of *course*
- Although several candidate keys may exist, one of the candidate keys is selected to be the **primary key**.

Keys for Relationship Sets

- The combination of primary keys of the participating entity sets forms a super key of a relationship set.
  - The relationship set "advisor" involves the 2 entity sets "instructor (i_id, instructor_name)" and "student (s-id, student_name)"
  - (*s_id, i_id*) is the super key of *advisor* relationship
  - *NOTE: this means* ***a pair of entity sets can have at most one relationship in a particular relationship set.***
    - Example: if we wish to track multiple meeting dates between a student and her advisor, we cannot assume a relationship for each meeting. We can use a multivalued attribute "date" though
    - Multivalued attribute "date" having a set value such as { 13-March-2016, 16-April-2016, 4-May-2016}
- Must consider the mapping cardinality of the relationship set when deciding what are the candidate keys
- Need to consider semantics of relationship set in selecting the *primary key* in case of more than one candidate key

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Redundant Attributes

- Suppose we have entity sets
  - *Instructor (ID, name, dept_name, salary) where ID is the primary key*
  - *Department* (*dept_name, building, budget) where dept_name is the primary key*

  and a relationship set
  - *inst_dept (ID, dept_name)* relating *instructor* and *department*

- The attribute *dept_name* in entity *instructor* is redundant since there is an explicit relationship *inst_dept* which relates instructors to departments
  - The attribute *dept_name* replicates information present in the relationship inst_dept, and should be removed from *instructor*
  - BUT: when converting back to tables, in some cases the attribute gets reintroduced, as we will see.

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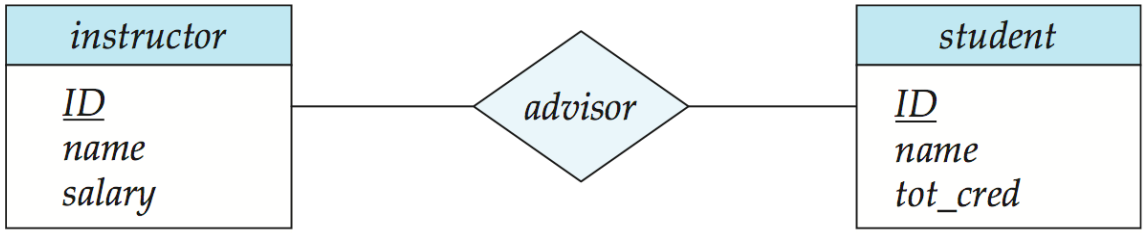
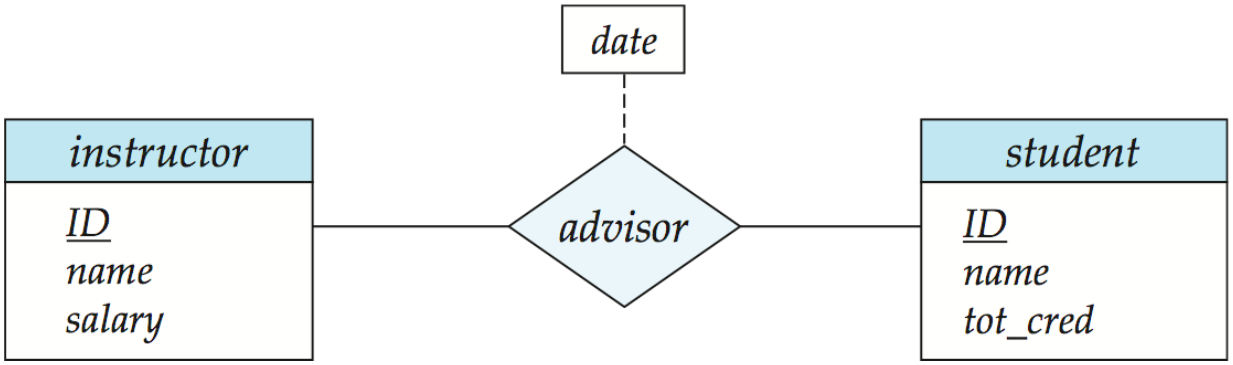
E-R Diagrams based on UML-like Notations



- Rectangles represent entity sets.
- Diamonds represent relationship sets.
- Attributes listed inside entity rectangle
- Underline indicates primary key attributes

Fig 7.08: Relationship Sets with Attributes



Cardinality Constraints

- A directed line (→), signifying "one," or an undirected line (—), signifying "many," between the relationship set and the entity set.

Fig 7.9a: One-to-One Relationship

- one-to-one relationship between an *instructor* and a *student*
  - an instructor is associated with at most one student via *advisor*
  - and a student is associated with at most one instructor via *advisor*

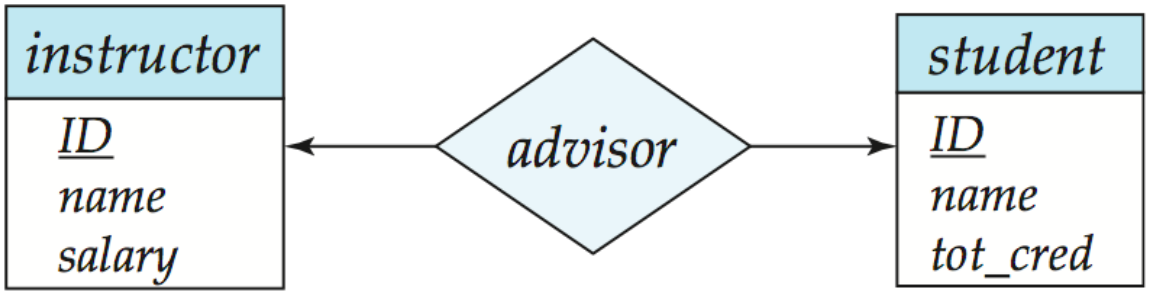
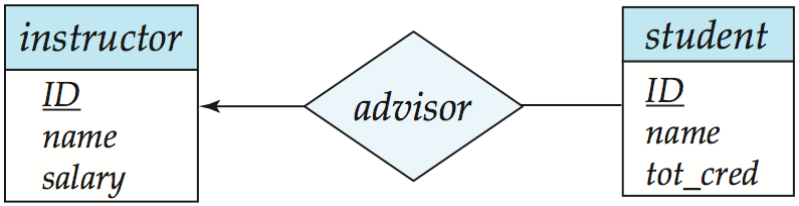


Fig 7.9b: One-to-Many Relationship

- one-to-many relationship between an *instructor* and a *student*
  - an instructor is associated with several (including 0) students via *advisor*
  - a student is associated with at most one instructor via advisor,
- In a many-to-one relationship between an *instructor* and a *student,*
  - an instructor is associated with at most one student via *advisor*,
  - and a student is associated with several (including 0) instructors via *advisor*



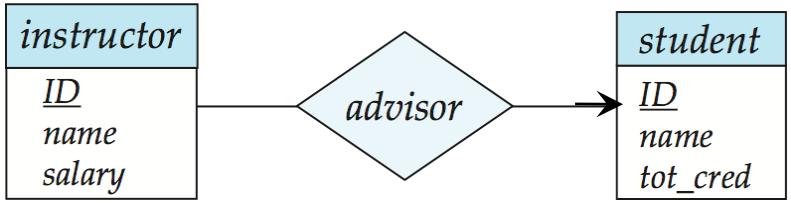


Fig 7.8c: Many-to-Many Relationship

- An instructor is associated with several (possibly 0) students via *advisor*
- A student is associated with several (possibly 0) instructors via *advisor*

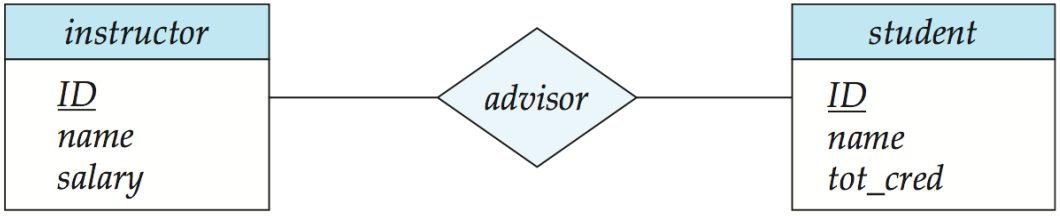


Fig 7.14: Participation of an Entity Set in a Relationship Set

- Total participation (indicated by double line): every entity in the entity set participates in at least one relationship in the relationship set
  - E.g., participation of *section* in *sec_course* is total
    - every *section* must have an associated course
- Partial participation: some entities may not participate in any relationship in the relationship set
  - Example: participation of *instructor* in *advisor* is partial

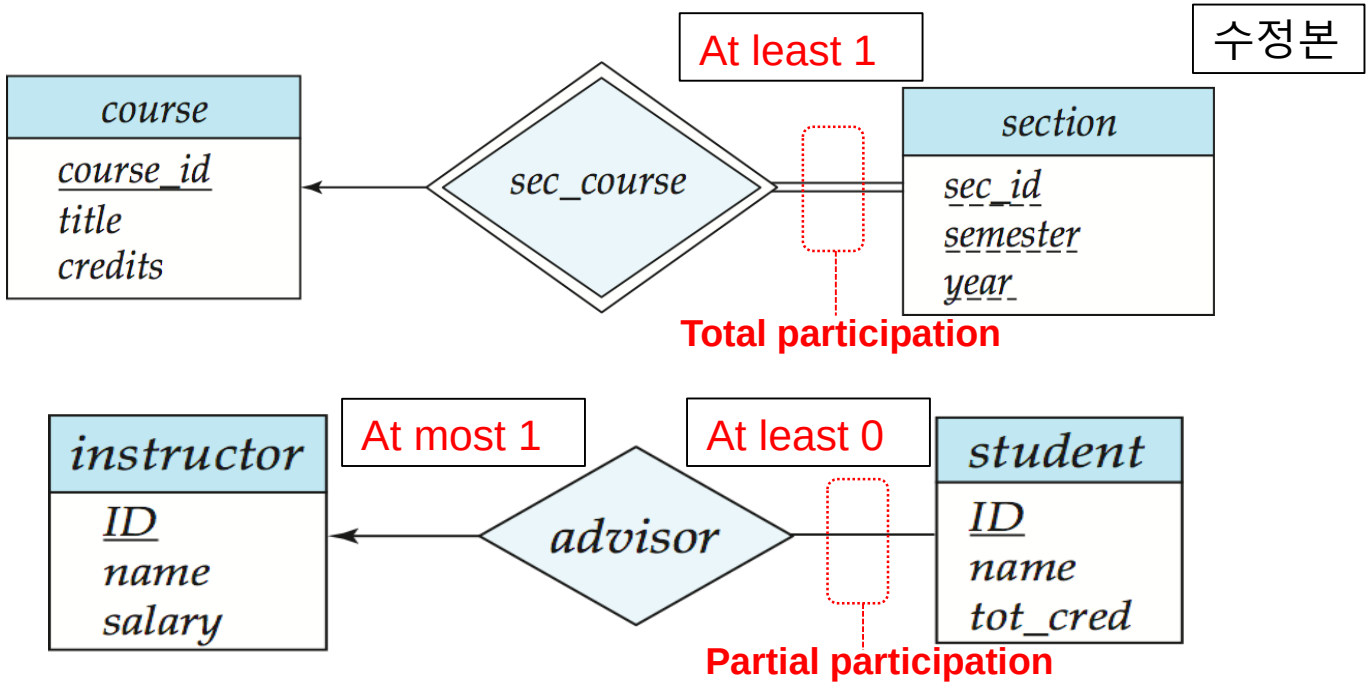
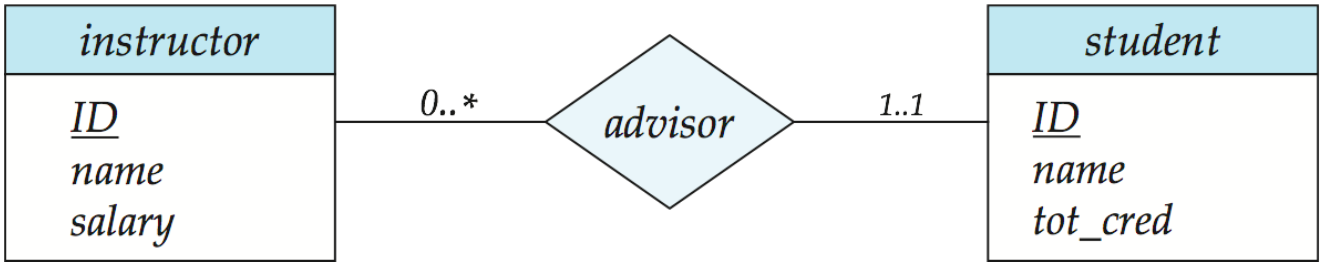


Fig 7.10: Alternative Notation for Cardinality Limits

- Cardinality limits can also express participation constraints



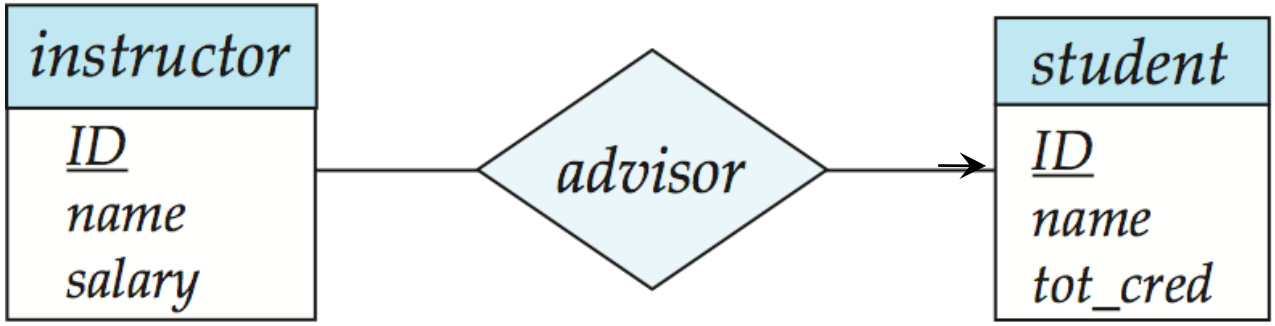
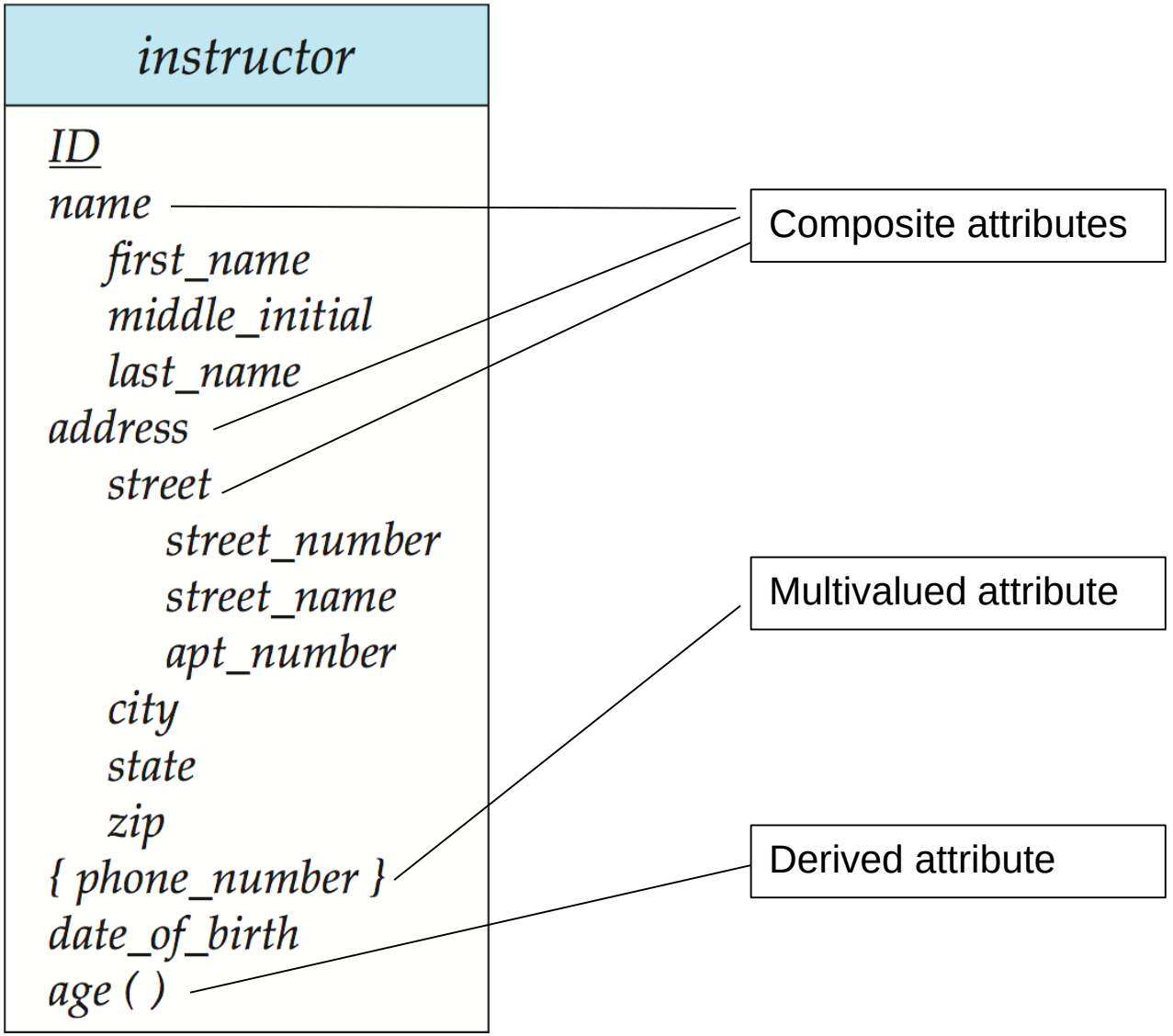
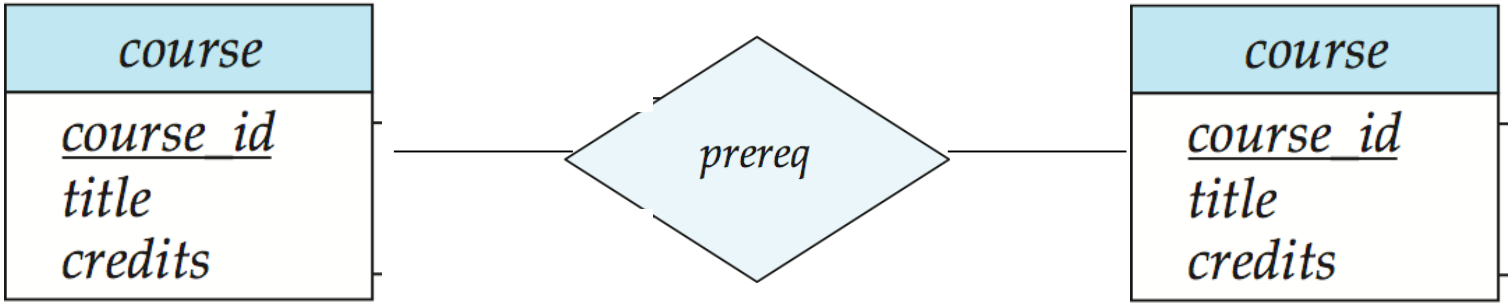


Fig 7.11: Entity With Composite, Multivalued, and Derived Attributes

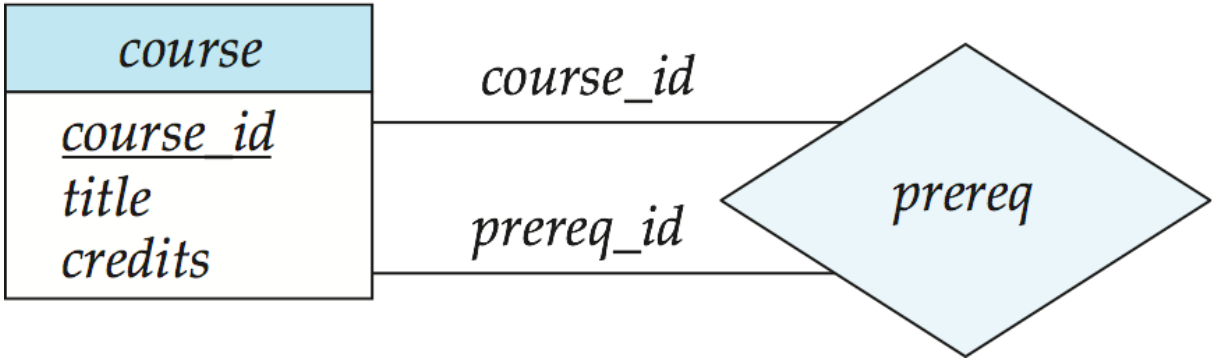


Role Indicator in Multiple Same Entities

- Entity sets of a relationship need not be distinct (may appear twice)
  - Each occurrence of an entity set plays a “role” in the relationship

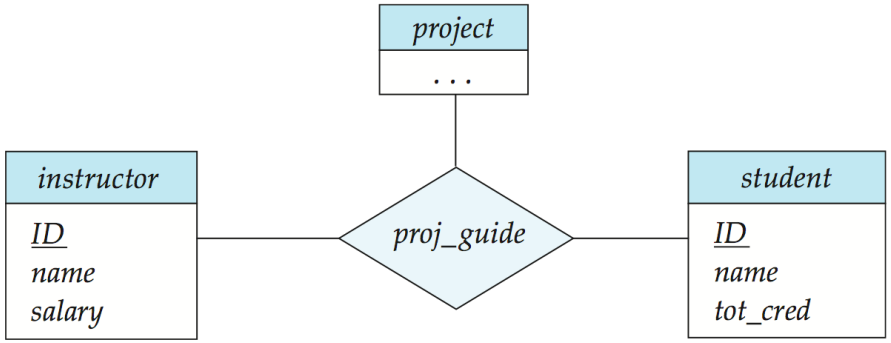


- The labels “*course_id*” and “*prereq_id*” are called **roles (role indicator)**



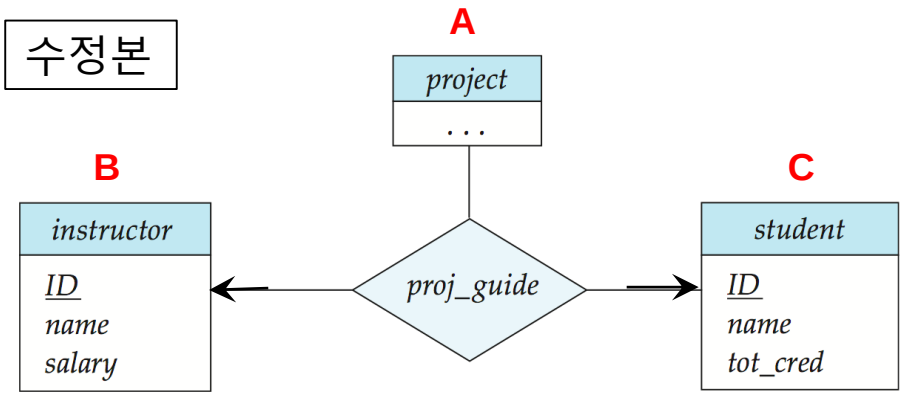
Non Binary Relationships

- **binary relationship**
  - involve two entity sets (or degree two).
  - most relationship sets in a database system are binary.
- Relationships between more than two entity sets are rare.
  - Example: *students* work on research *projects* under the guidance of an *instructor*.
  - The *proj_guide* is a ternary relationship between *instructor, student,* and *project*



Cardinality Constraints on Ternary Relationship

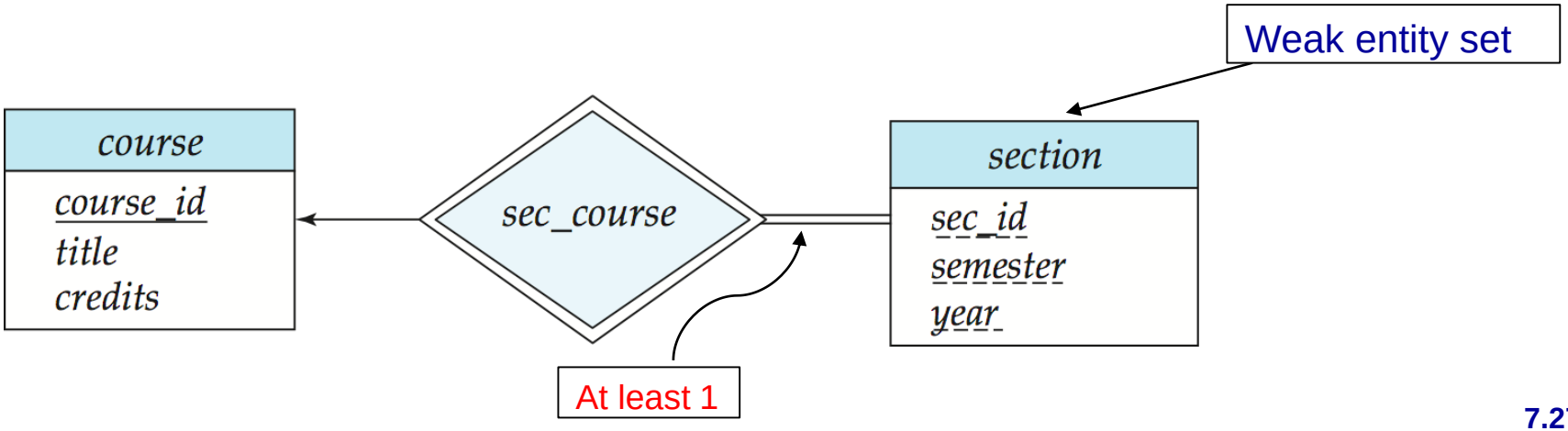
- We allow at most one arrow out of a ternary (or greater degree) relationship to indicate a cardinality constraint
- E.g., an arrow from *proj_guide* to *instructor* indicates each student has at most one guide for a project
- If there is more than one arrow, there are two ways of defining the meaning.
  - A relationship *R* between *A*, *B* and *C* with arrows to *B* and *C* could mean different formalisms
    1. each *A* entity is associated with a unique entity from *B* and *C*
    2. each pair of entities from (*A, B*) is associated with a unique *C* entity, and each pair (*A, C*) is associated with a unique *B*
  - To avoid confusion we outlaw more than one arrow



- One project is associated with a unique instructor and unique student
- Each pair of (project, instructor) is associated with a unique student and each pair of (project, student) is associated with a unique instructor

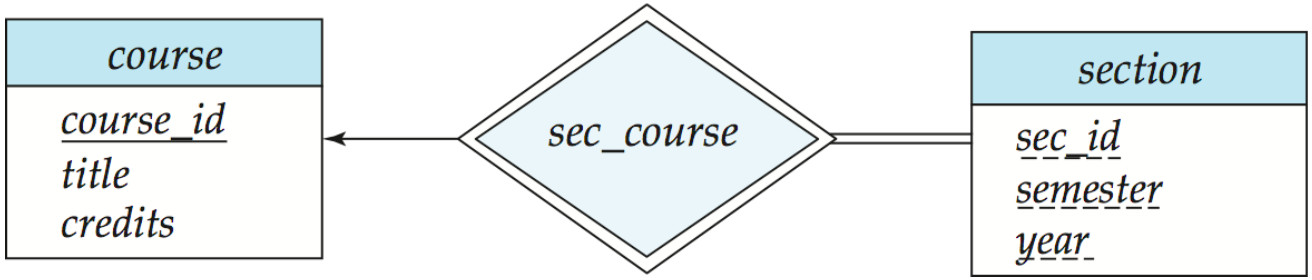
Weak Entity Sets [1/2]

- An entity set that does not have a primary key is referred to as a **weak entity set**.
- The existence of a weak entity set depends on the existence of a **identifying entity set**
  - It must relate to the identifying entity set via a total, one-to-many relationship set from the identifying to the weak entity set
  - **Identifying relationship** depicted using a double diamond
- The **discriminator** (*or partial key)* of a weak entity set is the set of attributes that distinguishes among all the entities of a weak entity set.
- The primary key of a weak entity set is formed by the primary key of the strong entity set on which the weak entity set is existence dependent, plus the weak entity set's discriminator.



Weak Entity Sets [2/2]

- We underline the discriminator of a weak entity set with a dashed line.
- We put the identifying relationship of a weak entity in a double diamond.
- Primary key for *section* – (*course_id, sec_id, semester, year*)



- Note: the primary key of the strong entity set is not explicitly stored with the weak entity set, since it is implicit in the identifying relationship.
- If *course_id* were explicitly stored in section entity, *section* could be made a strong entity, but then the relationship between *section* and *course* would be duplicated by an implicit relationship defined by the attribute *course_id* common to *course* and *section*

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Reduction ER Diagram to Relation DB Schemas

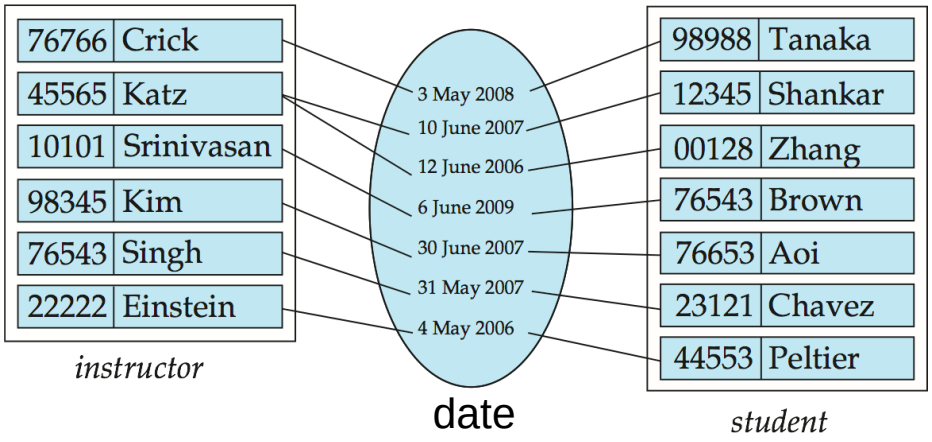
- A database which conforms to an E-R diagram can be represented by a collection of relation schemas.
- Entity sets and relationship sets can be expressed uniformly as *relation schemas* that represent the contents of the database.
  - For each entity set and relationship set there is a unique relation schema that is assigned the name of the corresponding entity set or relationship set.
  - Each relation schema has a number of columns (generally corresponding to attributes), which have unique names.

Instructor(ID, name)

76766	Crick
45565	Katz
10101	Srinivasan
98345	Kim
76543	Singh
22222	Einstein

student(ID, name)

98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

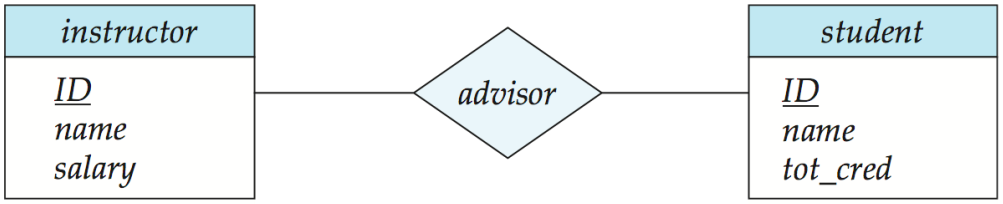


advice_meeting(Instructor.ID, Student.ID, Date)

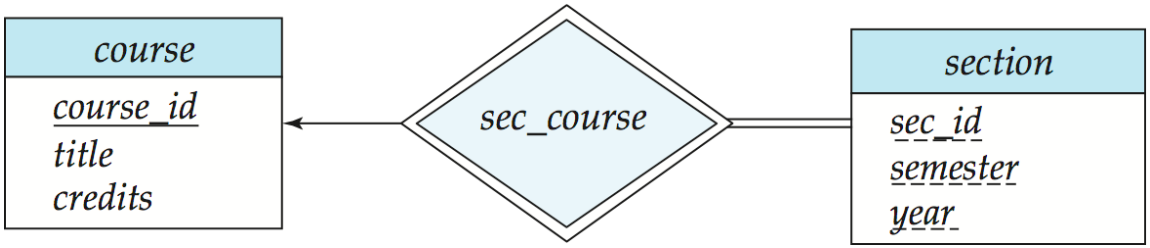
76766	12345	3 May 2008
45565	00128	10 June 2007
.....	.....	.....

Representing Entity Sets With Simple Attributes

- A strong entity set reduces to a RDB schema with the same attributes
  instructor(ID, name, salary), *student(ID, name, tot_cred)*



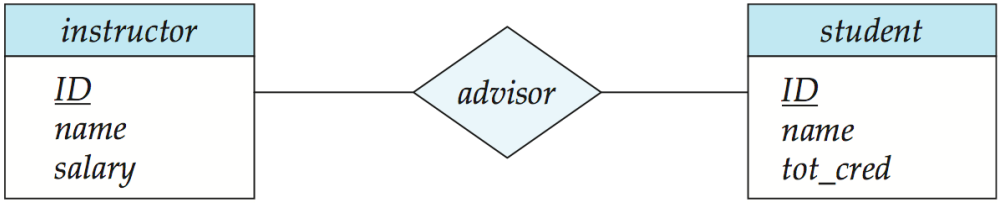
- A weak entity set becomes a table that includes a column for the primary key of the identifying strong entity set
  section (course_id, sec_id, sem, year)



Representing Relationship Sets to RDB Schema

- A many-to-many relationship set is represented as a schema with attributes for the primary keys of the two participating entity sets, and any descriptive attributes of the relationship set.
- Example: RDB schema for relationship set *advisor*

  advisor (*s_id, i_id*)



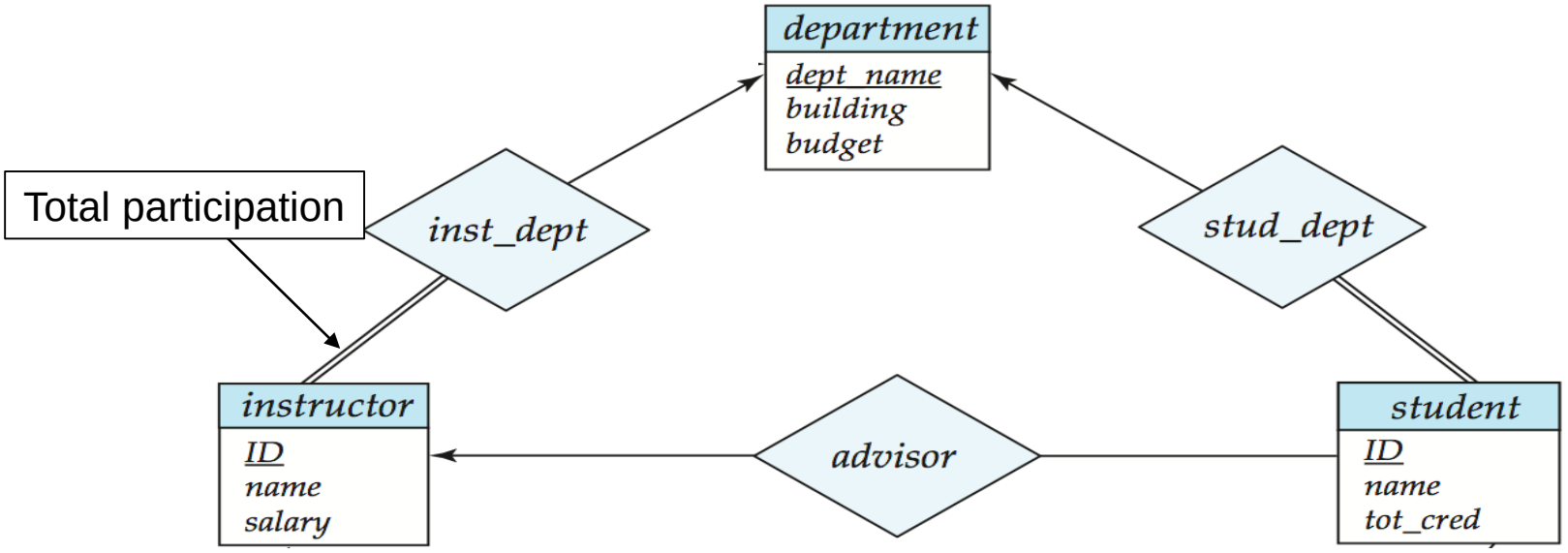
- Sometimes, we can skip a relation schema for certain relationship set! (next slide)

Redundancy of Schemas [1/2]

- Many-to-one and one-to-many relationship sets that are total on the many-side can be represented by adding an extra attribute to the "many" side entity, containing the primary key of the "one" side
- Example: Add an attribute *dept_name* to the schema arising from entity set *instructor*

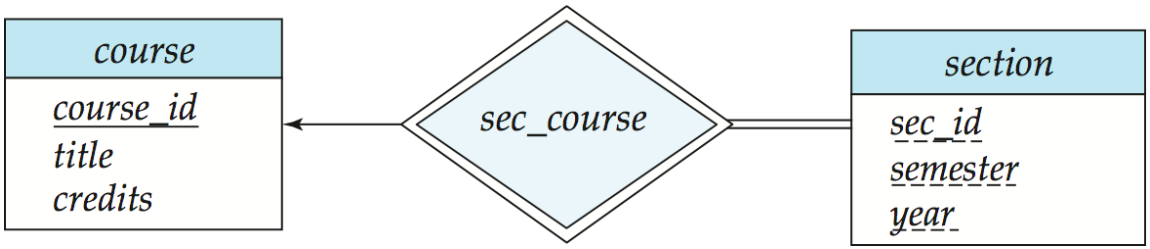
instructor (dept_name, ID, name, salary)

inst_dept(dept_name, ID) ➔ *redundant schema, so we can skip this relationship set*

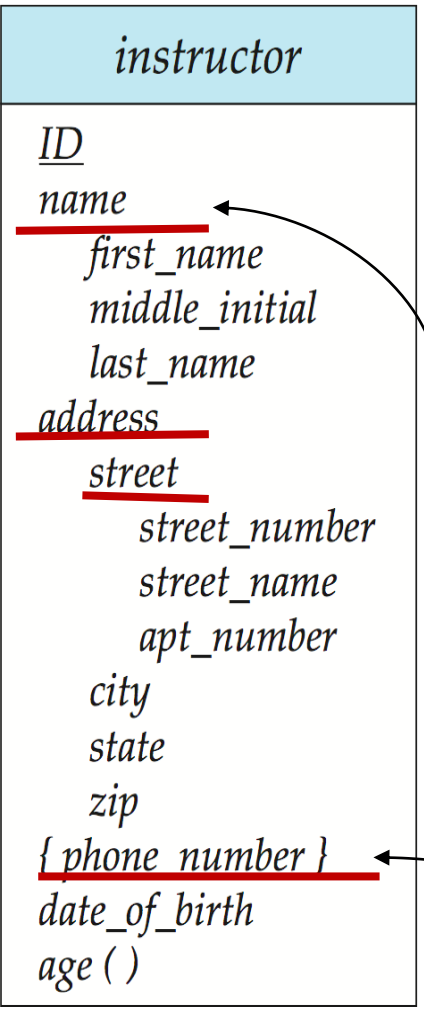


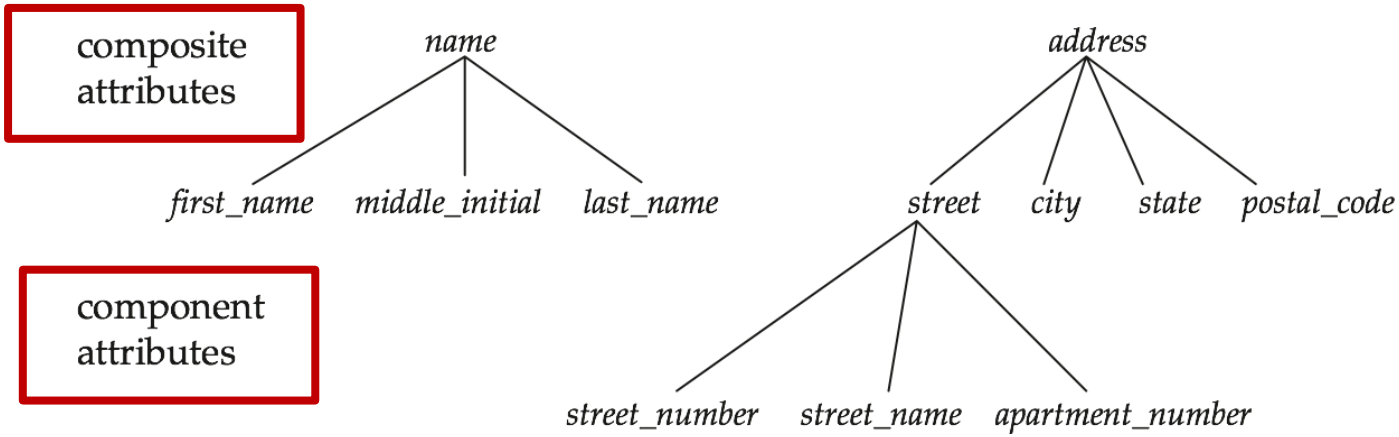
Redundancy of Schemas [2/2]

- If participation is *partial* on the "many" side, replacing a schema by an extra attribute in the schema corresponding to the "many" side could result in null values
  - section(course_id, sec_id, semester, year)
  - course(course_id, title, credits)
  - sec_course(course_id, sec_id) ➔ redundant schema, so we can skip it!
- The schema corresponding to a relationship set linking a weak entity set to its identifying strong entity set is redundant.
  - Example: The *section* schema already contains the attributes that would appear in the *sec_course* schema



Composite and Multivalued Attributes





Idea for composite attributes ➔ Flattening the tree structure

Idea for multivalued attributes ➔ Extra relation

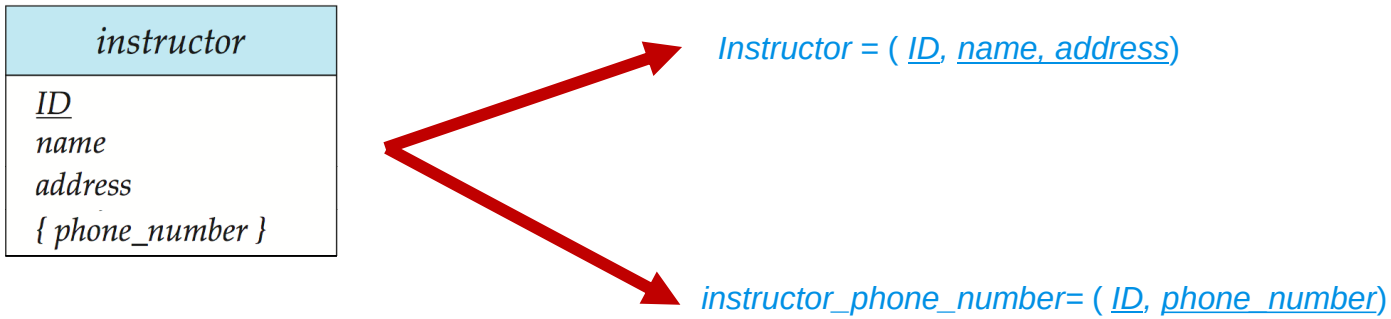
Composite Attributes into RDB Schema

- Composite attributes are flattened out by creating a separate attribute for each component attribute
  - Example: given entity set *instructor* with composite attribute *name* with component attributes *first_name* and *last_name* the schema corresponding to the entity set has two attributes *name_first_name* and *name_last_name*
    - *Prefix omitted if there is no ambiguity*
- Ignoring multivalued attributes, extended instructor schema is
  - *instructor(ID,*
    first_name, middle_initial, last_name,
    street_number, street_name,
    apt_number, city, state, zip_code,
    date_of_birth)

Multivalued Attributes into RDB Schemas [1/2]

- A multivalued attribute *M* of an entity *E* is represented by a separate schema *EM*
  - Schema *EM* has attributes corresponding to the primary key of *E* and a multivalued attribute *M*
  - Example: Multivalued attribute *phone_number* of *instructor* is represented by a schema:
    instructor_phone_number= (ID, phone_number)
  - Each value of the multivalued attribute maps to a separate tuple of the relation on schema *EM*
    - For example, an *instructor* entity with primary key 22222 and phone numbers 456-7890 and 123-4567 maps to two tuples:
    - (22222, 456-7890)

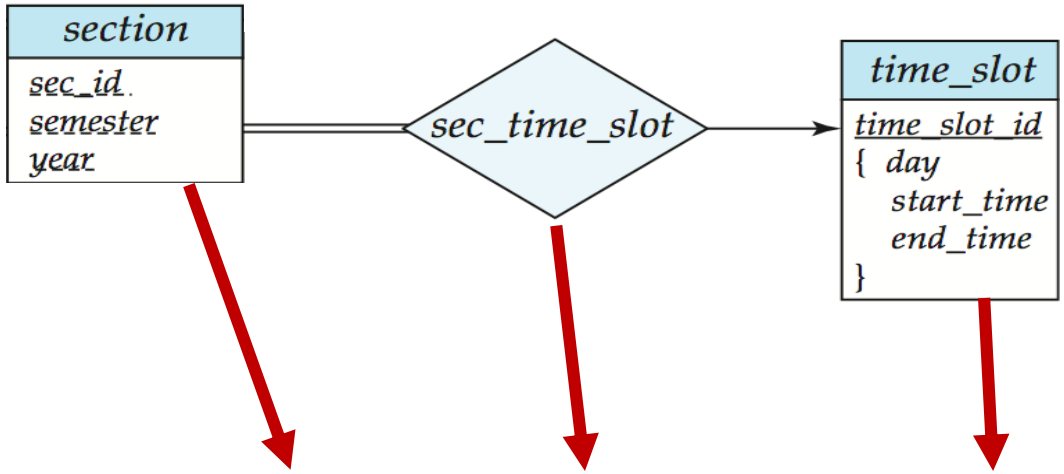
      (22222, 123-4567)



Multivalued Attributes into RDB Schemas [2/2]

- Special case: Entity has only primary-key attribute and multivalued attributes
  - Optimization: Don't create the relation corresponding to the relationship entity, just create the one corresponding to the multivalued attribute

    time_slot (*time_slot_id, day, start_time, end_time*)
  - Caveat: *time_slot_id* attribute of *section* (from *sec_time_slot*) cannot be a foreign key due to this optimization



section(sec_id, semester, year, time_slot_id)

time_slot (time_slot_id, day, start_time, end_time)

Chapter 7: Entity-Relationship Model

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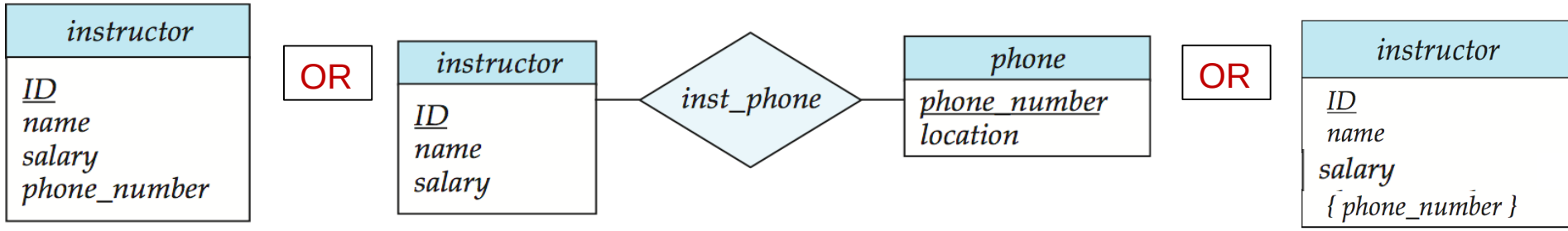
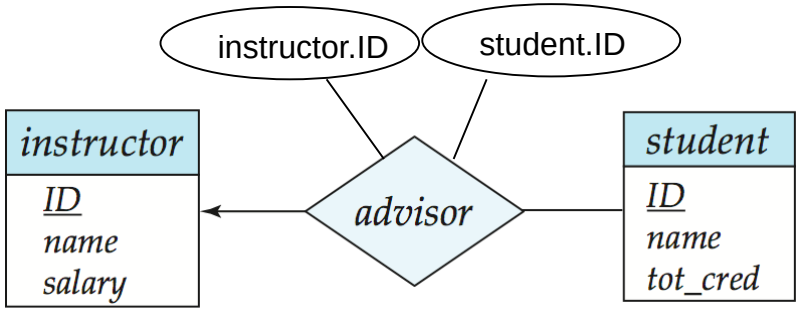
ER Design Issue: Entity sets vs. Attributes



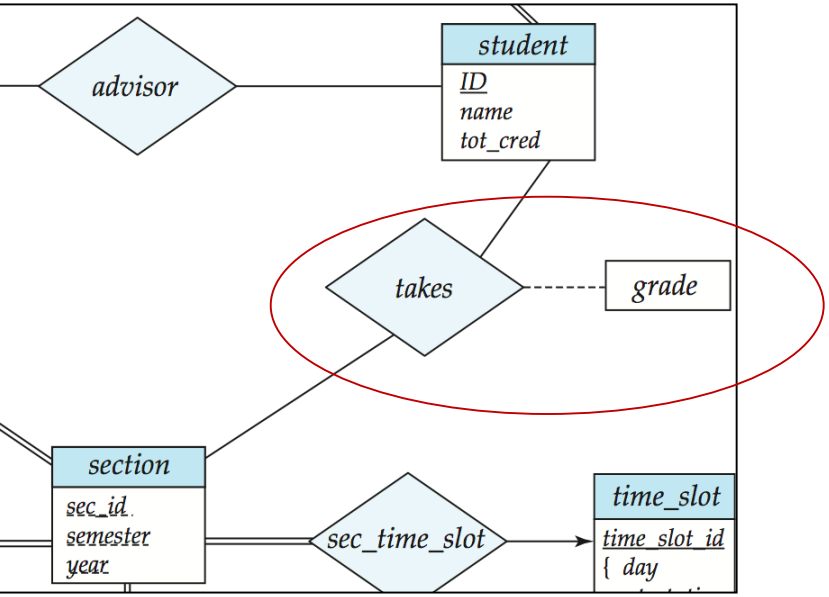
- What constitutes an attribute? Vs What constitutes an entity set?
  - There is no simple answers
  - Depends on the structure and semantics of real-world enterprise

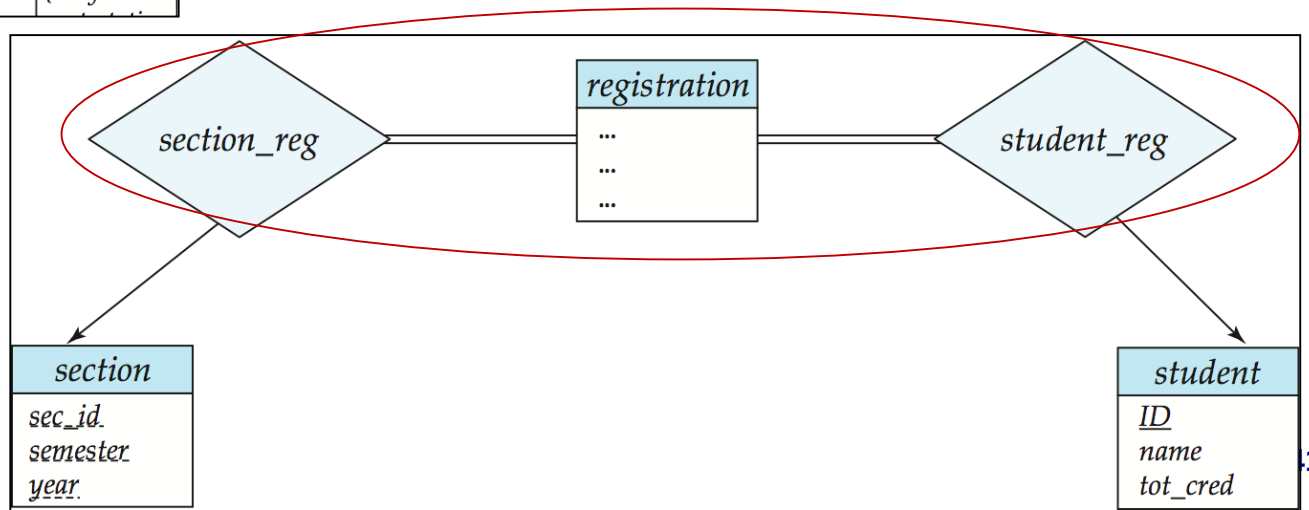
- Another frequent mistake



ER Design Issue: Entity sets vs. Relationship Sets

- Possible guideline is to designate a relationship set to describe an action that occurs between entities





ER Design Issue: Binary vs N-ary Relationship Set

- Although it is possible to replace any non-binary (*n*-ary, for *n* > 2) relationship set by a number of distinct binary relationship sets, sometimes a *n*-ary relationship set shows more clearly that several entities participate in a single relationship.
- Some relationships that appear to be non-binary may be better represented using binary relationships
  - E.g., A ternary relationship *parents*, relating a child to his/her father and mother, is best replaced by two binary relationships, *father* and *mother*
    - Using two binary relationships allows partial information (e.g., only mother being know)
  - But there are some relationships that are naturally non-binary
    - Example: *proj_guide*
- **Where to place attributes in relationship set?**

  e.g., attribute *date* as attribute of *advisor* or as attribute of *student*

Converting Non-Binary Relationships to Binary Form [1/2]

- In general, any non-binary relationship can be represented using binary relationships by creating an artificial entity set.
  - Replace *R* between entity sets A, B and C by an entity set *E*, and 3 relationship sets:

    1. R_A, relating *E* and *A* 2. R_B, relating *E* and *B* 3. R_C, relating *E* and *C*
  - Create a special identifying attribute for *E*
  - Add any attributes of *R* to *E*
  - For each relationship (a_i , b_i , c_i) in *R*, create

    1. a new entity e_i in the entity set *E* 2. add (e_i , a_i) to R_A

    3. add (e_i , b_i) to R_B 4. add (e_i , c_i) to R_C

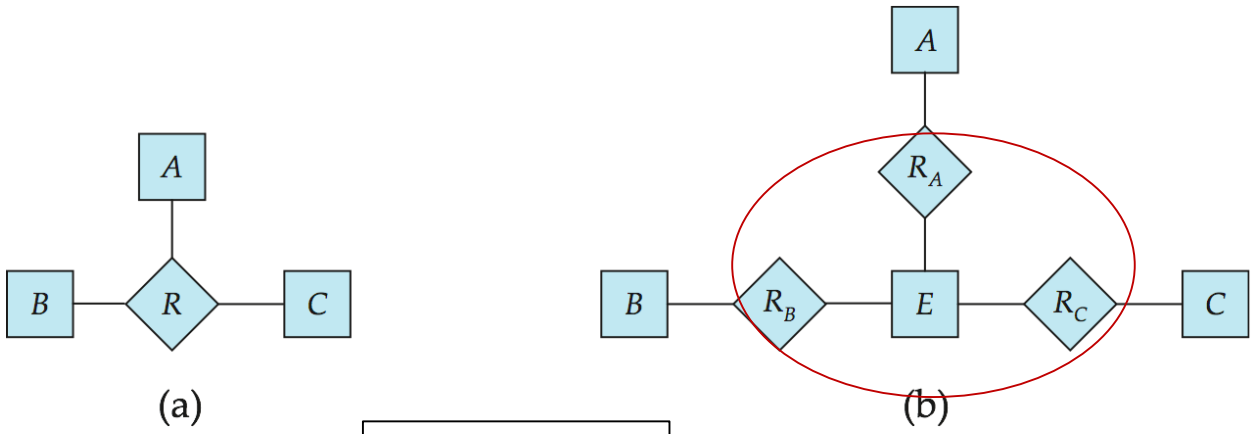
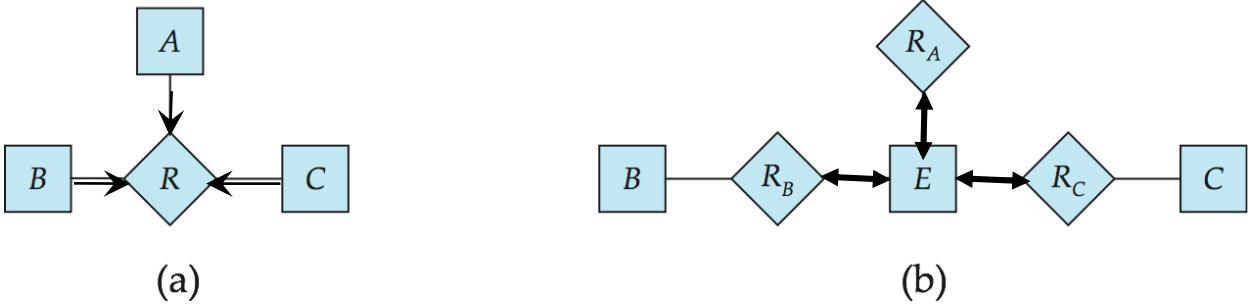


Fig 7.19

Converting Non-Binary Relationships to Binary Form [2/2]

- Not always possible to translate constraints in non-binary relationships into constraints on the binary relationships
  - Suppose R is many-to-one from A, B, and C
    - Exercise: *add constraints to the relationships R_A, R_B and R_C* to ensure that a newly created entity corresponds to exactly one entity in each of entity sets *A, B* and *C*



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Extended E-R Features: Specialization

- Top-down design process; we designate subgroupings within an entity set that are distinctive from other entities in the set.
- These subgroupings become lower-level entity sets that have attributes or participate in relationships that do not apply to the higher-level entity set.
- Depicted by a *triangle* component labeled ISA (E.g., *instructor* "is a" *person*).
- **Attribute inheritance** – a lower-level entity set inherits all the attributes and relationship participation of the higher-level entity set to which it is linked.

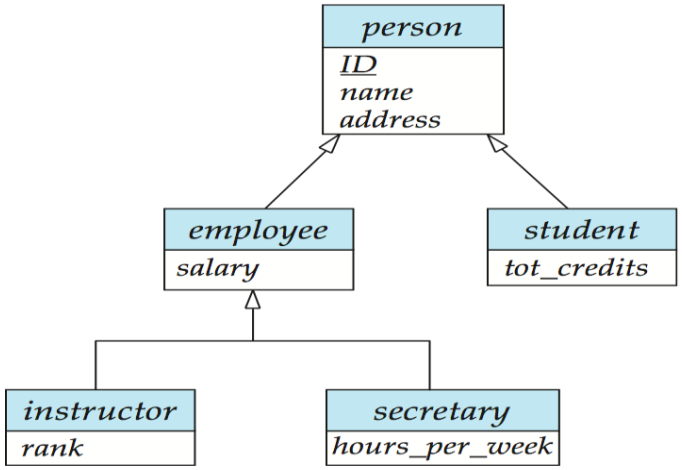


Fig 7.21: Specialization Example

Extended ER Features: Generalization

- **A bottom-up design process** – combine a number of entity sets that share the same features into a higher-level entity set.
- Specialization and generalization are simple inversions of each other
- The terms specialization and generalization are used interchangeably.
- Can have multiple specializations of an entity set based on different features.
  - E.g., *permanent_employee* vs. *temporary_employee*, in addition to *instructor* vs. *secretary*
- Each particular employee would be
  - a member of one of *permanent_employee* or *temporary_employee*,
  - and also a member of one of *instructor*, *secretary*
- The ISA relationship also referred to as **superclass - subclass** relationship

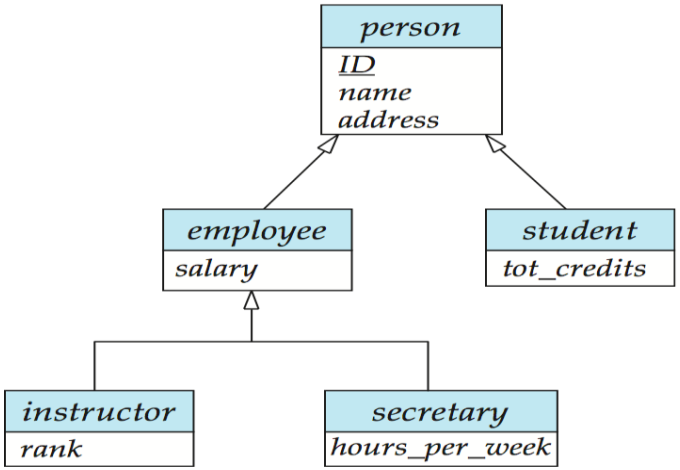
Design Constraints on a Specialization/Generalization

- Constraint on which entities can be members of a given lower-level entity set.
  - condition-defined (condition or predicate based)
    - Example: all customers over 65 years are members of *senior-citizen* entity set; *senior-citizen* ISA *person*.
  - user-defined
    - Example: a new employee is assigned to one of teams in the company
- Constraint on whether entities may belong to more than one lower-level entity set
  - **Disjoint:** an entity can belong to only one lower-level entity set
    - Noted in E-R diagram by having multiple lower-level entity sets link to the same triangle
  - **Overlapping:** an entity can belong to more than one lower-level entity set
- **Completeness constraint** on whether or not an entity in the higher-level entity set must belong to at least one of the lower-level entity sets within a generalization.
  - **total**: an entity must belong to one of the lower-level entity sets
  - **partial**: an entity need not belong to one of the lower-level entity sets

Relation Schemas for Specialization/Generalization [1/2]

- Method 1:
  - Form a schema for the higher-level entity
  - Form a schema for each lower-level entity set, include primary key of higher-level entity set and local attributes

schema	attributes
person	*ID, name, street, city*
student	*ID, tot_cred*
employee	*ID, salary*

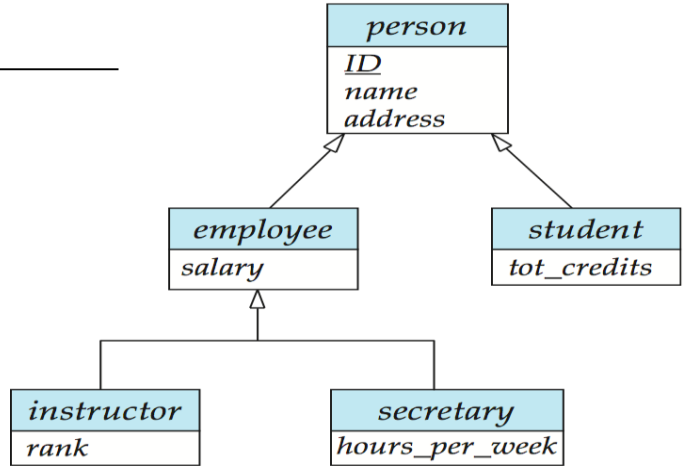


  - Drawback: getting information about, an *employee* requires accessing two relations, the one corresponding to the low-level schema and the one corresponding to the high-level schema

Relation Schemas for Specialization/Generalization [2/2]

- Method 2:
  - Form a schema for each entity set with all local and inherited attributes

schema	attributes
person	*ID, name, street, city*
student	*ID, name, street, city, tot_cred*
employee	*ID, name, street, city, salary*

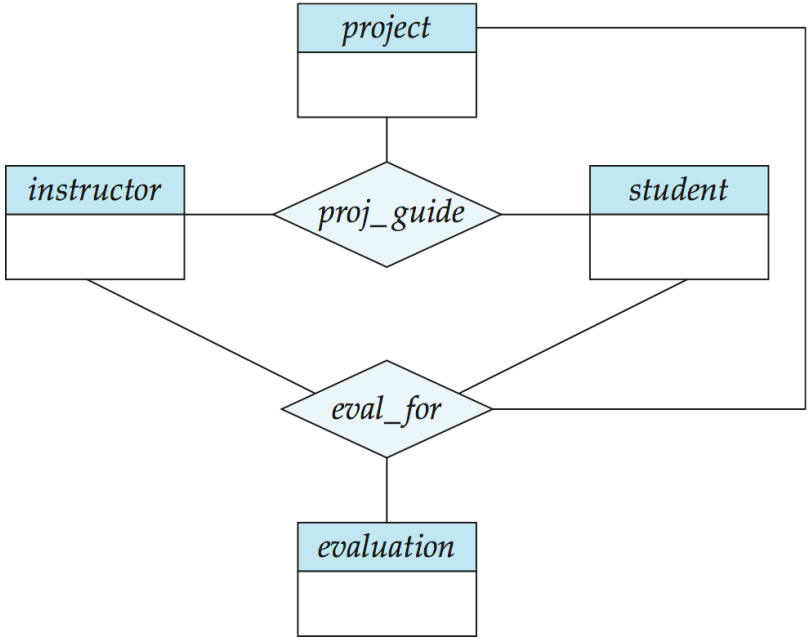


  - If specialization is total, the schema for the generalized entity set (*person*) not required to store information
    - Can be defined as a "view" relation containing union of specialization relations
    - But explicit schema may still be needed for foreign key constraints
  - Drawback: *name, street* and *city* may be stored redundantly for people who are both students and employees

Extended ER Feature: Aggregation [1/2]

- Consider the ternary relationship *proj_guide*, which we saw earlier
- Suppose we want to record evaluations of a student by a guide on a project

Fig 7.22

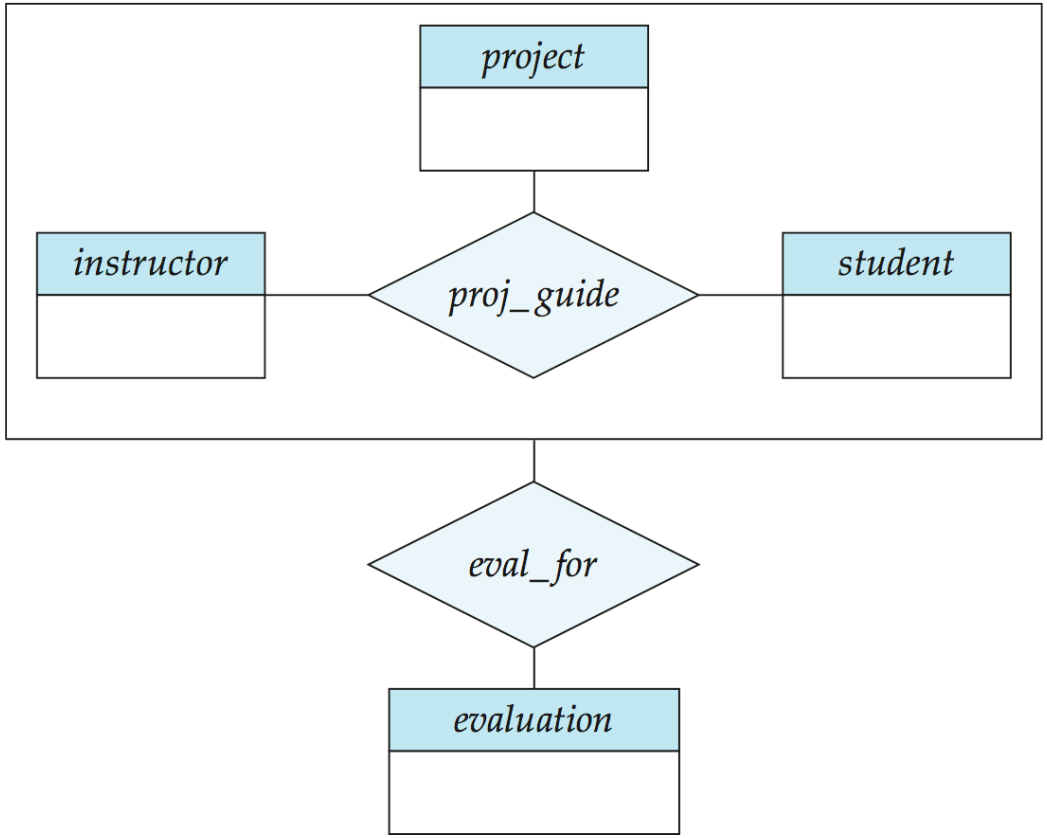


- Relationship sets *eval_for* and *proj_guide* represent overlapping information
- Eliminate this redundancy via *aggregation*
  - Treat relationship as an abstract entity
  - Allows relationships between relationships
  - Abstraction of relationship into new entity

Extended ER Features: Aggregation [2/2]

- Without introducing redundancy, the following diagram represents:
  - A student is guided by a particular instructor on a particular project
  - A student, instructor, project combination may have an associated evaluation

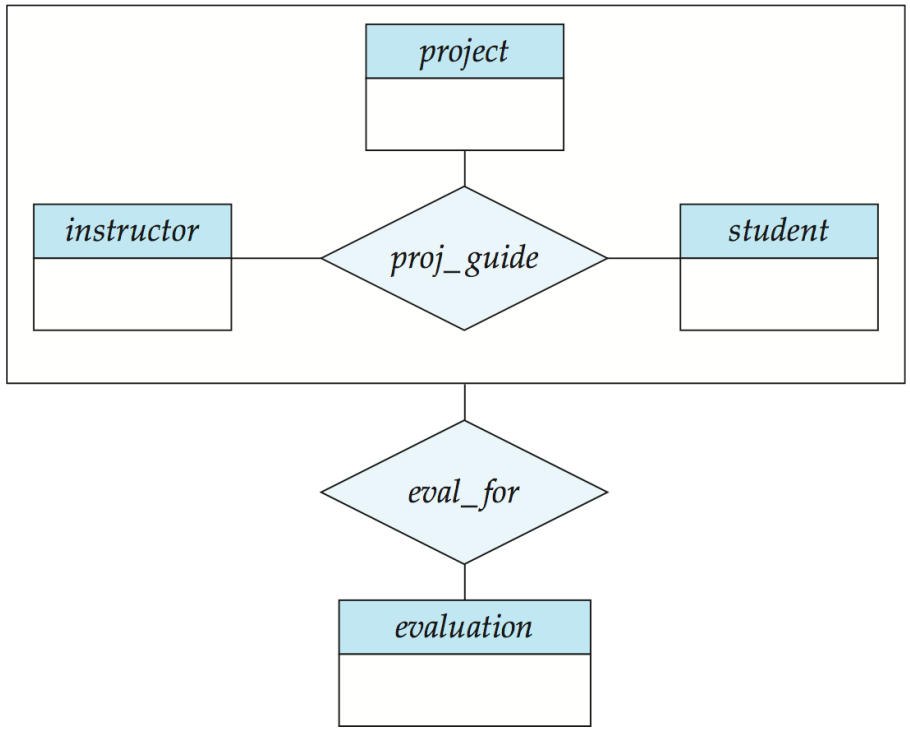
Fig 7.23



Relation Schemas for Aggregation

- To represent aggregation, create a RDB schema containing
  - primary key of the aggregated relationship,
  - the primary key of the associated entity set
  - any descriptive attributes

eval_for (*student_ID, project_id, instructor_ID, evaluation_id*)



E-R Design Decisions: Summary

- The use of an attribute or entity set to represent an object.
- Whether a real-world concept is best expressed by an entity set or a relationship set.
  - Noun ➔ entity set
  - Verb ➔ relationship set
  - Adjective ➔ attribute
- The use of a ternary relationship versus a pair of binary relationships.
- The use of a strong or weak entity set.
- The use of specialization/generalization – contributes to modularity in the design.
- The use of aggregation – can treat the aggregate entity set as a single unit without concern for the details of its internal structure.

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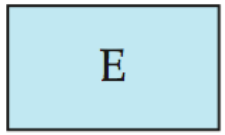
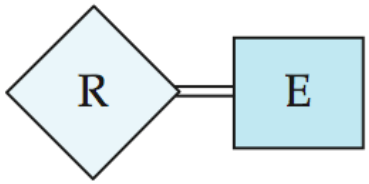
UML-like E-R Notation in the Book [1/2]



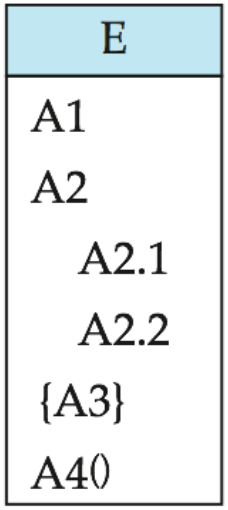
entity set

relationship set

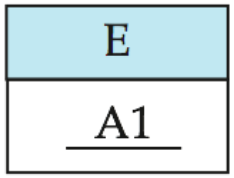
identifying relationship set for weak entity set



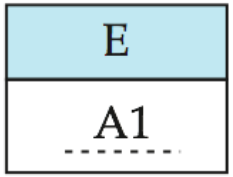
total participation of entity set in relationship



attributes:
simple (A1),
composite (A2) and
multivalued (A3)
derived (A4)

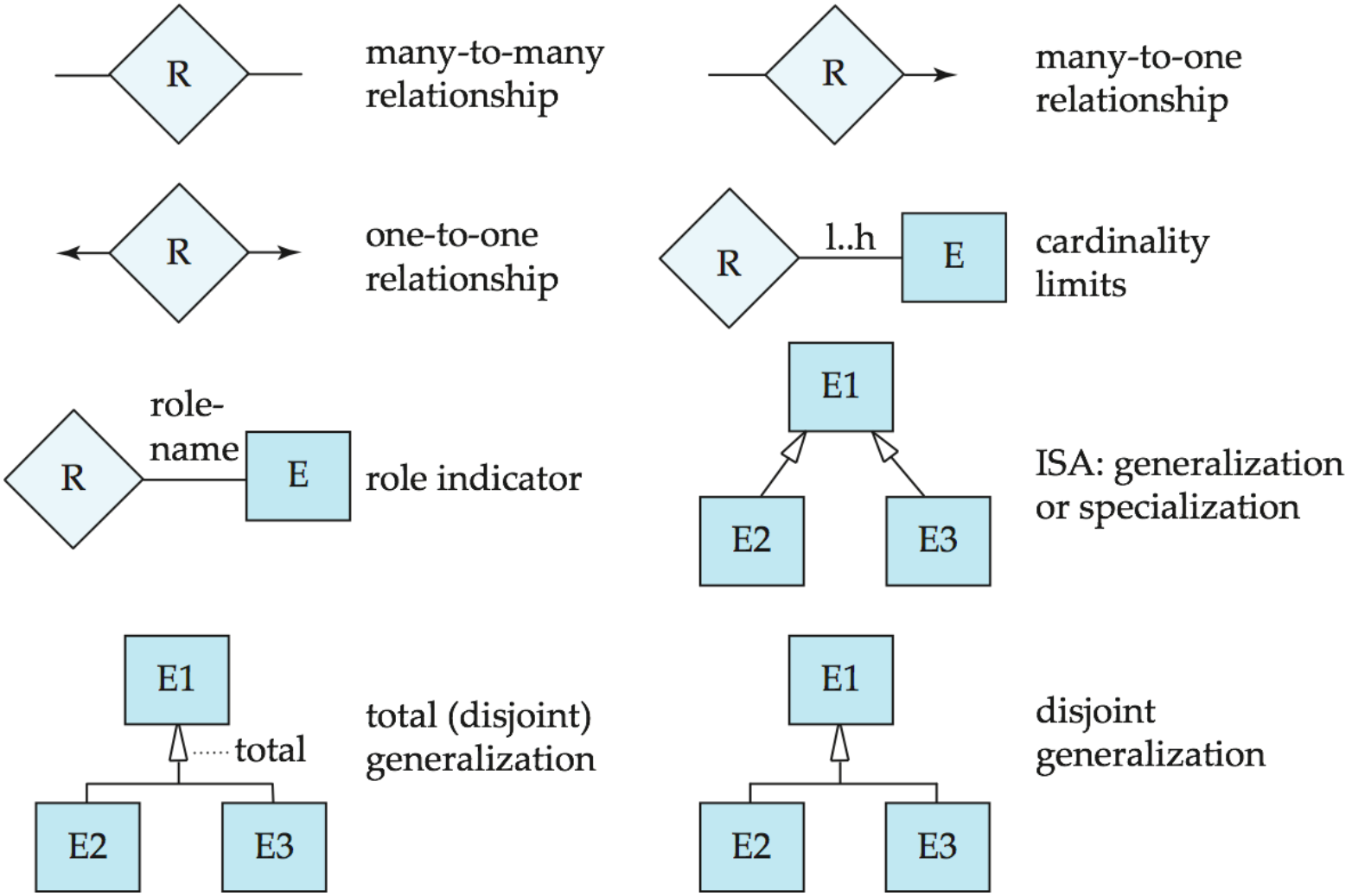


primary key



discriminating attribute of weak entity set

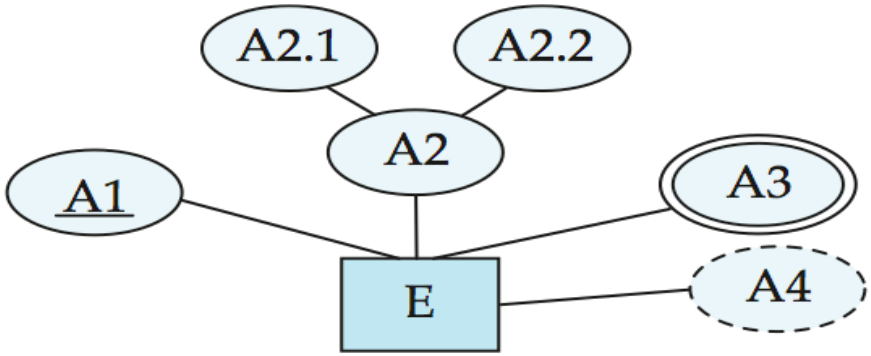
UML-like E-R Notation in the Book [2/2]



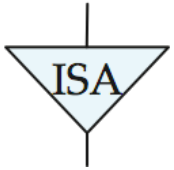
Alternative ER Notations [1/2]

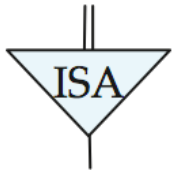
- Chen's ER notation: P.P. Chen, 1976, "The ER Model: Toward a Unified View of Data, ACM Transactions of Database Systems
- IDE1FX: The US National Institute of Standards and Technology (NIST), 1993

entity set E with
simple attribute A1,
composite attribute A2,
multivalued attribute A3,
derived attribute A4,
and primary key A1



weak entity set 

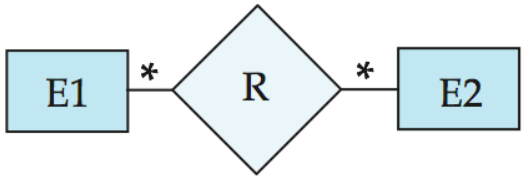
generalization 

total generalization 

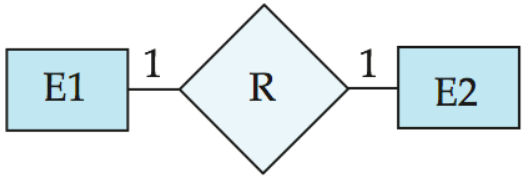
Alternative ER Notations [2/2]

Chen's ER Notation

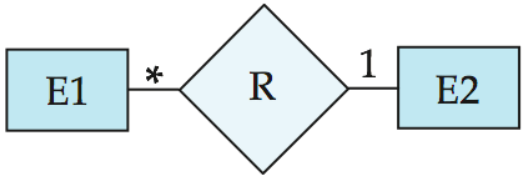
many-to-many relationship



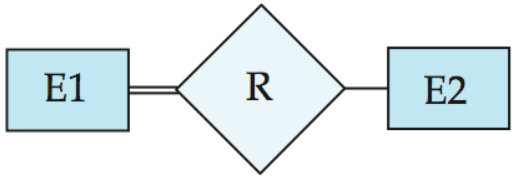
one-to-one relationship



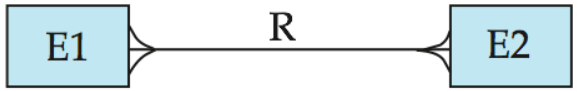
many-to-one relationship

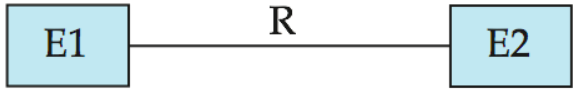


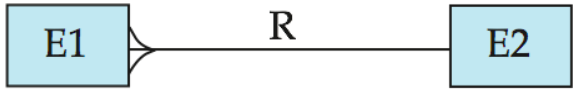
participation in R: total (E1) and partial (E2)

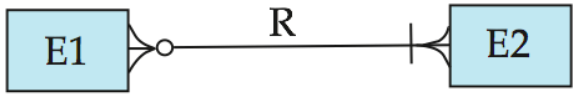


IDE1FX (Crows feet notation)









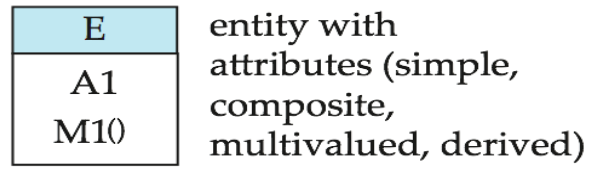
UML (Unified Modeling Language) [1/2]

- Standard by OMG (Object Management Group)
  - Long history of various modeling languages
    - Rambaugh's OMT-1, OMT-2
    - Booch92 Method
    - Jacobson OOSE Method
  - Now a "de facto" standard
- UML has many components (10 Diagrams) to graphically model different aspects of an entire software system
  - Use case Diagram
  - Class/Object diagram
  - Sequence/Collaboration Diagram
  - State/Activity Diagram
  - Component/Deployment Diagram
  - …….

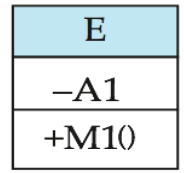
UML (Unified Modeling Language) [2/2]

- Various Application besides Database Modeling
  - Software design
  - Hardware design
    - Computer hardware
    - Ship building
    - Mechanical design
    - …….
- In our textbook, ER diagram is drawn with UML-like notations

Our Book UML-like ER Diagram Notations vs. Original UML Class Diagrams

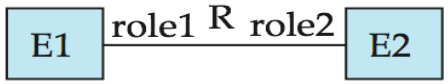


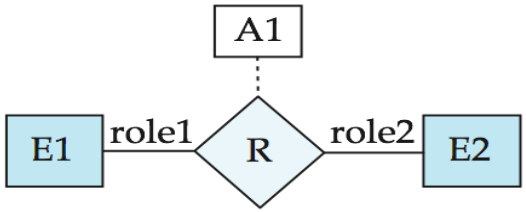
entity with attributes (simple, composite, multivalued, derived)



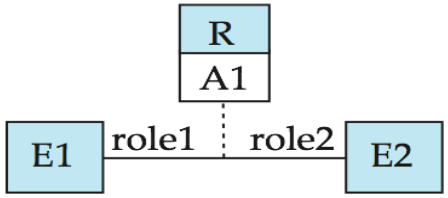
class with simple attributes and methods (attribute prefixes: + = public, – = private, # = protected)

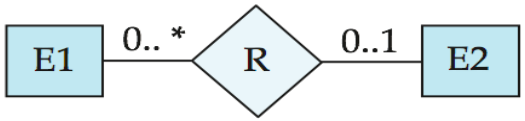
binary relationship



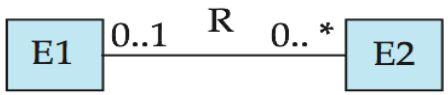


relationship attributes





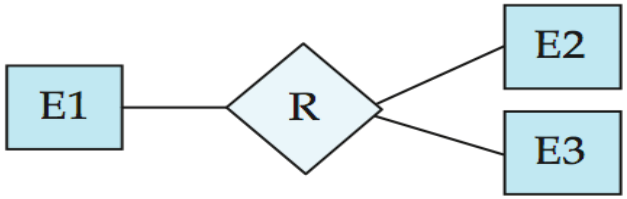
cardinality constraints



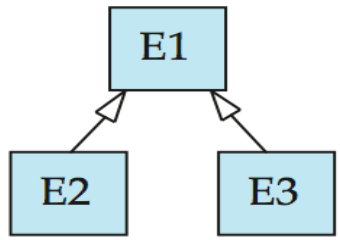
*Note reversal of position in cardinality constraint depiction

- Binary relationship sets are represented in UML by just drawing a line connecting the entity sets. The relationship set name is written adjacent to the line.
- The role played by an entity set in a relationship set may also be specified by writing the role name on the line, adjacent to the entity set.
- The relationship set name may alternatively be written in a box, along with attributes of the relationship set, and the box is connected, using a dotted line, to the line depicting the relationship set.

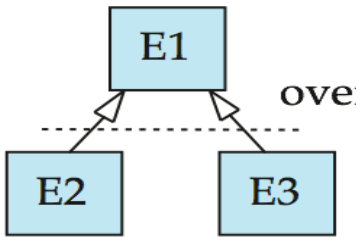
Our Book UML-like ER Diagram Notations vs. Original UML Class Diagrams



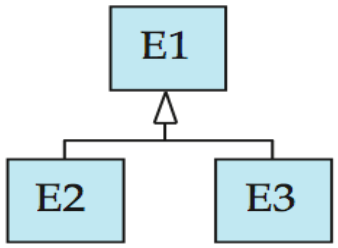
n-ary relationships



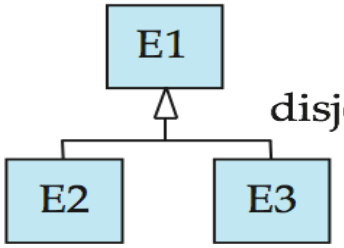
overlapping generalization



overlapping



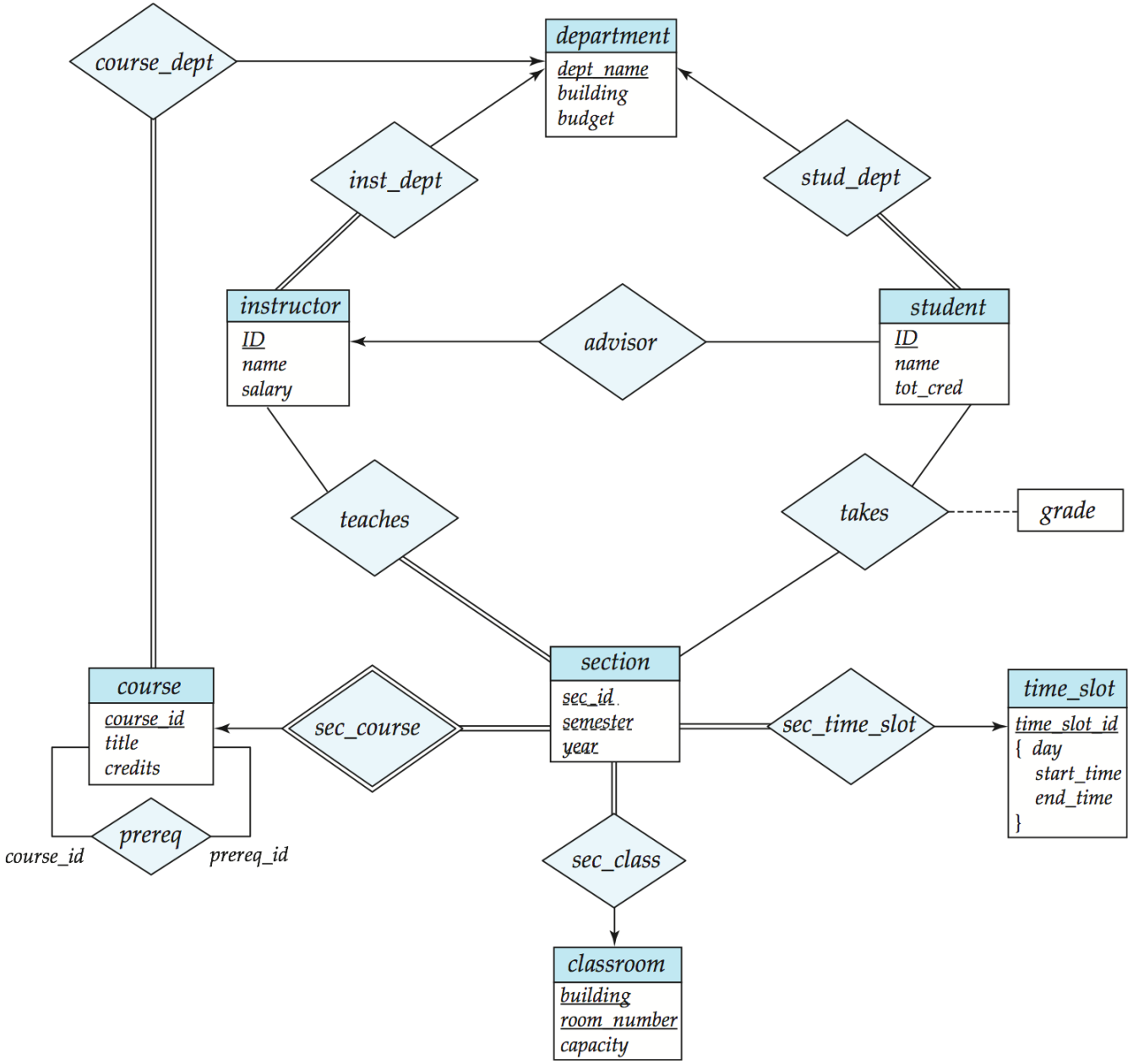
disjoint generalization



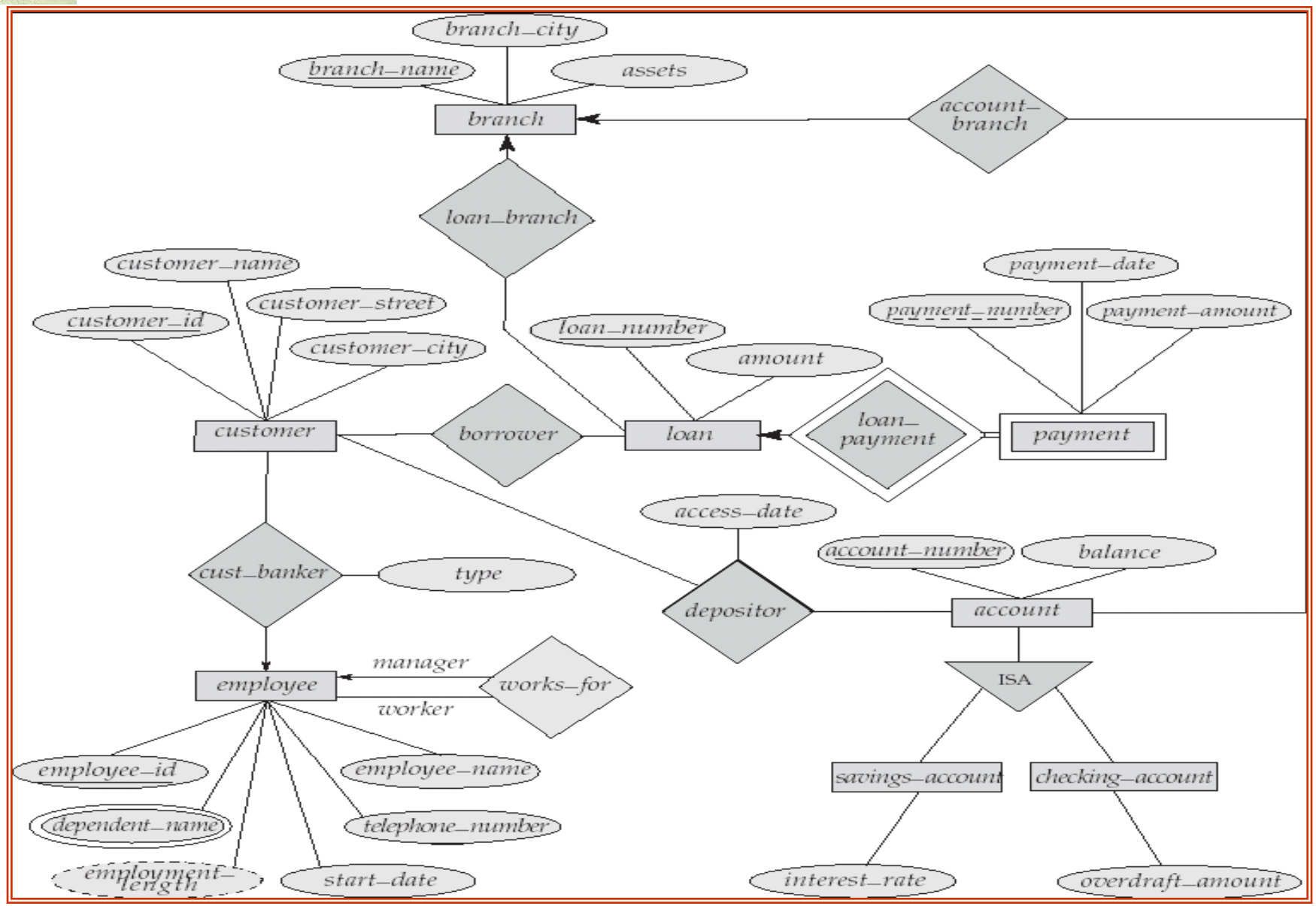
disjoint

*Generalization can use merged or separate arrows independent of disjoint/overlapping

UML-like ER Diagram for University Database



Chen's ER Notation for Bank Database



Chapter 7: Entity-Relationship Model

- 7.1 Overview of the Design Process
- 7.2 The Entity-Relationship Model
- 7.3 Constraints
- 7.4 Removing Redundant Attributes in Entity Sets
- 7.5 Entity-Relationship Diagrams
- 7.6 Reduction to Relational Schemas
- 7.7 Entity-Relationship Design Issues
- 7.8 Extended E-R Features
- 7.9 Alternative Notation for Modeling Data
- 7.10 Other Aspects of Database Design

Other Aspects of Database Design

- Data Constraints and Relational Database Design
- Usage Requirements: Queries, Performance
  - Throughput
  - Response time
- Authorization Requirements
  - Creating views
  - Control user's accessibility to views and relations
- Data Flow, Work Flow
  - Specification of a series of queries and updates for accomplishing tasks
- Schema updates rarely happen, but are very hectic!
- Data Conversion is necessary in interacting multiple databases
- Other Issues
  - Enterprise evolution
  - Interaction with other enterprises
  - End user vs. Database designer