ECE30030/ITP30010 Database Systems

E-R Model

Reading: Chapter 6

Charmgil Hong

charmgil@handong.edu

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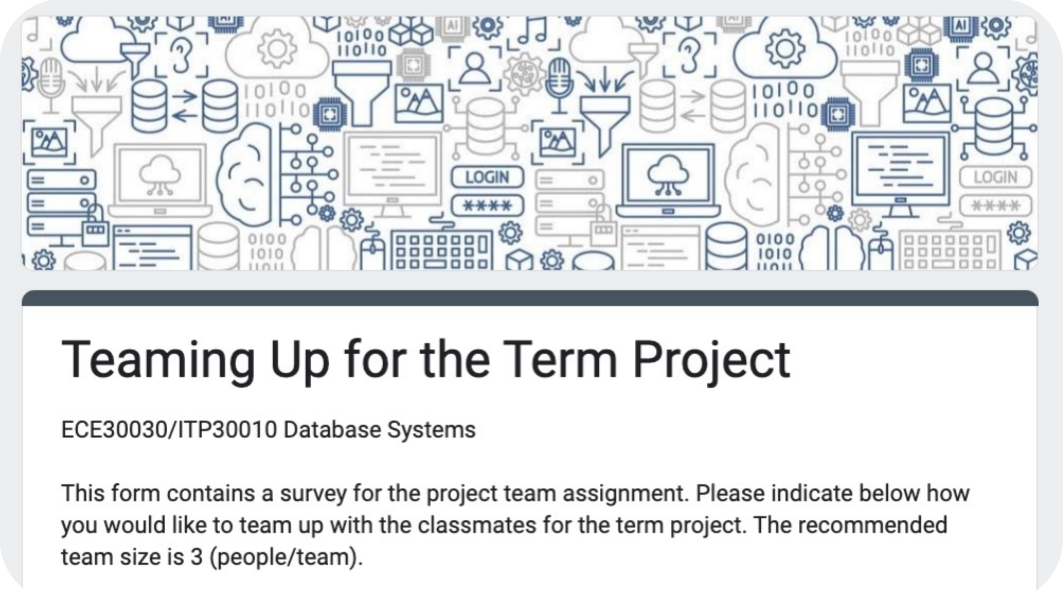
Handong Global University

Announcements

- Make teams for the term project
  - https://forms.gle/T742G8LQBikzfrUv9 Reponse due: Thursday, April 17
  - Problem & data release: Week #8 (tentative)



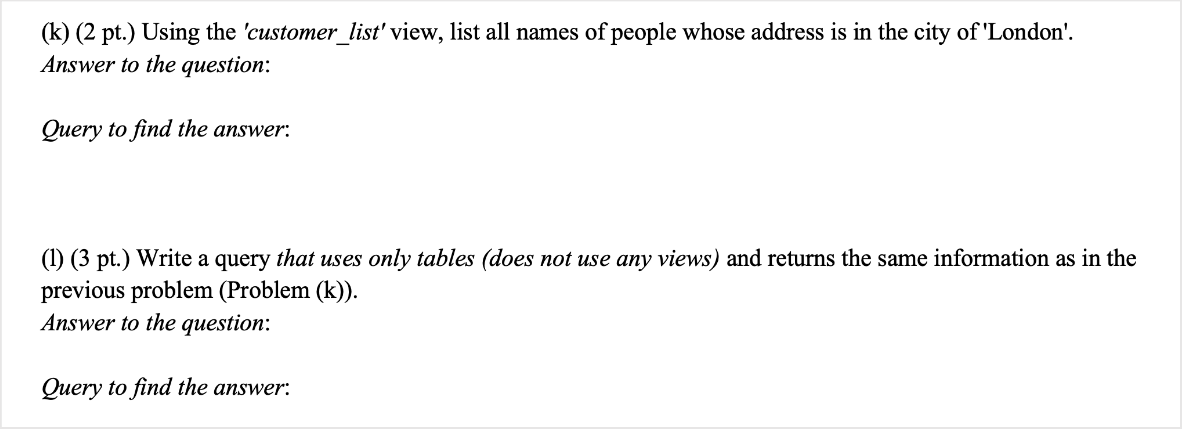
Teaming Up for the Term Project

ECE30030/ITP30010 Database Systems

This form contains a survey for the project team assignment. Please indicate below how you would like to team up with the classmates for the term project. The recommended team size is 3 (people/team).

Announcements

- HW#3 is released
  - Due: Thursday, April 24
  - For Problem 4 (k)-(l), treat *views* as pseudo-tables:
    - (k) Write a query that uses ‘custsomer_list’ as a table.
    - (l) Write an alternative query that does the same as (k) while not using ‘custsomer_list’.



(k) (2 pt.) Using the *'customer_list'* view, list all names of people whose address is in the city of 'London'.
Answer to the question:

Query to find the answer:

(l) (3 pt.) Write a query *that uses only tables (does not use any views)* and returns the same information as in the previous problem (Problem (k)).
Answer to the question:

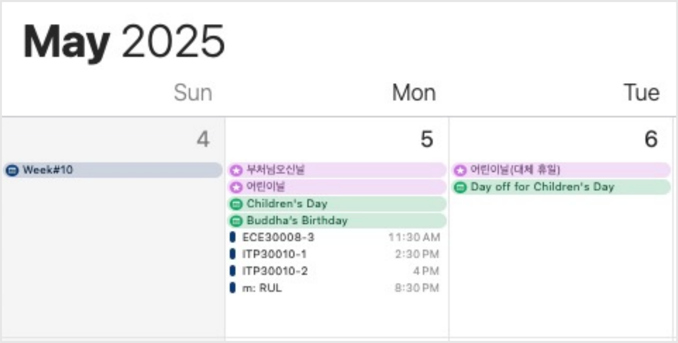
Query to find the answer:

- Heads-up: HW#4 will be released before the midterm exam
  - Check out the problems before the midterm exam

Announcements

- Midterm is scheduled on Thursday, May 1 (Week #9)
  - Coverage: ~ Advanced SQL

- No offline meeting on May 5 (National holiday)
  - Review on the midterm exam is on Thursday, May 8 (Week #10)



May 2025

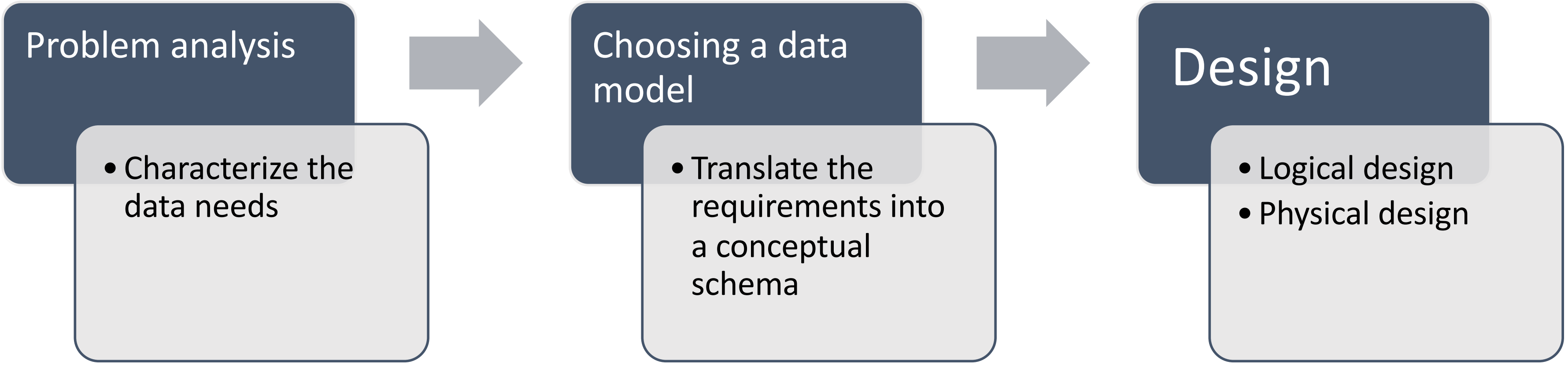
Sun	Mon	Tue
4	5	6
Week#10	부처님오신날 어린이날 Children's Day Buddha's Birthday ECE30008-3 11:30 AM ITP30010-1 2:30 PM ITP30010-2 4 PM m: RUL 8:30 PM	어린이날(대체 휴일) Day off for Children's Day

Agenda

- Designing a database
- E-R diagrams

Design Phases

- Initial phase: characterize fully the data needs of the prospective database users
- Second phase: choose a data model
  - Apply the concepts of the chosen data model
  - Translate the requirements into a conceptual schema of the database
  - A fully developed conceptual schema indicates the functional requirements of the enterprise
    - Describe the kinds of operations (or transactions) that will be performed on the data



Problem analysis

- Characterize the data needs

Choosing a data model

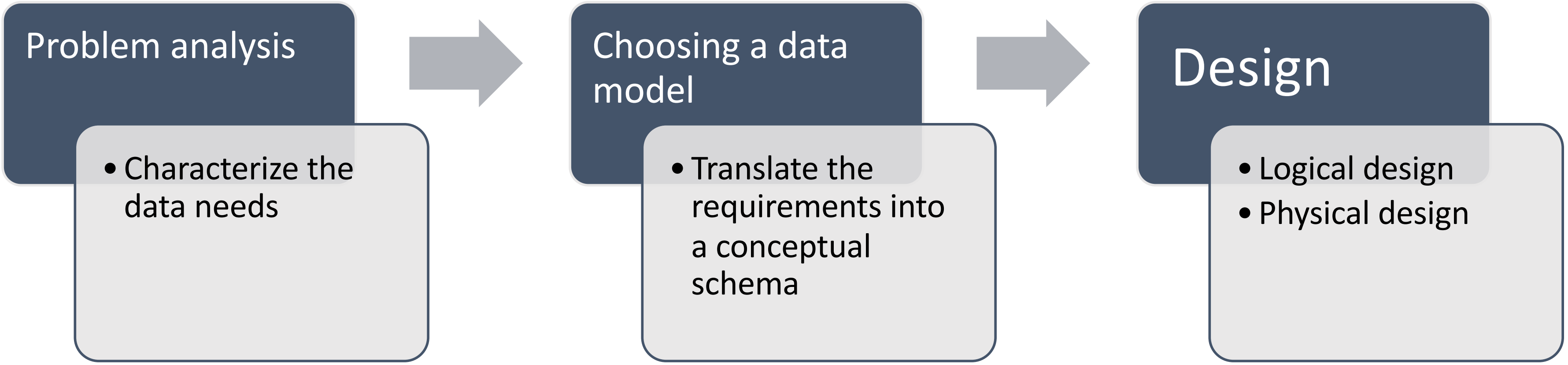
- Translate the requirements into a conceptual schema

Design

- Logical design
- Physical design

Design Phases

- Final Phase: Move from an abstract data model to the implementation of the database
  - Logical Design – Deciding on the database schema
    - Database design requires that we find a "good" collection of relation schemas
    - *Business decision – What attributes should we record in the database?*
    - *Computer Science decision – What relation schemas should we have and how should the attributes be distributed among the various relation schemas?*
  - Physical Design – Deciding on the physical layout of the database



Problem analysis

- Characterize the data needs

Choosing a data model

- Translate the requirements into a conceptual schema

Design

- Logical design
- Physical design

Design Phases

- In designing a database schema, we must ensure that we avoid two major pitfalls:
  - Redundancy: a bad design may result in repeated information
    - Redundant representation of information may lead to data inconsistency among the various copies of information
  - Incompleteness: a bad design may make certain aspects of the enterprise difficult or impossible to model

- Avoiding bad designs is not enough. There may be a large number of good designs from which we must choose

Design Approaches

- Entity Relationship Model
  - Models an enterprise as a collection of *entities* and *relationships*
    - Entity: a "thing" or "object" in the enterprise that is distinguishable from other objects
      - Described by a set of *attributes*
    - Relationship: an association among several entities
  - Represented diagrammatically by an *entity-relationship diagram* (E-R diagram)

- Normalization Theory
  - Formalize what designs are bad, and test for them

Agenda

- Designing a database
- **E-R diagrams**
  - Mapping cardinalities
  - Primary keys in E-R models
  - Weak entity sets
  - Reduction to relation schemas

E-R Model for Database Modeling

- The E-R data model was developed to facilitate database design by allowing specification of a database schema
  - Database schema represents the overall logical structure of a database

- The E-R data model employs three basic concepts:
  - Entity sets
  - Relationship sets
  - Attributes

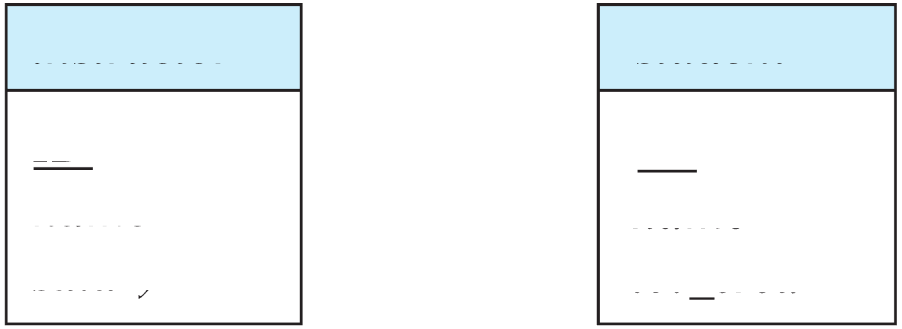
- The E-R model has an associated diagrammatic representation
  - E-R diagram can express the overall logical structure of a database graphically

Entity Sets

- An entity is an object that exists and is distinguishable from other objects
    - *E.g.*, specific person, company, event, plant
- An entity set is a set of entities of the same type that share the same properties
    - *E.g.*, set of all persons, companies, trees, holidays
- An entity is represented by a set of attributes; *i.e.*, descriptive properties possessed by all members of an entity set
    - *E.g., instructor =* (*ID, name, salary*)
      course= (*course_id, title, credits*)
- A subset of the attributes form a primary key of the entity set; *i.e.*, uniquely identifying each member of the set

Representing Entity Sets in E-R Diagrams

- Entity sets can be represented graphically as follows:
  - Rectangles represent entity sets
  - Attributes listed inside entity rectangle
  - Underline indicates primary key attributes



Example: Entity and Relationship Sets

- Entity Sets – *instructor* and *student*

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

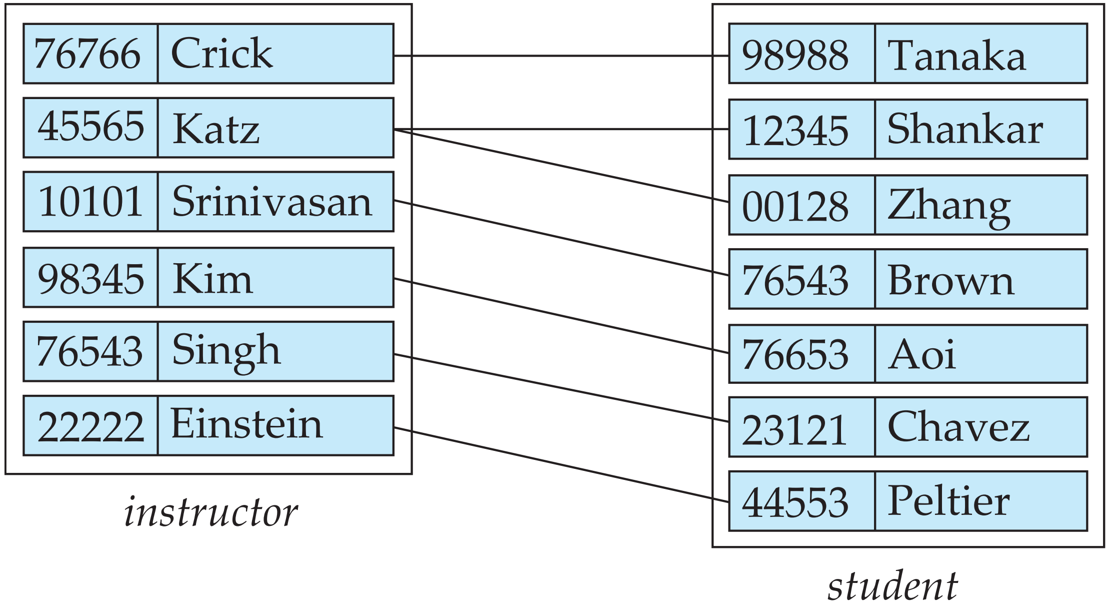
instructor

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

student

Example: Entity and Relationship Sets

- Relationship Sets – define the relationship set *advisor* to denote the associations between students and the instructors who act as their advisors



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instructor

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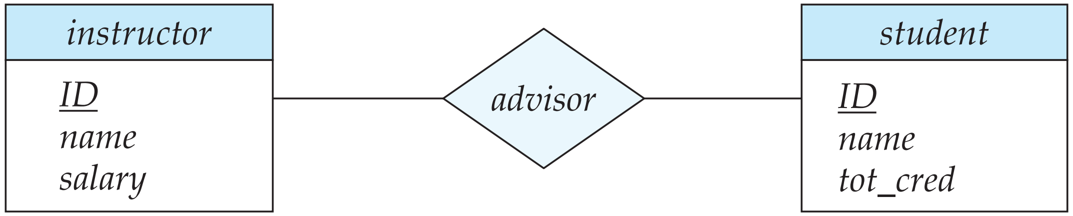
student

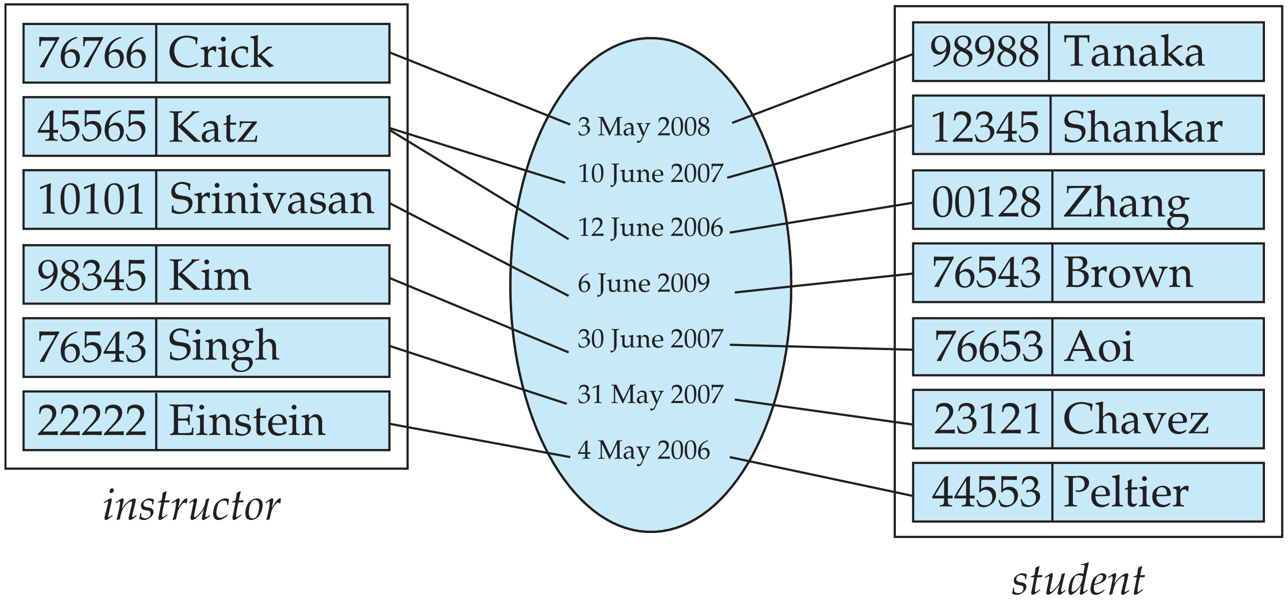
Representing Relationship Sets via E-R Diagrams

- Diamonds represent relationship sets



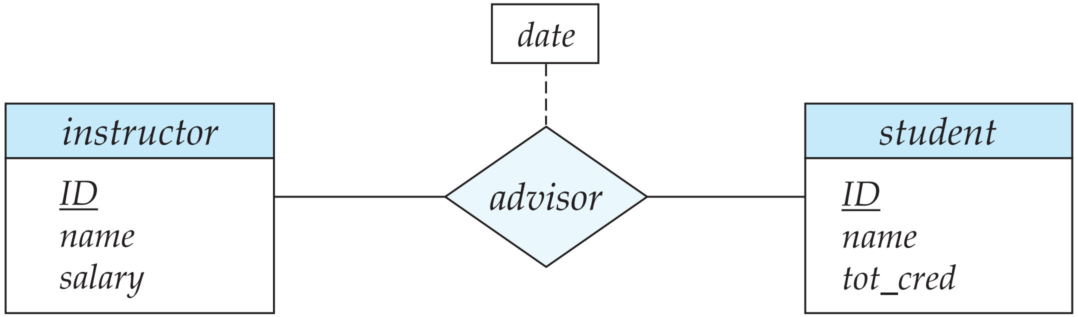
Example: Entity and Relationship Sets

- An attribute can also be associated with a relationship set
    - *E.g.*, 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



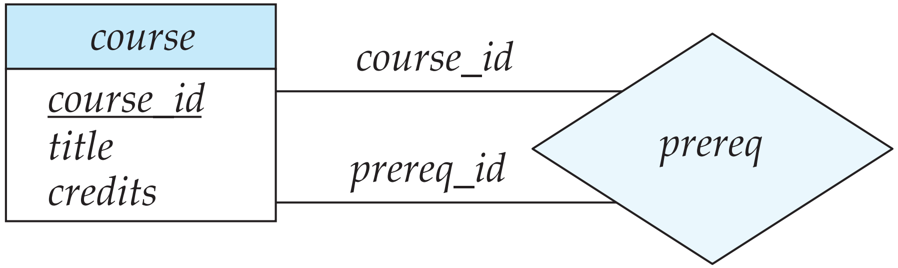
Relationship Sets with Attributes

- An attribute can also be associated with a relationship set



Roles

- Entity sets of a relationship need not be distinct
  - Each occurrence of an entity set plays a "role" in the relationship
  - *E.g.*, The labels "*course_id*" and "*prereq_id*" are called roles



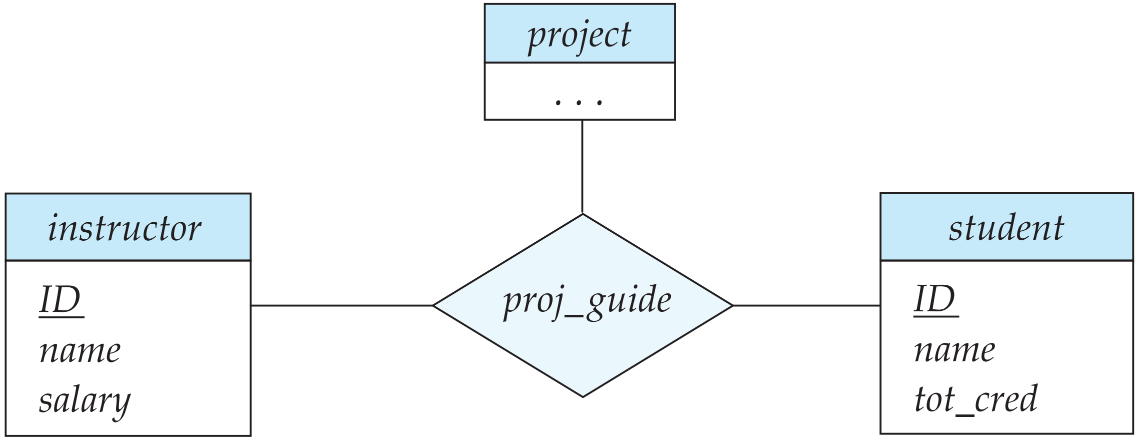
Degree of a Relationship Set

- Binary relationship
  - Involves two entity sets (or degree two)
  - Most relationship sets in a database system are binary

- Relationships between more than two entity sets are rare but possible
  - *E.g., students* work on research *projects* under the guidance of an *instructor*
  - Relationship *proj_guide* is a ternary relationship between *instructor, student,* and *project*

Non-binary Relationship Sets

- Most relationship sets are binary
- There are occasions when it is more convenient to represent relationships as non-binary
- E-R diagram with a ternary relationship:



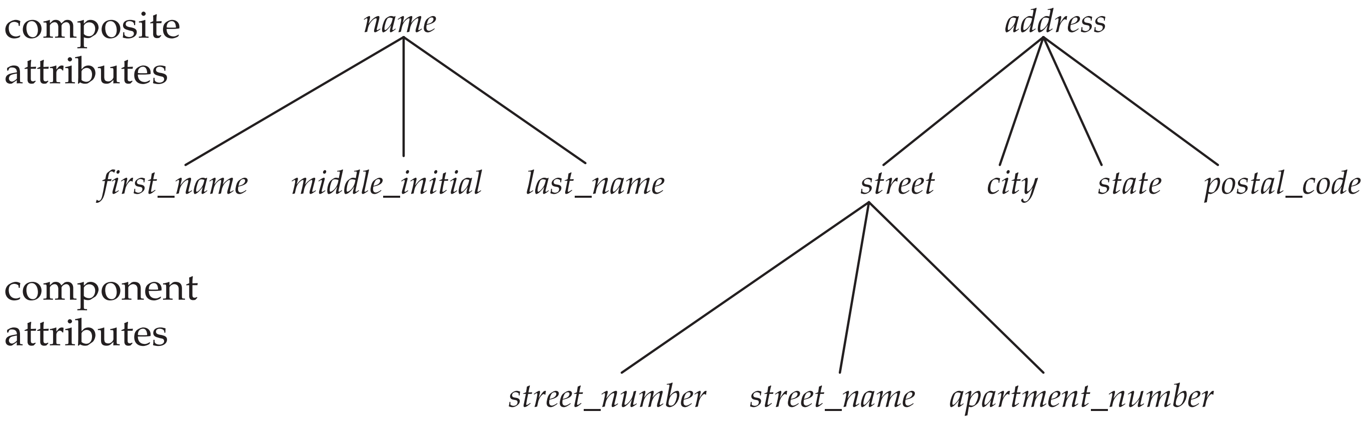
Complex Attributes

- Attribute types:
  - Simple and composite attributes
  - Single-valued and multivalued attributes
    - *E.g.*, multivalued attribute: *phone_numbers* – a person can have more than one phone numbers
  - Derived attributes: attributes that can be computed from other attributes
    - *E.g.*, age, given date_of_birth

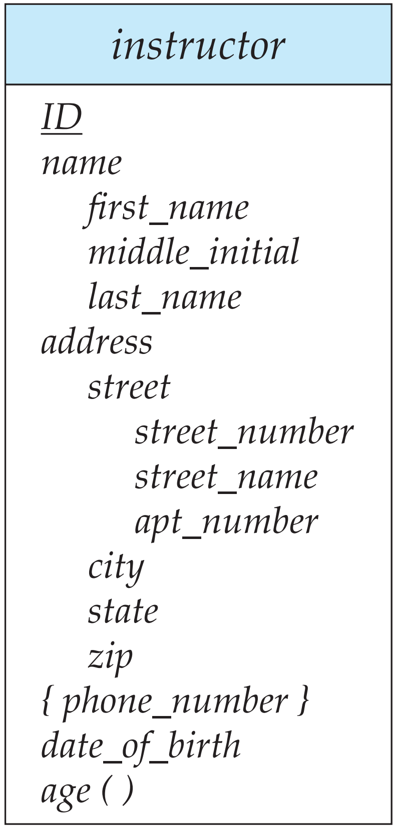
- Domain: the set of permitted values for each attribute

Composite Attributes

- Composite attributes allow us to divided attributes into subparts (other attributes)



Representing Complex Attributes in E-R Diagrams



```
instructor
ID
name
    first_name
    middle_initial
    last_name
address
    street
        street_number
        street_name
        apt_number
    city
    state
    zip
{ phone_number }
date_of_birth
age ( )
```

Agenda

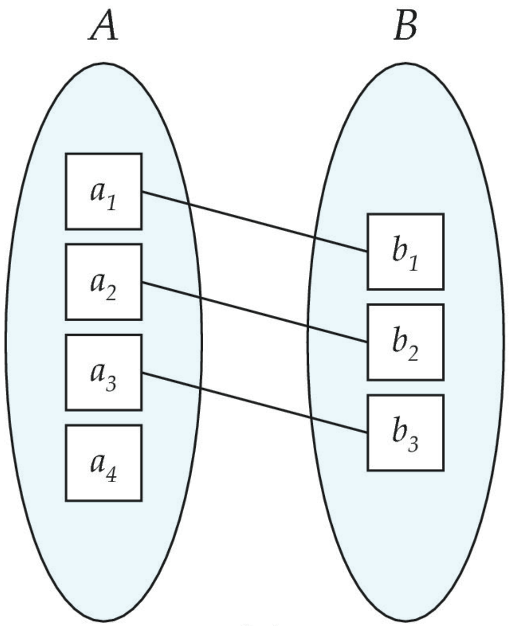
- Designing a database
- E-R diagrams
  - **Mapping cardinalities**
  - Primary keys in E-R models
  - Weak entity sets
  - Reduction to relation schemas

Mapping Cardinalities

- Express the number of entities to which another entity can be associated via a relationship set
  - Most useful in describing binary relationship sets

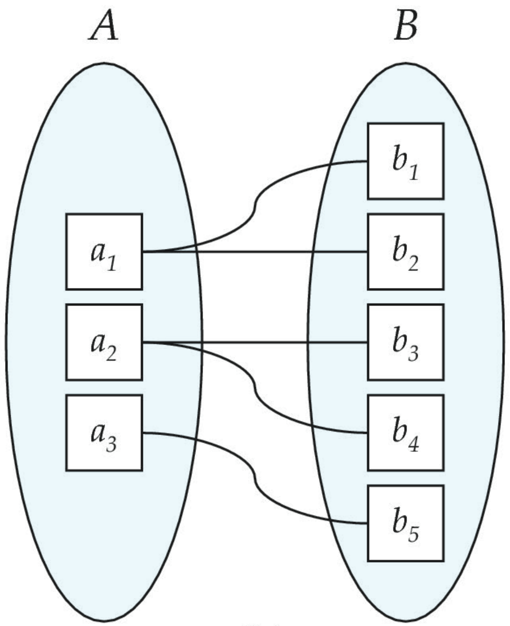
- For a binary relationship set the mapping cardinality must be one of the following types:
  - *One to one*
  - *One to many*
  - *Many to one*
  - *Many to many*

Mapping Cardinalities



(a)

One to one

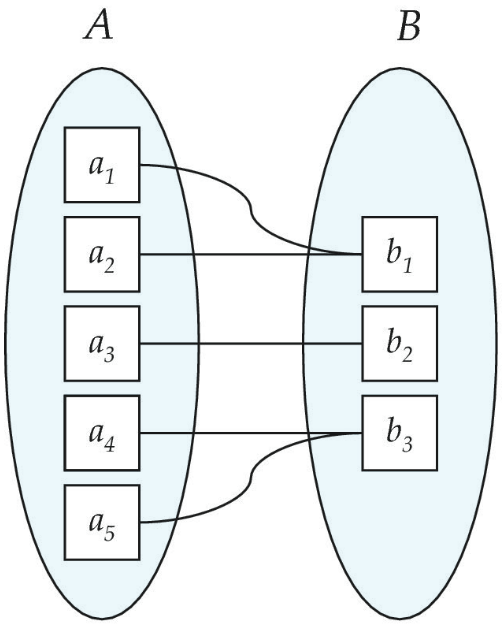


(b)

One to many

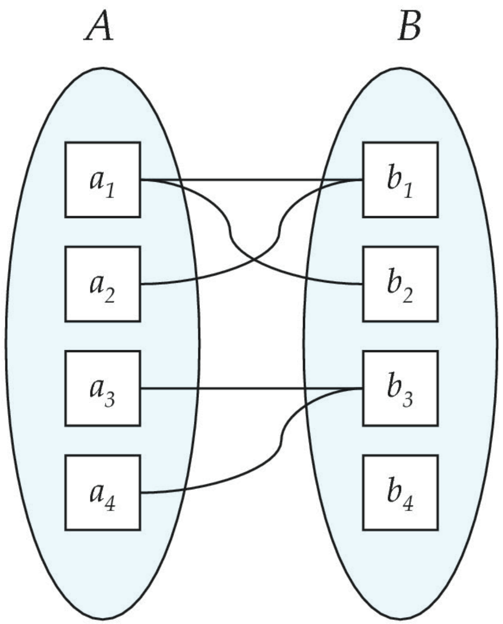
- Note: Some elements in *A* and *B* may not be mapped to any elements in the other set

Mapping Cardinalities



(a)

Many to one



(b)

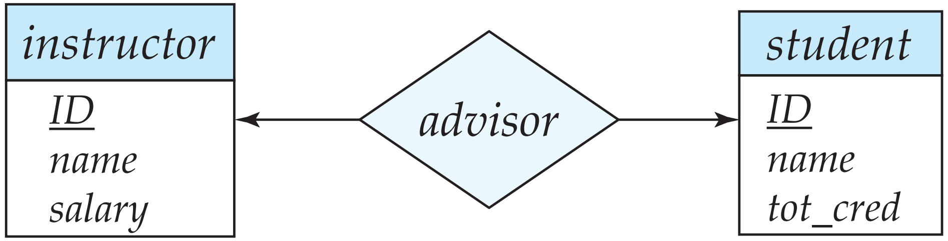
Many to many

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

Representing Cardinalities in E-R Diagrams

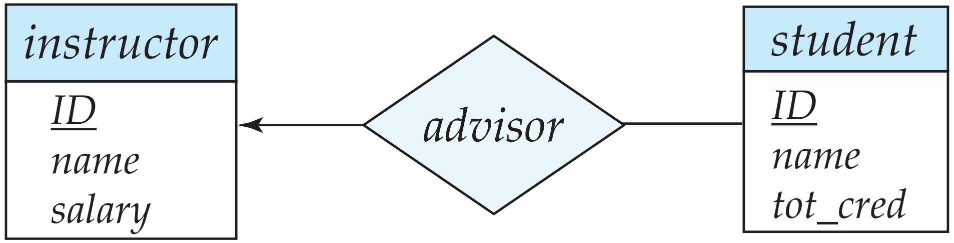
- Express cardinality constraints by drawing either a directed line (→), signifying "one," or an undirected line (—), signifying "many," between the relationship set and the entity set

- One-to-one relationship between an *instructor* and a *student*:
  - A *student* is associated with at most one *instructor* via the relationship *advisor*, and *vice versa*



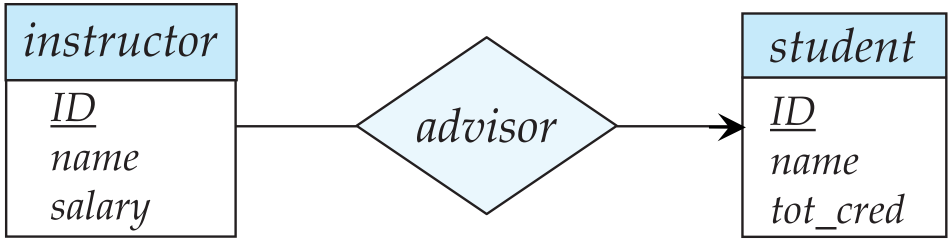
One-to-Many Relationship

- 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*



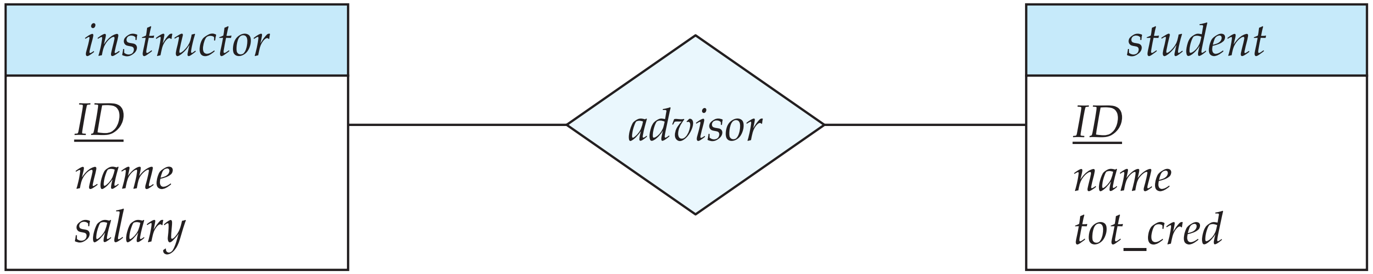
Many-to-One Relationship

- Many-to-one relationship between an *instructor* and a *student*
  - An *instructor* is associated with at most one *student* via *advisor*
  - A *student* is associated with several (including 0) *instructors* via *advisor*



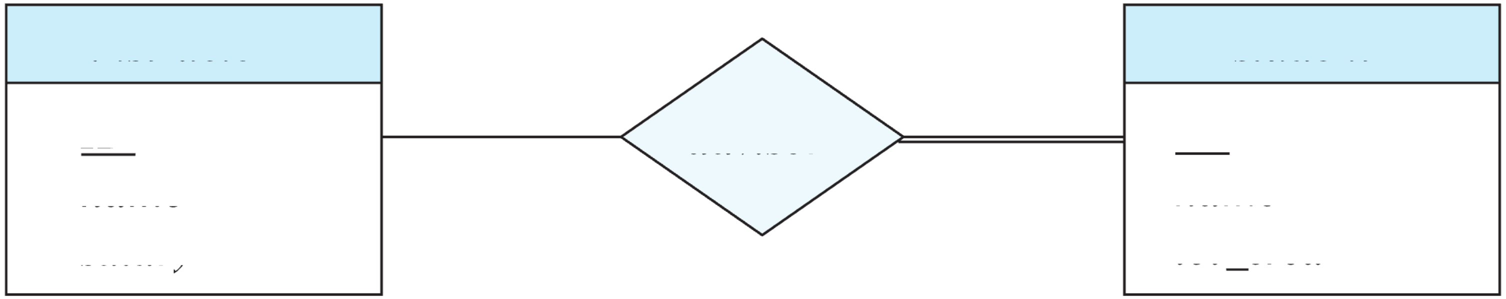
Many-to-Many Relationship

- Many-to-many relationship between an *instructor* and a *student*
  - An *instructor* is associated with several (possibly 0) *students* via *advisor*
  - A *student* is associated with several (possibly 0) *instructors* via *advisor*



Total and Partial Participation

- Total participation (*indicated by double line*): every entity in an entity set participates in at least one relationship in the relationship set



participation of *student* in *advisor r*elation is total

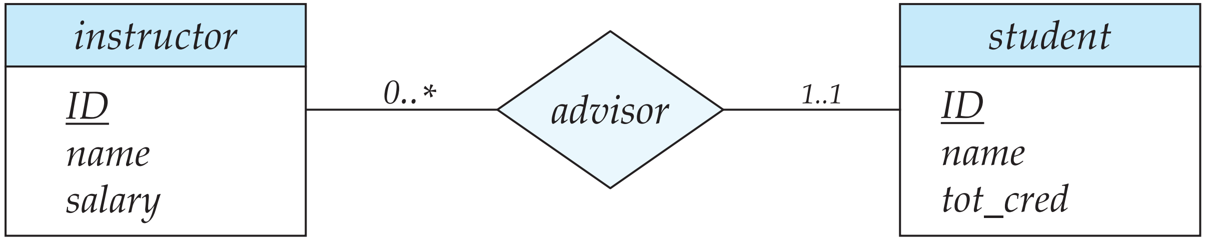
  - *E.g.*, Every *student* must have an associated *instructor*

- Partial participation: some entities may not participate in any relationship in the relationship set
  - *E.g.*, Participation of *instructor* in *advisor* is partial

Notation for Expressing More Complex Constraints

- A line may have an associated minimum and maximum cardinality, shown in the form *l..h*, where *l* is the minimum and *h* the maximum cardinality
  - A minimum value of 1 indicates total participation
  - A maximum value of 1 indicates that the entity participates in at most one relationship
  - A maximum value of * indicates no limit

- Examples
  - Instructor can advise 0 or more students
  - A student must have 1 advisor; cannot have multiple advisors



Agenda

- Designing a database
- E-R diagrams
    - Mapping cardinalities
    - **Primary keys in E-R models**
    - Weak entity sets
    - Reduction to relation schemas

Primary Key

- Primary keys provide a way to specify how entities and relationships are distinguished
- We consider:
  - Entity sets
  - Relationship sets
  - Weak entity sets

Primary Key for Entity Sets

- By definition, individual entities are distinct
- From database perspective, the *differences among entities must be expressed in terms of their attributes*
  - The attribute values of an entity must be such that they can uniquely identify the entity
  - No two entities in an entity set are allowed to have exactly the same value for all attributes
- A key for an entity is a set of attributes that suffice to distinguish entities from each other

Primary Key for Relationship Sets

- To distinguish among the various relationships of a relationship set, use the individual primary keys of the entities in the relationship set
  - Let R be a relationship set involving entity sets E_1, E_2, …, E_n
  - The primary key for R is consists of the union of the primary keys of entity sets E_1, E_2, …, E_n
  - If the relationship set R has attributes a_1, a_2, ..., a_m associated with it, then the primary key of R also includes the attributes a_1, a_2, ..., a_m

- Example: relationship set "*advisor*"
  - The primary key consists of *inrsructor.ID* and *student.ID*

Choice of Primary Key for Binary Relationship

- The choice of the primary key for a relationship set depends on the mapping cardinality of the relationship set
  - Many-to-Many relationships: The preceding union of the primary keys is a minimal super key and is chosen as the primary key
  - One-to-Many relationships: The primary key of the "Many" side is a minimal super key and is used as the primary key
    - Many-to-one relationships: The primary key of the "Many" side is a minimal super key and is used as the primary key
  - One-to-one relationships: The primary key of either one of the participating entity sets forms a minimal super key, and either one can be chosen as the primary key

Agenda

- Designing a database
- E-R diagrams
  - Mapping cardinalities
  - Primary keys in E-R models
  - **Weak entity sets**
  - Reduction to relation schemas

Weak Entity Sets

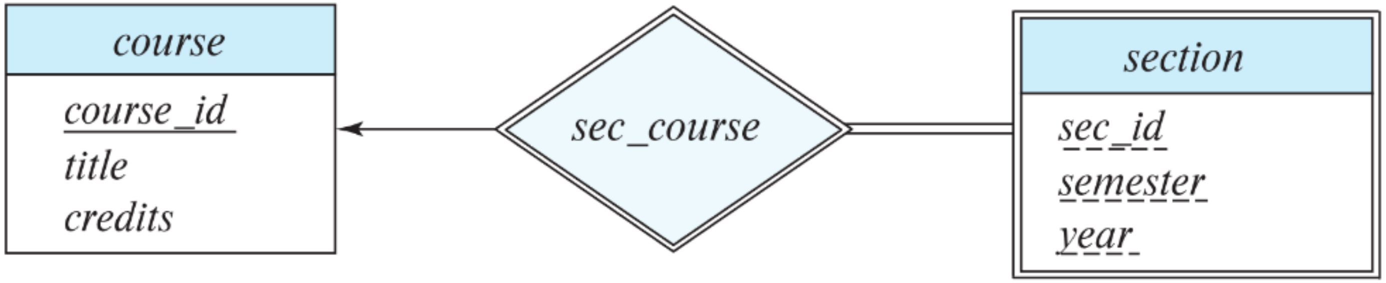
- A weak entity set is one whose existence is dependent on another entity, called its identifying entity
- Instead of associating a primary key with a weak entity, use the identifying entity, along with extra attributes called discriminator to uniquely identify a weak entity
  - A weak entity set does not have a primary key
  - We still need a *means of distinguishing* among an entity set
    - Discriminator of a weak entity: a set of attributes allowing such distinction
    - Primary key of a weak entity set

      = primary key of a strong entity set (which its existence depends)

      + its discriminator

Weak Entity Sets

- A weak entity set is one whose existence is dependent on another entity, called its identifying entity
- Instead of associating a primary key with a weak entity, use the identifying entity, along with extra attributes called discriminator to uniquely identify a weak entity
  - *E.g.*, Consider a *section* entity, which is uniquely identified by a *course_id*, *semester, year*, and *sec_id* → Section entities are related to course entities
    - Treat the relationship *sec_course* as a special relationship that provides extra information
    - In this case, the *course_id*, required to identify *section* entities uniquely



Weak Entity Sets

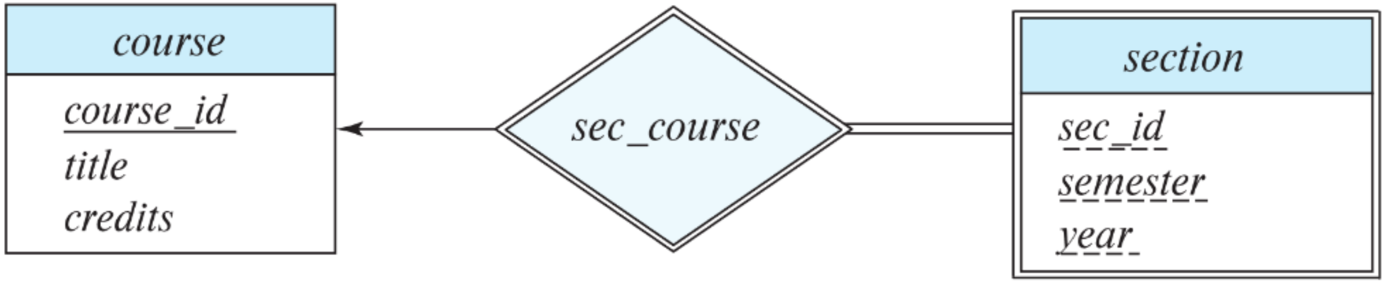
- Identifying entity
  - Every weak entity must be associated with an identifying entity;
    - That is, the weak entity set is said to be existence dependent on the identifying entity set

- The identifying entity set is said to own the weak entity set that it identifies
  - Identifying entity set: an entity set that has a primary key
  - Identifying entity set = strong entity set

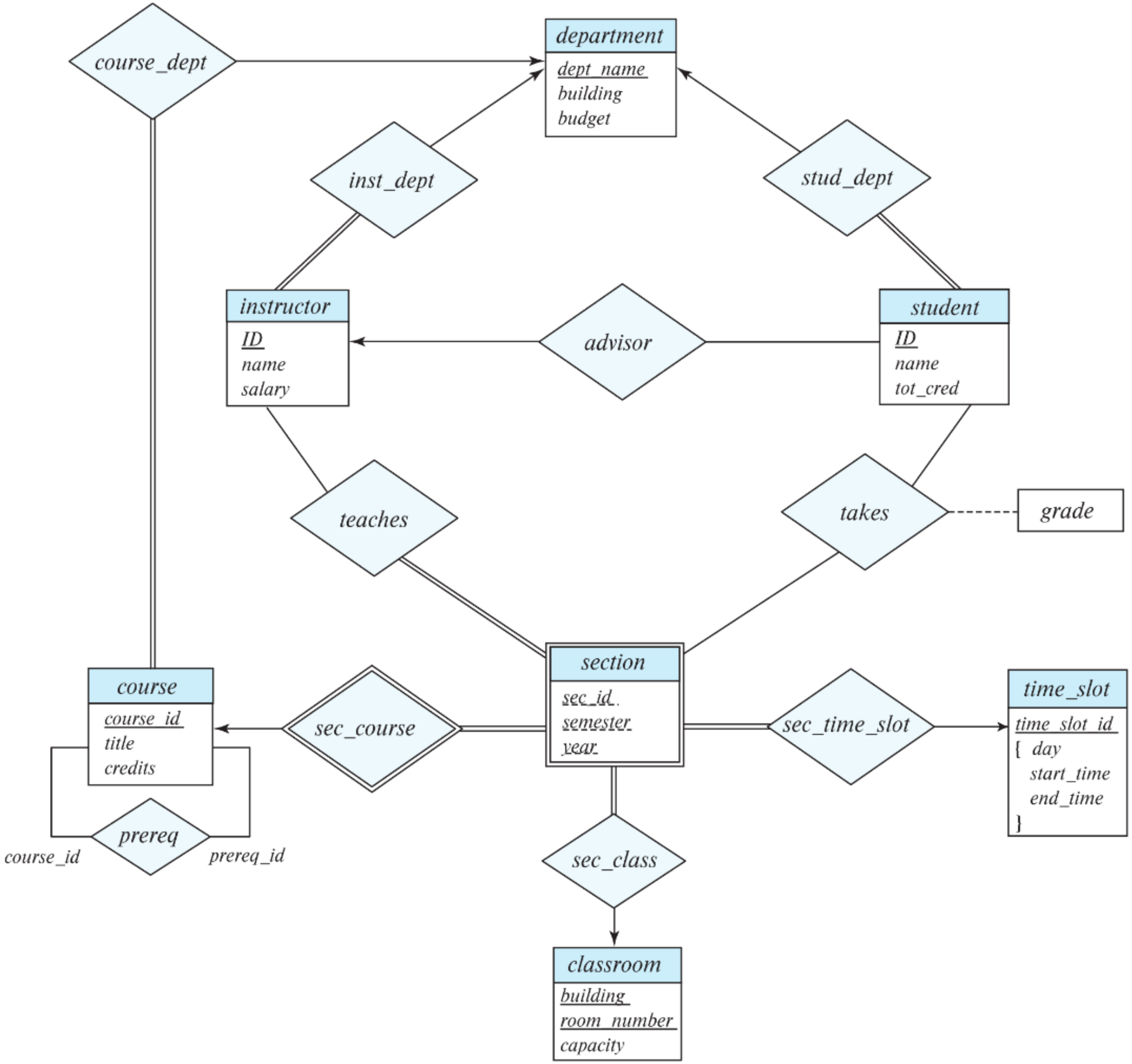
- Identifying relationship
  - Identifying relationship: The relationship associating the weak entity set with the identifying entity set

Expressing Weak Entity Sets

- A weak entity set is depicted via a double rectangle
- Underline the discriminator of a weak entity set with a dashed line
- The relationship set connecting the weak entity set to the identifying strong entity set is depicted by a double diamond
  - *E.g.*, Primary key for section – (*course_id, sec_id, semester, year*)



E-R Diagram for a *University* Database



Agenda

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  - Primary keys in E-R models
  - Weak entity sets
  - **Reduction to relation schemas**

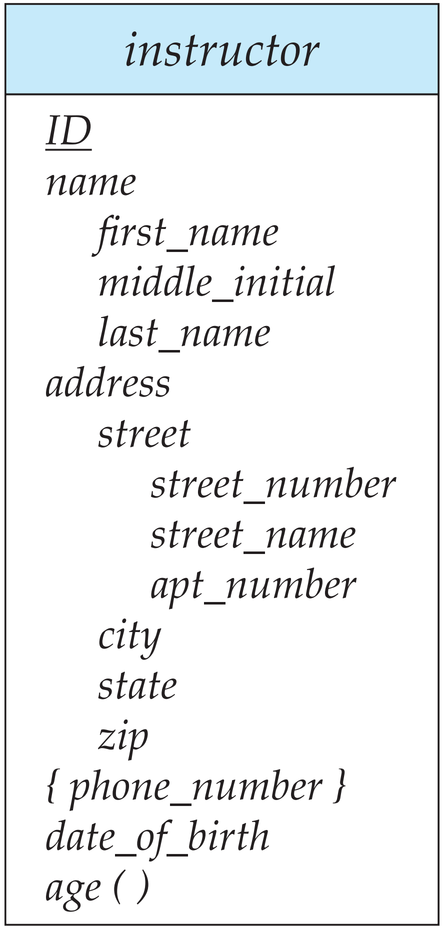
Reduction to Relation Schemas

- Entity sets and relationship sets can be expressed uniformly as relation schemas
  - For each entity set and relationship set, there is a unique schema that is assigned the name of the corresponding entity set or relationship set
  - Each schema has a number of columns (generally corresponding to attributes), which have unique names

Representing Entity Sets

- A strong entity set reduces to a schema with the same attributes
  - *E.g., 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
  - *E.g., section (course_id, sec_id, sem, year)*

Representation of Entity Sets with Composite Attributes



instructor

ID
name
first_name
middle_initial
last_name
address
street
street_number
street_name
apt_number
city
state
zip
{ phone_number }
date_of_birth
age ( )

- Composite attributes are flattened out by creating a separate attribute for each component attribute
  - *E.g., first_name* → *name_first_name*
    last_name → *name_last_name*
  - Prefixes can be omitted if there is no ambiguity
  - *E.g.*, Ignoring multivalued attributes (*phone_number*), a corresponding instructor schema is:
    - *instructor(ID,*
      first_name, middle_initial, last_name,
      street_number, street_name, apt_number,
      city, state, zip_code,
      date_of_birth)

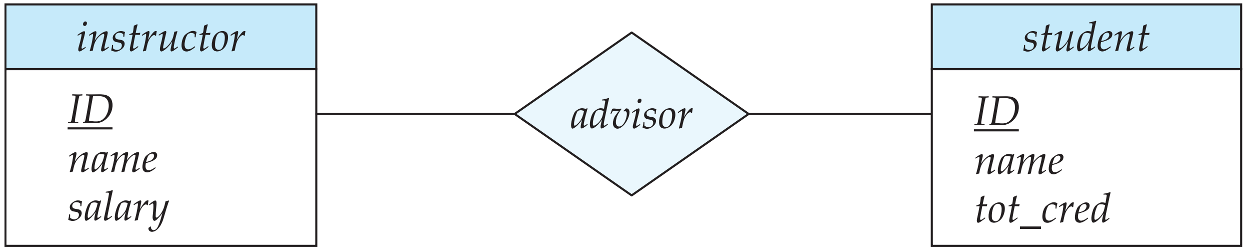
Representation of Entity Sets with Multivalued Attributes

- 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 an attribute corresponding to multivalued attribute *M*
  - *E.g.*, Multivalued attribute *phone_number* of *instructor*:
    - *inst_phone*(<u>*ID*</u>, <u>*phone_number*</u>)

- Each value of the multivalued attribute maps to a separate tuple of the relation on schema *EM*
  - *E.g.*, an *instructor* entity with primary key 22222
    and phone numbers 456-7890 and 123-4567
    → maps to two tuples

Representing Relationship Sets

- Any relationship set of strong entity sets can be represented as a schema with attributes for the primary keys of the two participating entity sets, and any descriptive attributes of the relationship set
  - *E.g.*, schema for relationship set *advisor*
    - *advisor* = (*s_id*, *i_id*)



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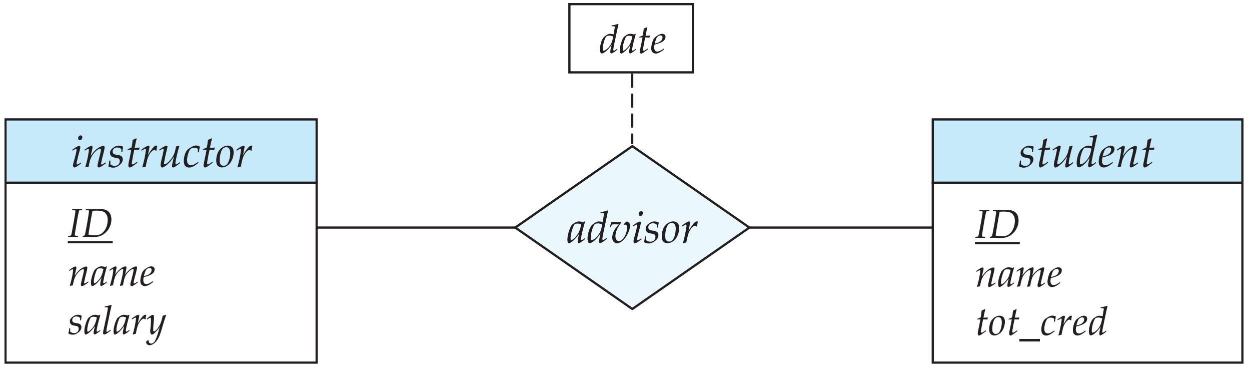
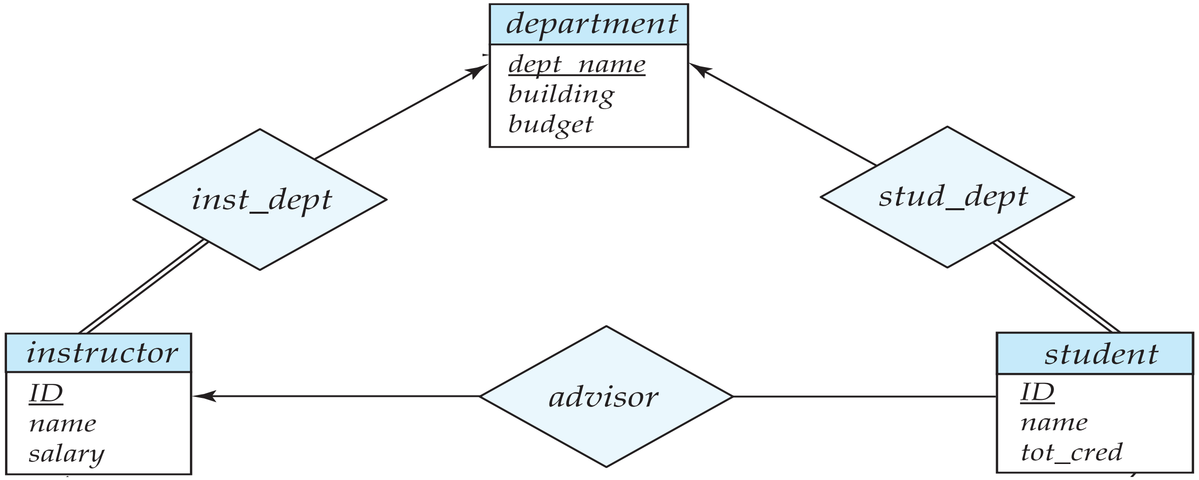
  - *E.g.*, schema for relationship set *advisor*
    - *advisor* = (*s_id*, *i_id*)



Redundancy of Schemas

- Such "mapping tables" may be redundant
  - 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, containing the primary key of the "one" side
    - *E.g.*, Instead of creating a schema for relationship set *inst_dept*, add an attribute *dept_name* to the schema arising from entity set *instructor*



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  - Can be represented by adding an extra attribute to the “many” side, containing the primary key of the “one” side
    - *E.g.*, Instead of creating a schema for relationship set *inst_dept*, add an attribute *dept_name* to the schema arising from entity set *instructor*
  - When 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

Redundancy of Schemas

- Such “mapping tables” may be redundant
  - For one-to-one relationship sets, either side can be chosen to act as the “many” side
    - An extra attribute can be added to either of the tables corresponding to the two entity sets