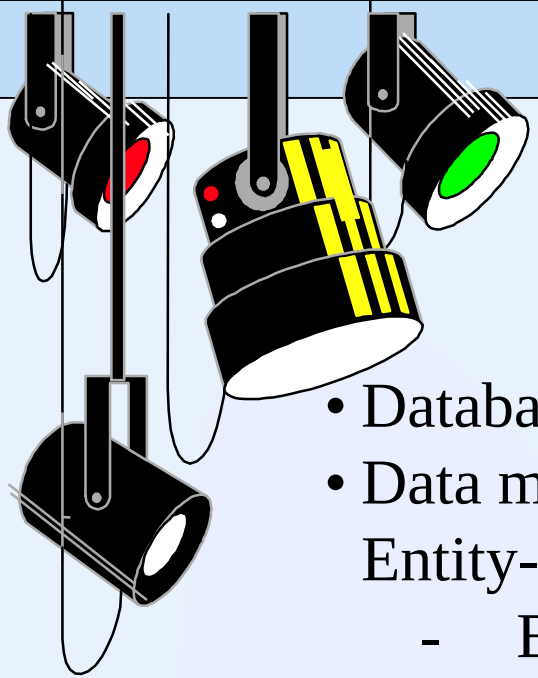
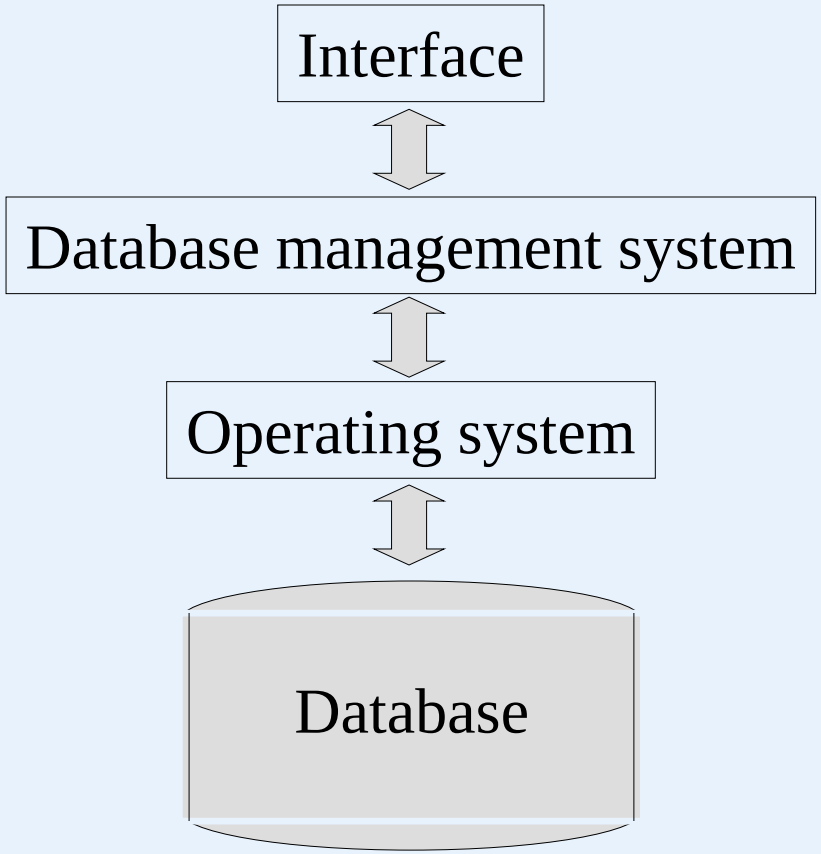


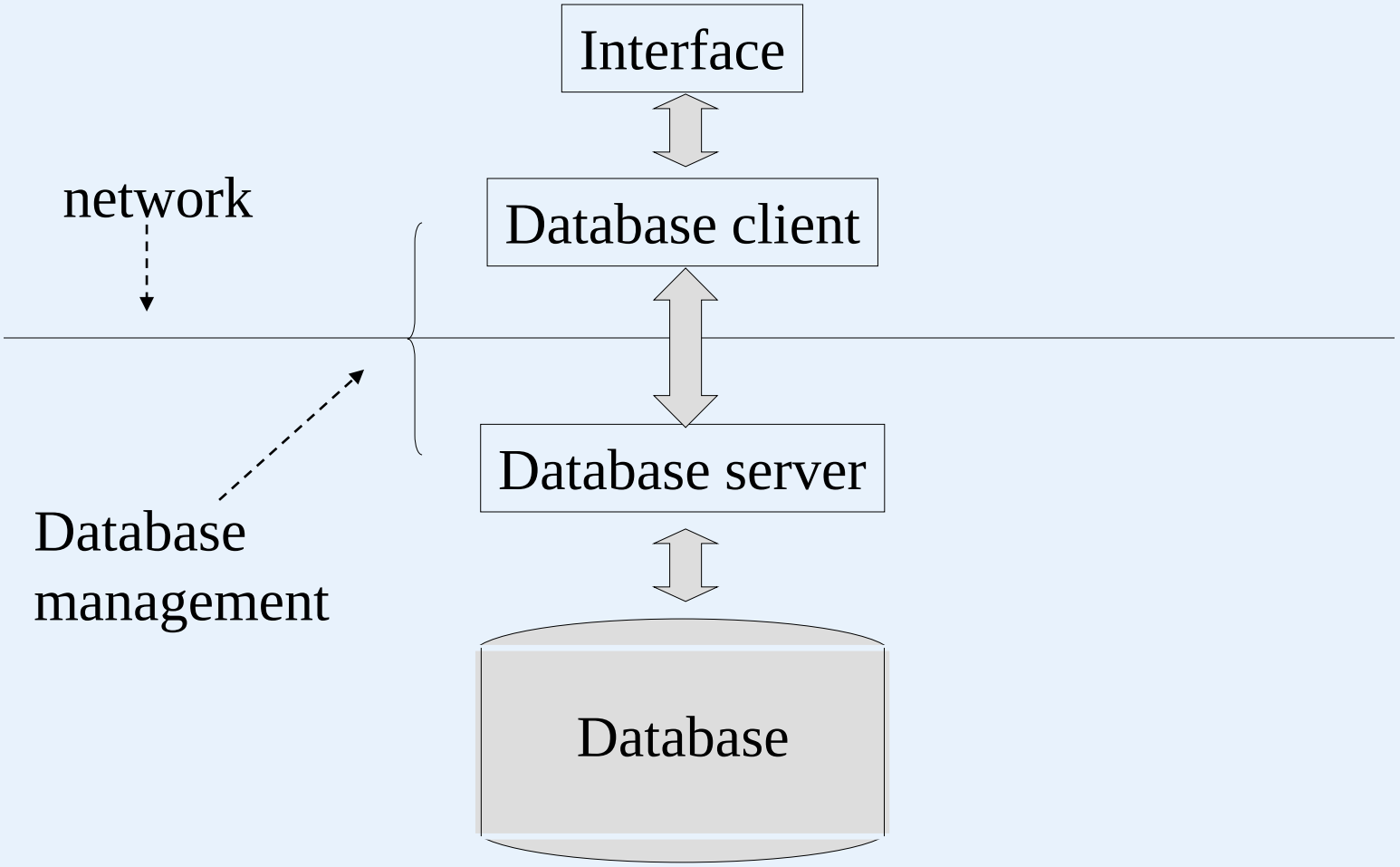
Outline: Database Basics

- Database system architecture
- Data modeling
  Entity-relationship model
  - Entity types
    - strong entities
    - weak entities
  - Relationships among entities
  - Attributes - attribute classification
  - Constraints
    - cardinality constraints
    - participation constraints
- ER-to-Relation-mapping

- **Database system architecture**

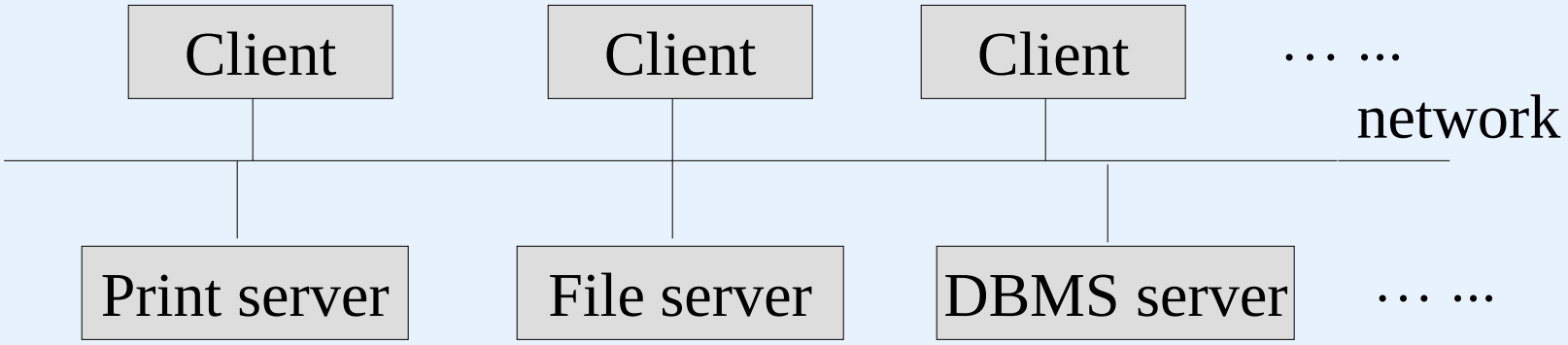


- Client-server database system Architecture

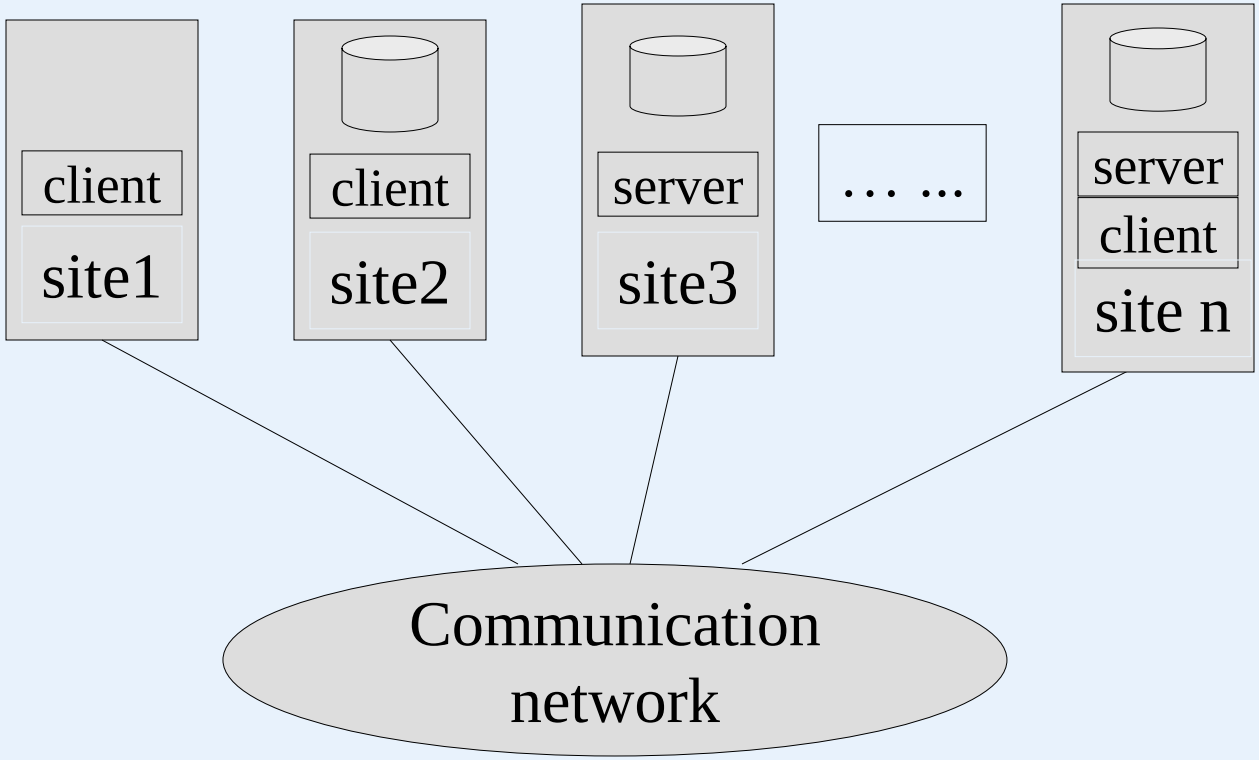


- Client-Server Computer Architecture
  - Terminals are replaced with PCs and workstations
  - Mainframe computer is replaced with specialized servers (with specific functionalities).

    File server, DBMS server, mail server, print server, …



- **Client-server database System Architectures**



Database Basics

- Client-Server database system architecture
  - database client

    user interface, application programs
  - database server

    SQL language, transaction management
  - database connection

    ODBC - open database connectivity

    API - application programming interface

- Client-server database system architecture
  - database client

    user interface, data dictionary functions, DBMS interaction with programming language compiler, global query optimization, structuring of complex objects from the data in the buffers, ...
  - database server

    data storage on disk, index mechanism, local concurrency control and recovery, buffering and caching of disk storage, ...

- Data dictionary – system catalog (meta data)
  - relation names, attribute names, attribute domains (data types)
  - description of constraints

    primary keys, secondary keys, foreign keys, NULL/NON-NULL, cardinality constraints, participation constraints, ...
  - views, storage structure, indexes
  - security, authorization, owner of each relation

- Catalog is stored as relations. (It can then be queried, updated and managed using DBMS software - SQL.)

REL_AND_ATTR_CATALOG

REL_NAME	ATTR_NAME	ATTR_TYPE	MEMBER_OF_PK	MEMBER_OF_FK	FK_RELATION
EMPLOYEE	FNAME	VSTR15	no	no	
…	…				
EMPLOYEE	SUPERSSN	STR9	no	yes	EMPLOYEE
EMPLOYEE	DNO	INTEGER	no	yes	DEPARTMENT
…	…				

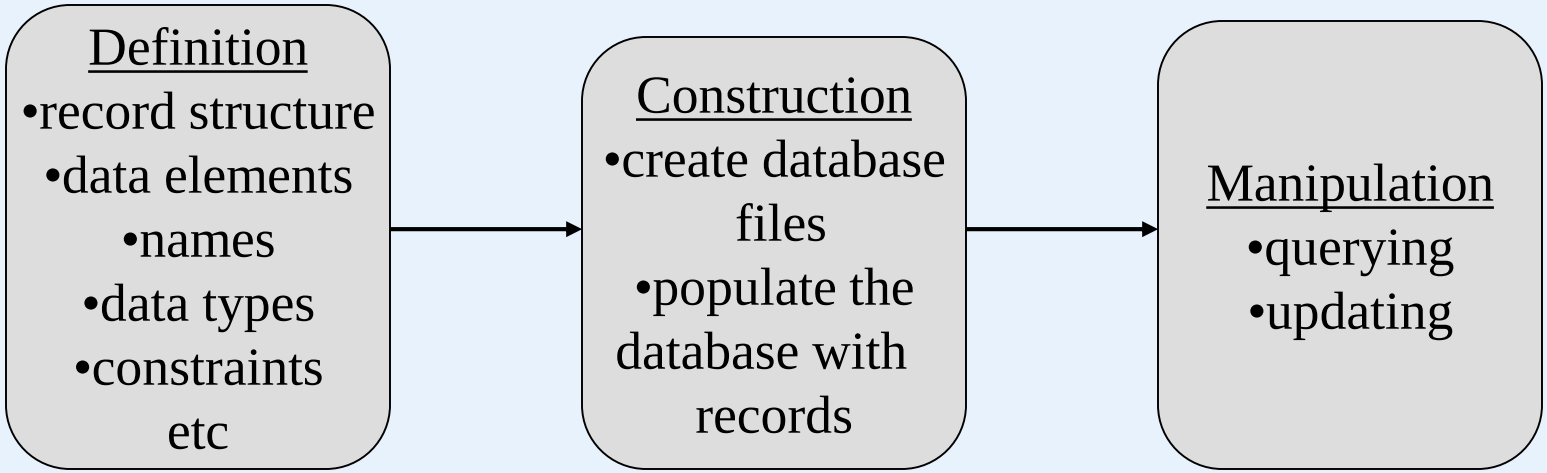
Employee relation schema:

FNAME	**LNAME**	**SSN**	**SUPERSSN**	**DNO**	…

Illustration for DBMS interaction with programming language compiler:

```
EXEC SQL DECLARE C1 CURSOR FOR
SELECT au_fname, au_lname FROM authors FOR BROWSE;
EXEC SQL OPEN C1;
while (SQLCODE == 0)
{
        EXEC SQL FETCH C1 INTO :fname, :lname;
}
```

- Working process with DBMS

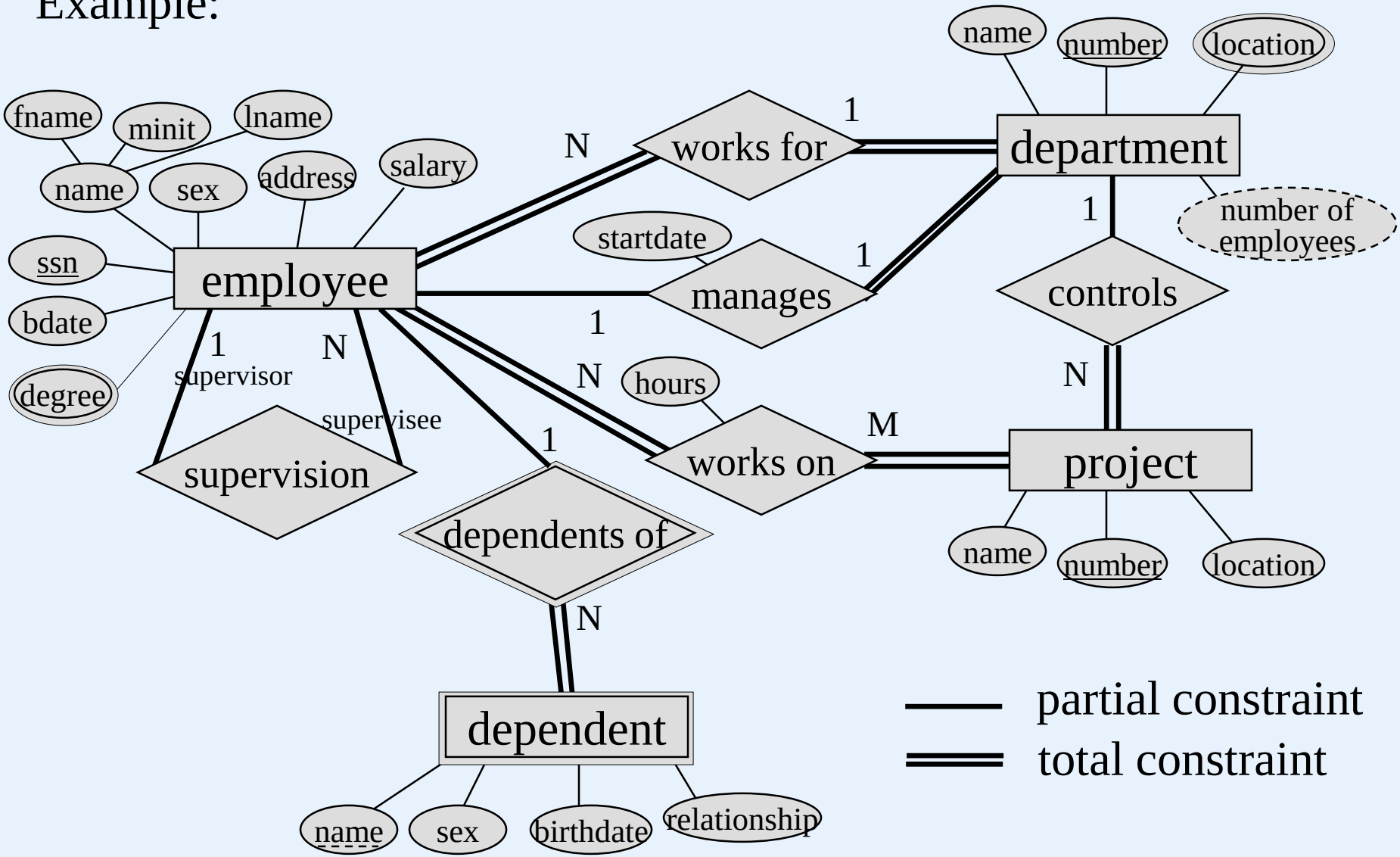


- **Entity-relationship model (ER model)**

ER model:

- is used to create a conceptual data model that reflects all the user data requirements.
- It includes detailed descriptions of
    - entity types,
    - relationships, and
    - constraints
- no implementation details. So it can be used for communication with non-technical users

Example:


name
number
location
fname
minit
lname
name
sex
address
salary
ssn
bdate
degree
employee
works for
1
N
department
1
number of employees
startdate
manages
1
1
controls
1
supervisor
N
supervisee
N
hours
N
M
supervision
1
works on
project
dependents of
name
number
location
N
dependent
name
sex
birthdate
relationship
partial constraint
total constraint

Entities

•entity type – logical object (concept), physical object

•strong entity

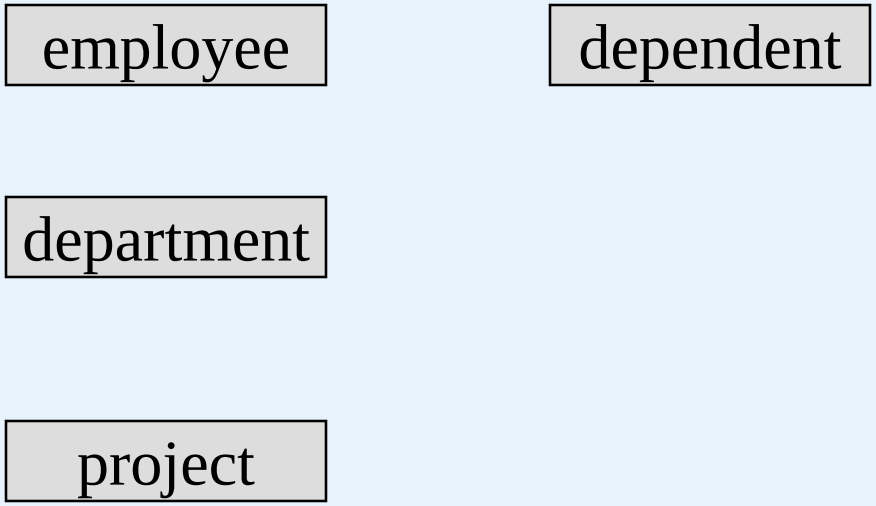
- key attribute – uniquely identifies an individual entity
- entity has a key attribute or a combination of attributes which can be used as a key.

•weak entity

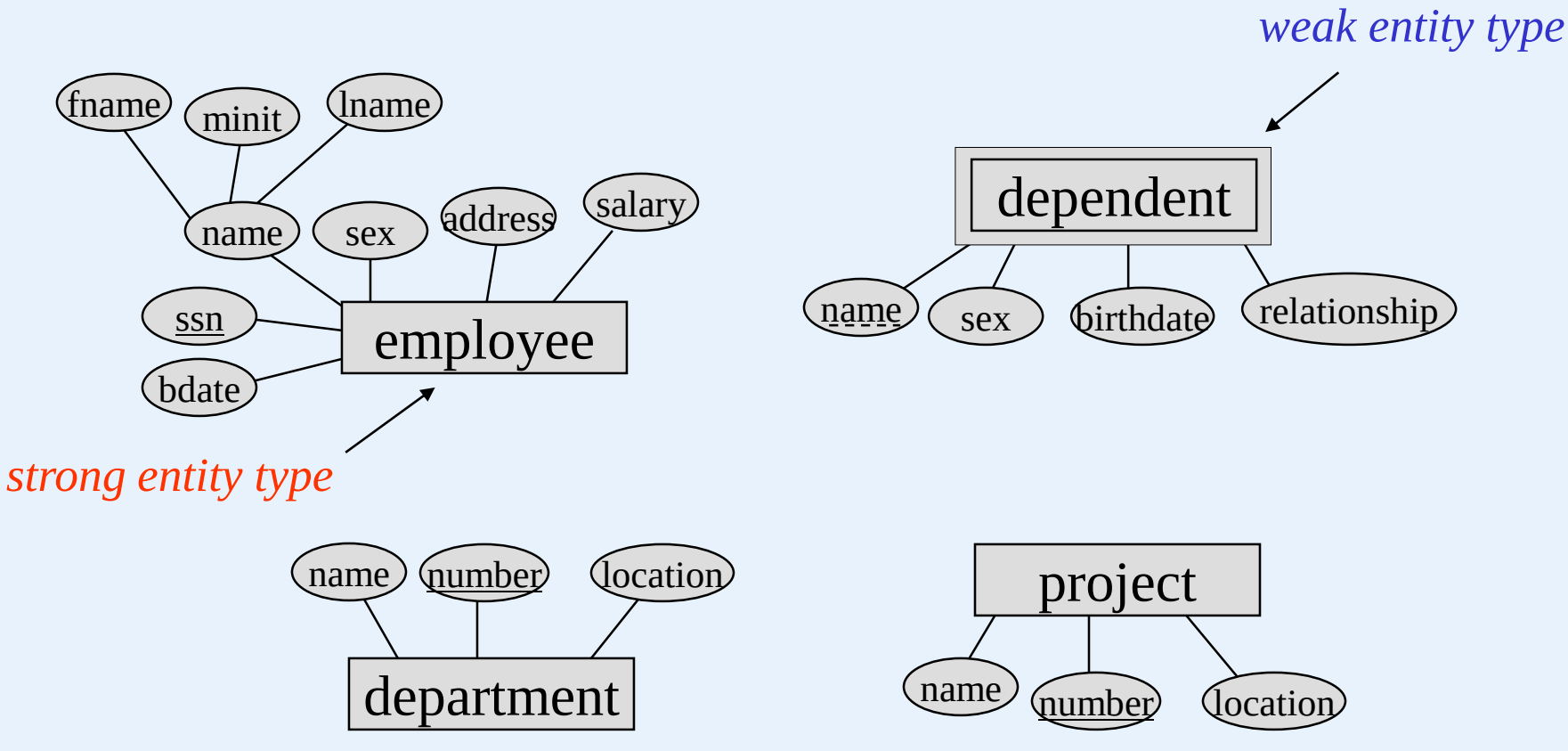
No key attributes. Entities belonging to a weak entity type are identified by being related to specific entities from another entity type in combination with some of their attribute values.

- identifying owner
- identifying relationship
- partial key

The entities:



The entities:



Attribute – property of an entity type

Attribute classification

- atomic attribute
- multivalued attribute
- composite attribute
- complex (nested) attributes

Attribute storage

- stored & derived attribute

- null values

  not applicable, unknown, missing

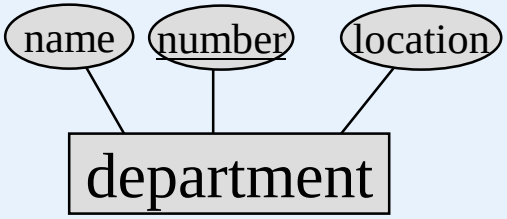
- key attribute
- Domain

  From a domain, an attribute takes its values.

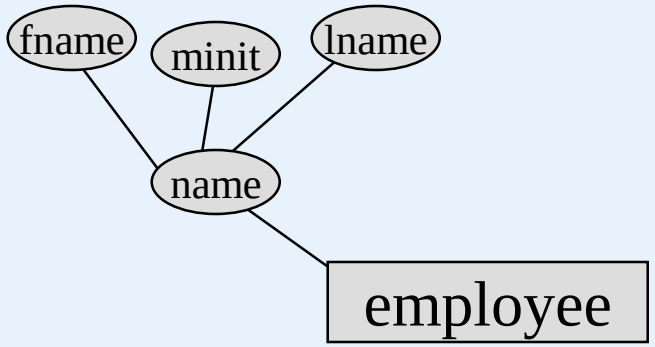
  data type

Attribute classification

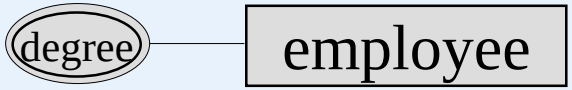
- atomic attribute



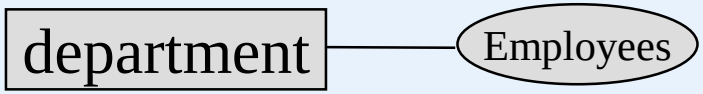
- composite attribute



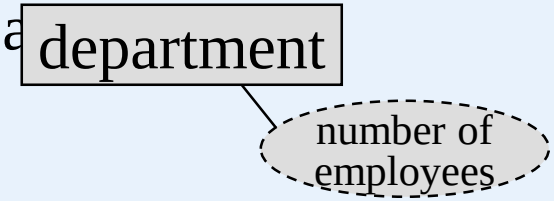
- Multivalued attribute



- Complex attribute



- stored & derived



not often used in practice

- **Relationships**

  - degree of a relationship

  - recursive relationship

  - role names

  - constraints

    cardinality: 1:1, 1:*n*, *m*:*n*

    participation (existence dependency) :

      partial – all the entities take part in a relationship

      total – all the entities take part in a relationship

Example

The company database keeps track of a company's employees, departments, and projects:

Requirements:

concerning the department:

1. company is organized into departments
2. a department has a unique name, a unique number, and a specific employee is its' manager
3. we track the start date for the manager function
4. a department may be in several locations
5. a department controls a number of projects

concerning the project:

6. a project has a unique name, a unique number, and is in a single location

example continued

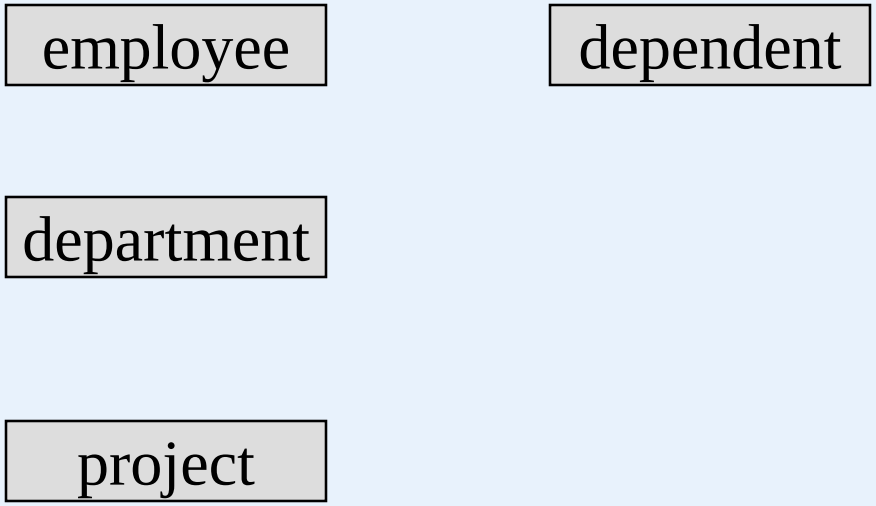
concerning the employee:

7. each employee has a name, social insurance number, address, salary, sex, and birth date
8. an employee is assigned to one department but may work on several projects which are not necessarily controlled by the same department
9. we track the number of hours per week that an employee works on each project
10. we keep track of the direct supervisor of each employee
11. we track the dependents of each employee (for insurance purposes)

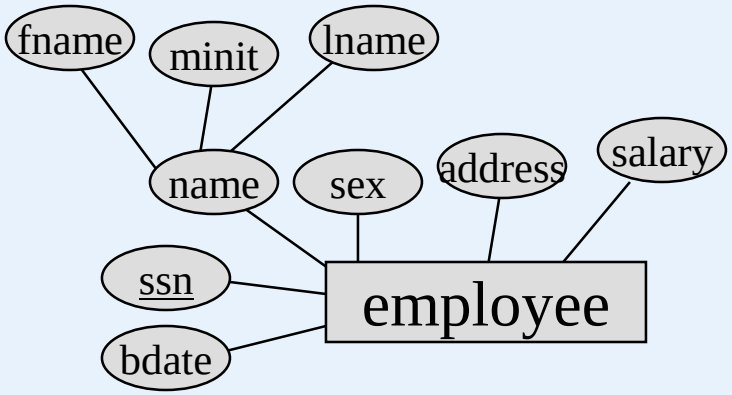
concerning the dependent:

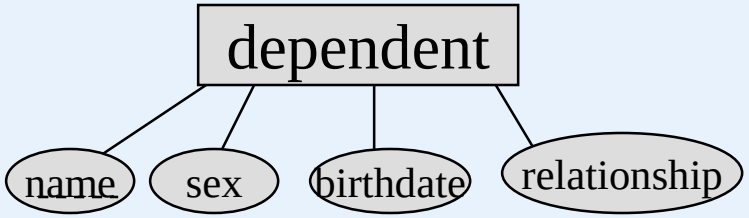
12. we record each dependent's first name, sex, birth date, and relationship to the employee

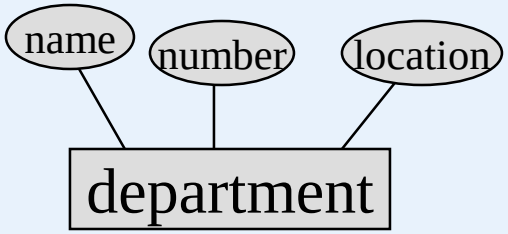
The entities:

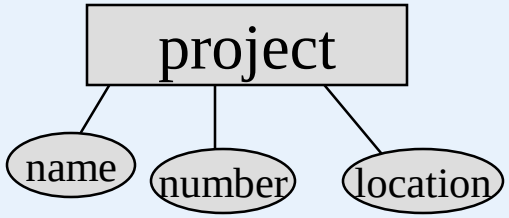


The entities:

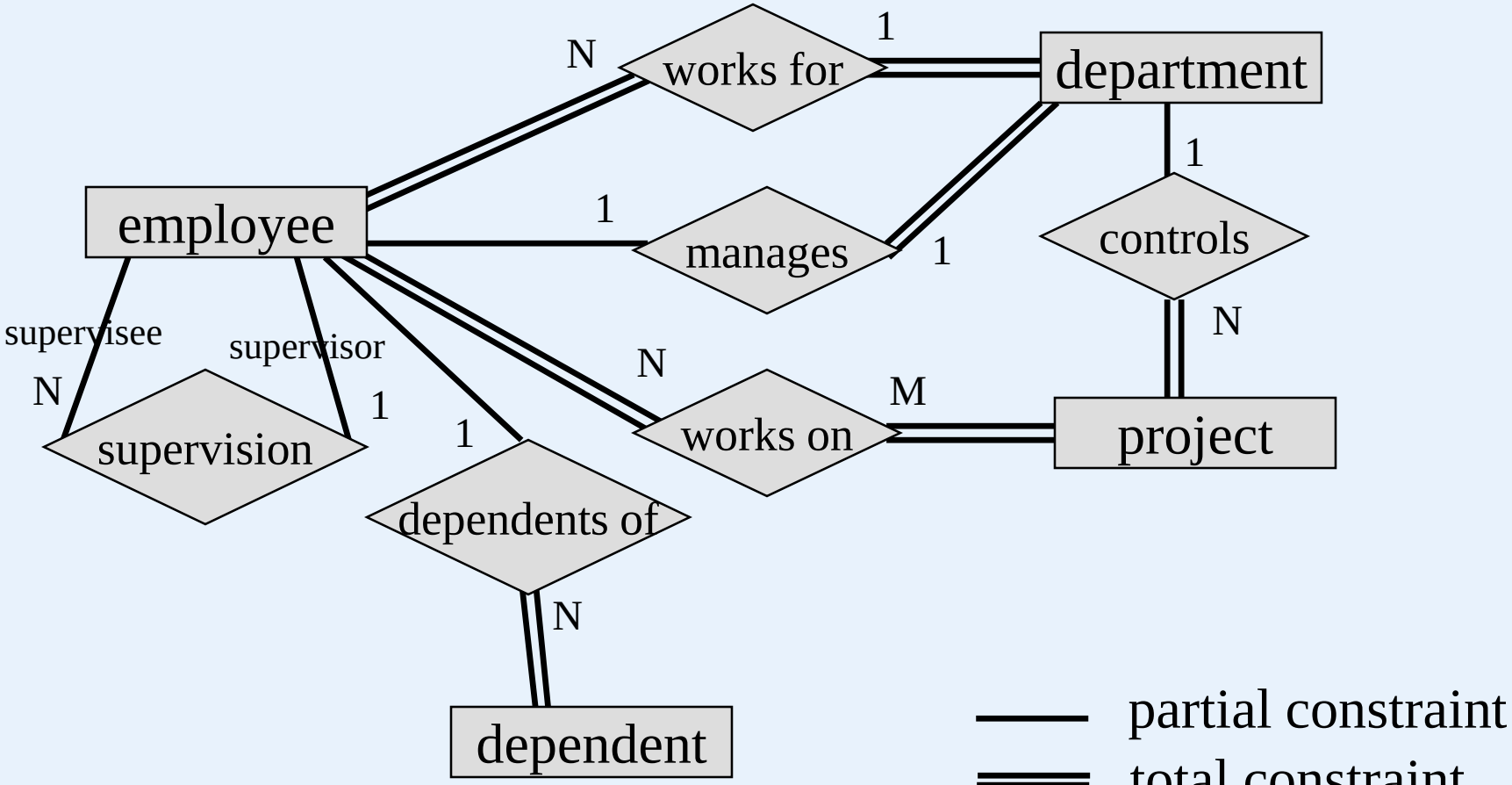




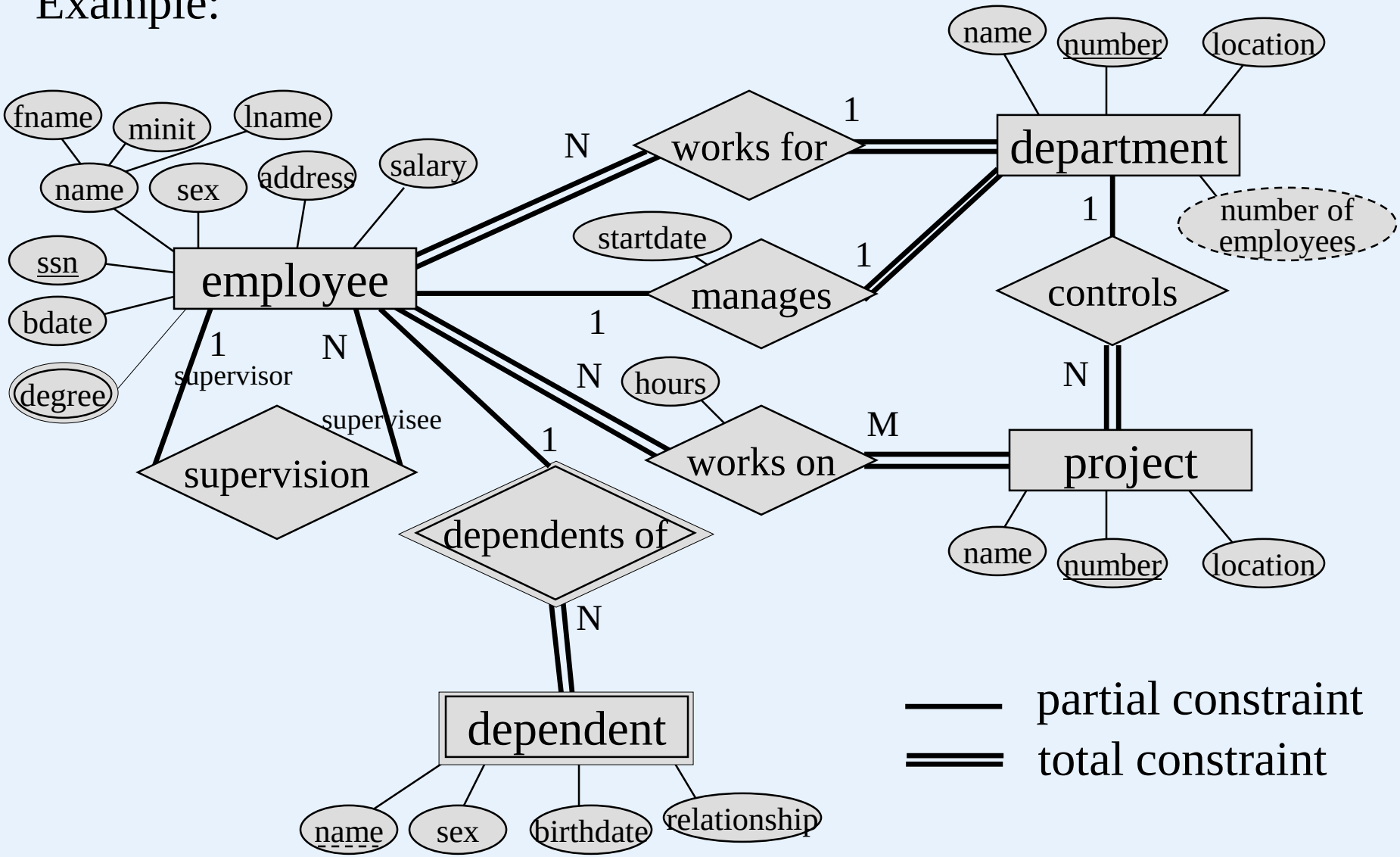




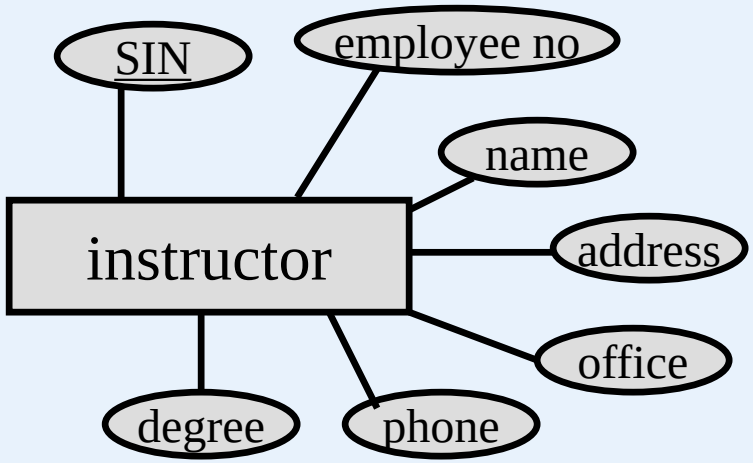
With relationships:



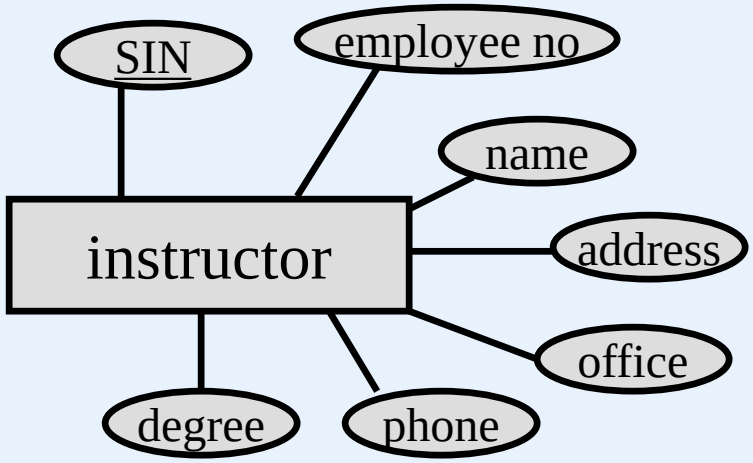
Example:


name
number
location
fname
minit
lname
name
sex
address
salary
ssn
bdate
degree
employee
works for
1
N
department
1
number of employees
startdate
manages
1
1
controls
1
supervisor
N
N
hours
N
supervisee
1
M
supervision
works on
project
dependents of
name
number
location
N
dependent
name
sex
birthdate
relationship
partial constraint
total constraint

Instructors: let's assume this classification includes instructors, professors, part-time people (at least for now). These people have SINs, employee numbers, names, addresses, offices, phones, ...



Is there a *key* attribute*?* What are the *domains?* Can any attribute be *null?* Is any attribute *composite*, *derived*, *complex*, *multivalued?*

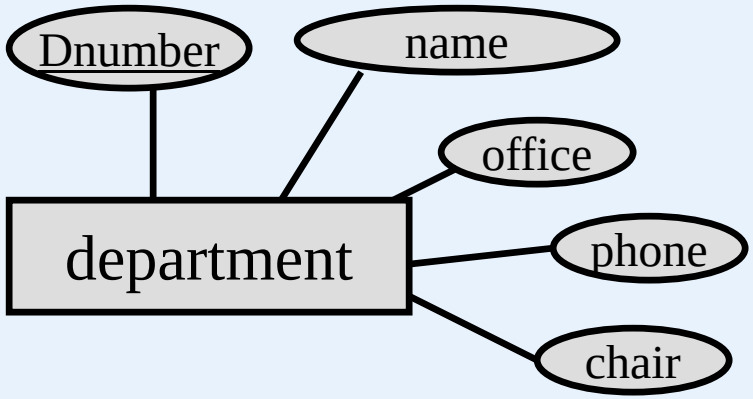


Is this a *weak* entity or a *strong* entity*?*

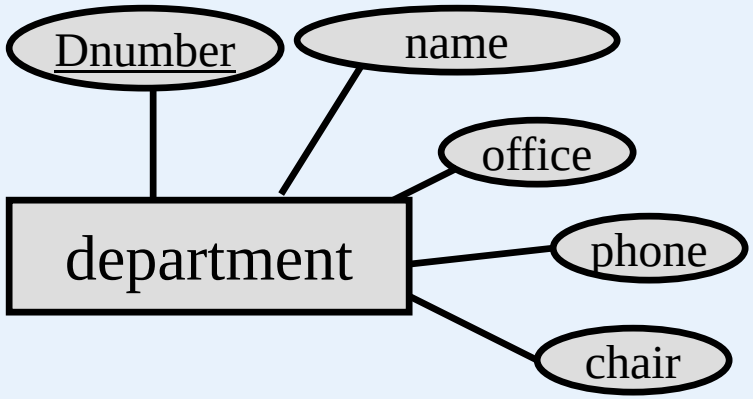
Should department be an attribute?

Departments: obviously instructors are employed by the University and associated with a department

A department has a name, number, office, chair, ...

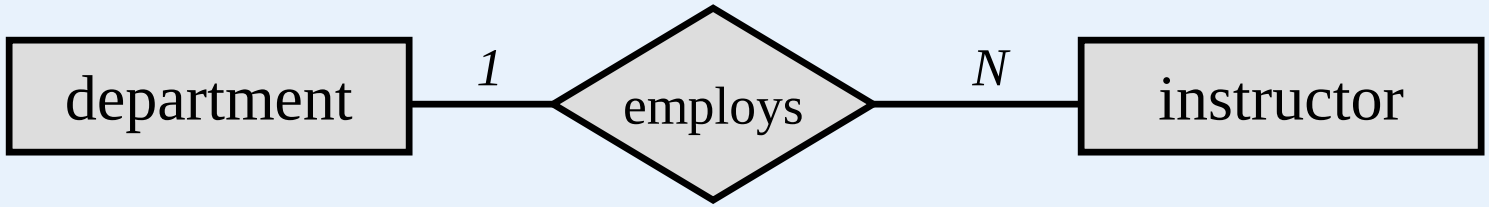


Is there a *key* attribute*?* What are the *domains?* Can any attribute be *null?* Is any attribute *composite, derived, complex, multivalued?*



Should chair be an attribute, or is there a relationship between two entity types?

Employs relationship: If we assume the relationship between department and instructor is *1:N* then we only associate each department with a single instructor, but we associate any number of instructors with a single department

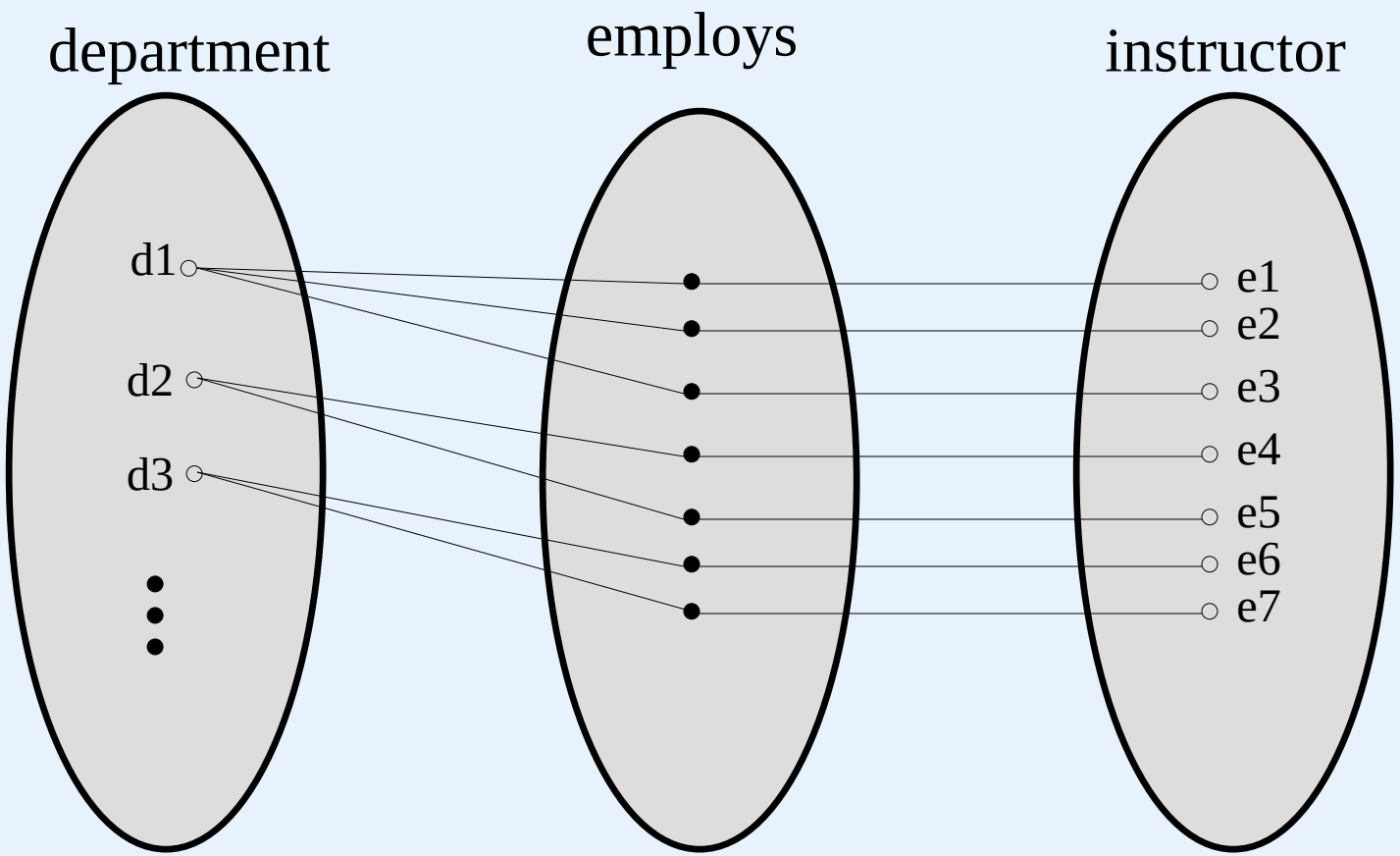


1:N is the *cardinality* of the relationship

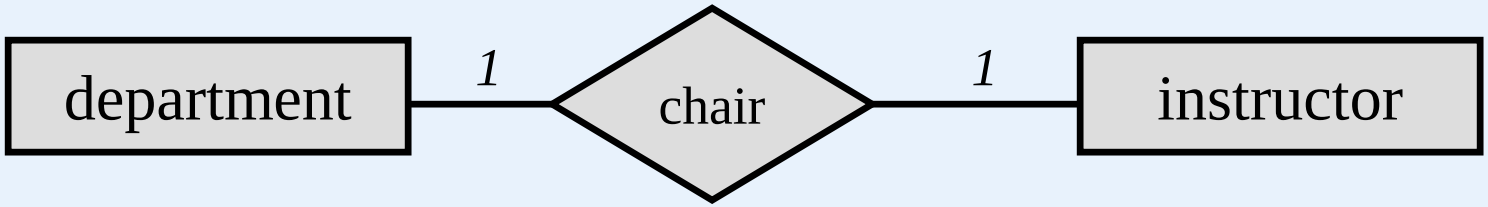
the relationship is of *degree 2;* it is a *binary* relationship

Both entities are considered *strong* entities

Consider some instances



Chair relationship: A department has a *chair* who has special responsibilities. One person (instructor) is designated as such.



1:1 is the *cardinality* of the relationship

the relationship is of *degree 2;* it is a *binary* relationship.

Weak entity types

a weak entity does not have a key of its own - may have a partial key

the identifying relationship will have total participation for the weak entity

e.g. consider courses and sections at UWinnipeg

Consider courses and course sections

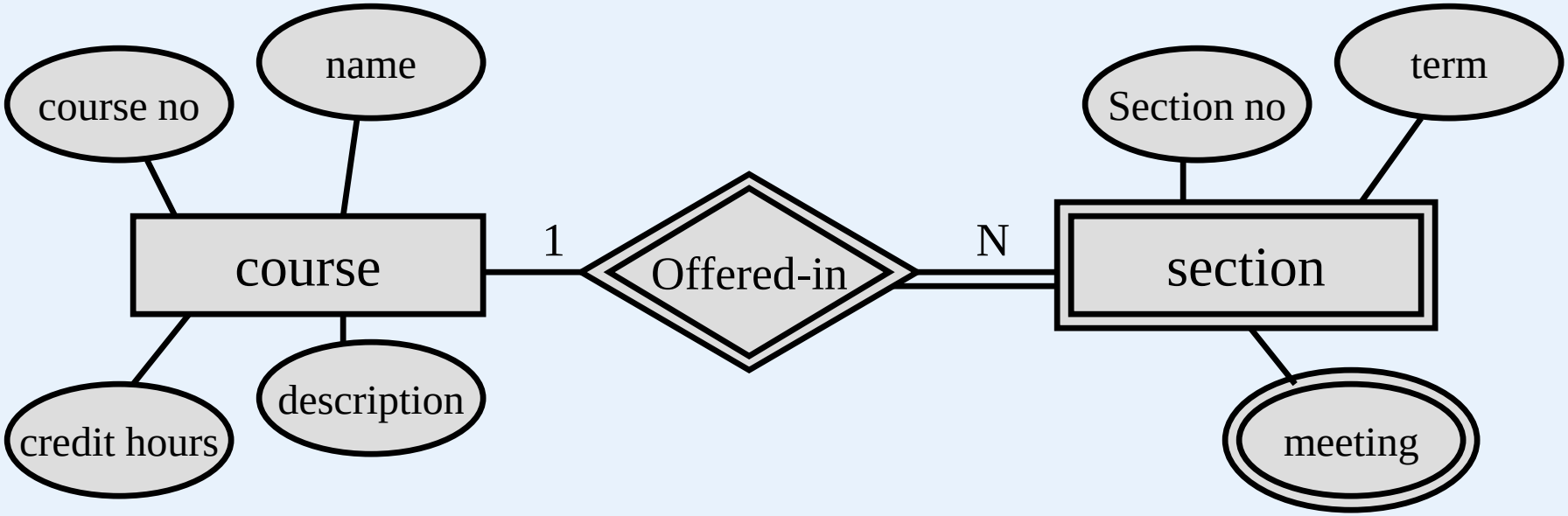
In the fall and winter we have:

```
91.1453/3-001 F Intro Computers staff MW 16:30-17:45 3C13 ..
91.1453/3-002 W Intro Computers staff MW 16:30-17:45 3C13 ..
91.1453/3-050 F Intro Computers staff T  18:00-21:00 3C13 ..
91.1453/3-051 W Intro Computers staff T  18:00-21:00 3C13 ..
```

Section numbers are 001, 002, 050, 051, …

Sections have a section number, a term, days and times, …

Consider courses and course sections



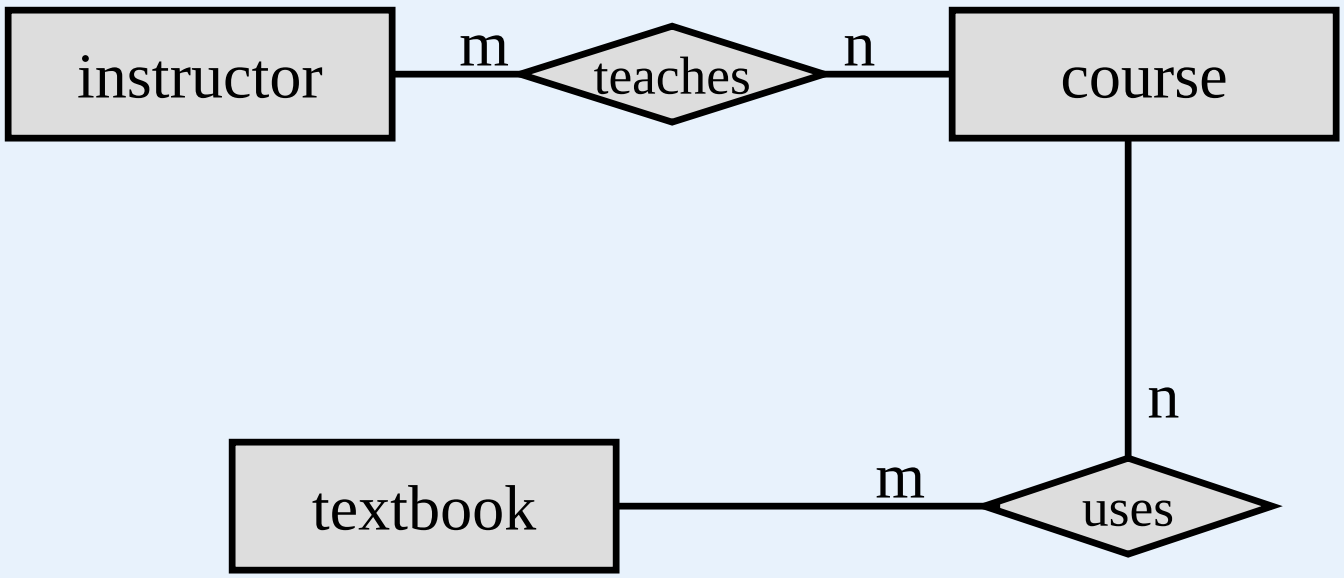
Section is a *weak entity* - it has a *discriminator* (partial key), section number.

Section *totally* participates in the *offered in* relationship

PK (primary key) of Section is … (*offered_in* is an *identifying* relationship)

Is meeting *multivalued?*

Data analysis:

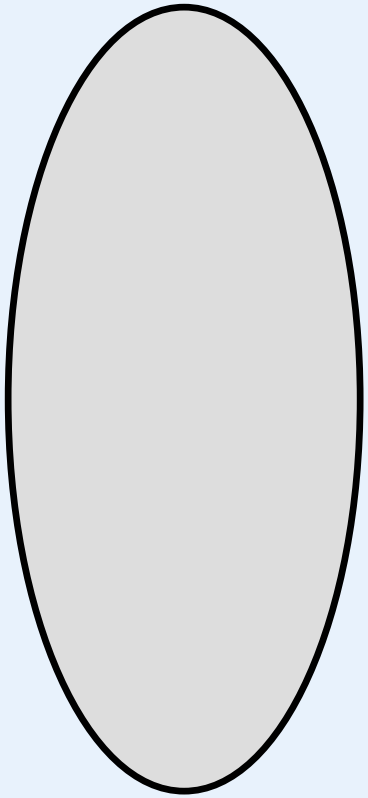


Note that *teaches* and *uses* are both binary relationships:

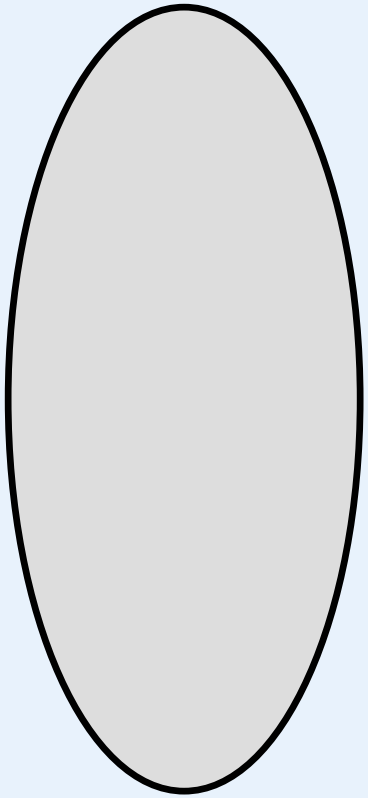
- we expect situations where a specific Instructor *teaches* a specific Course, and where
- a specific Course *uses* a specific text

Consider instances

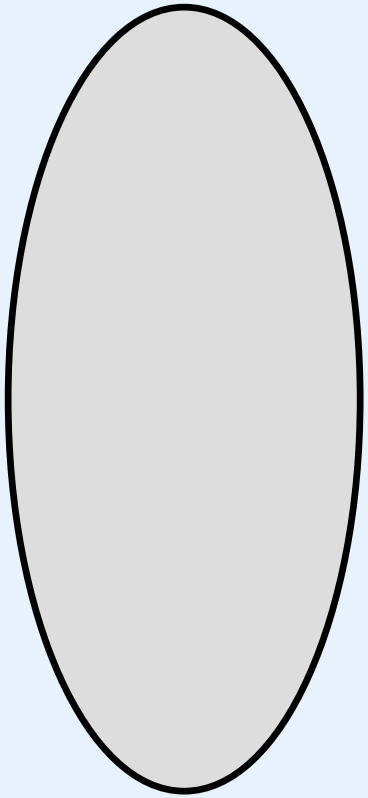
instructor

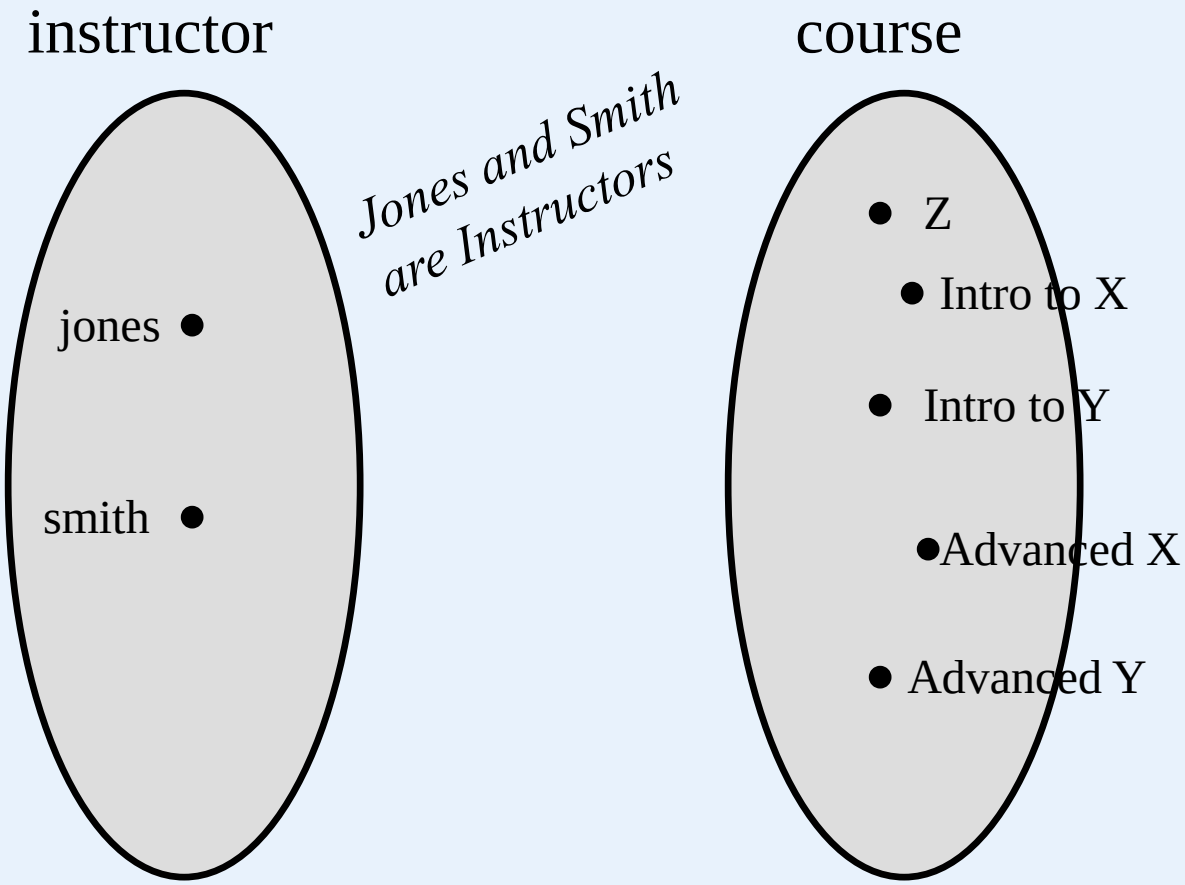


course

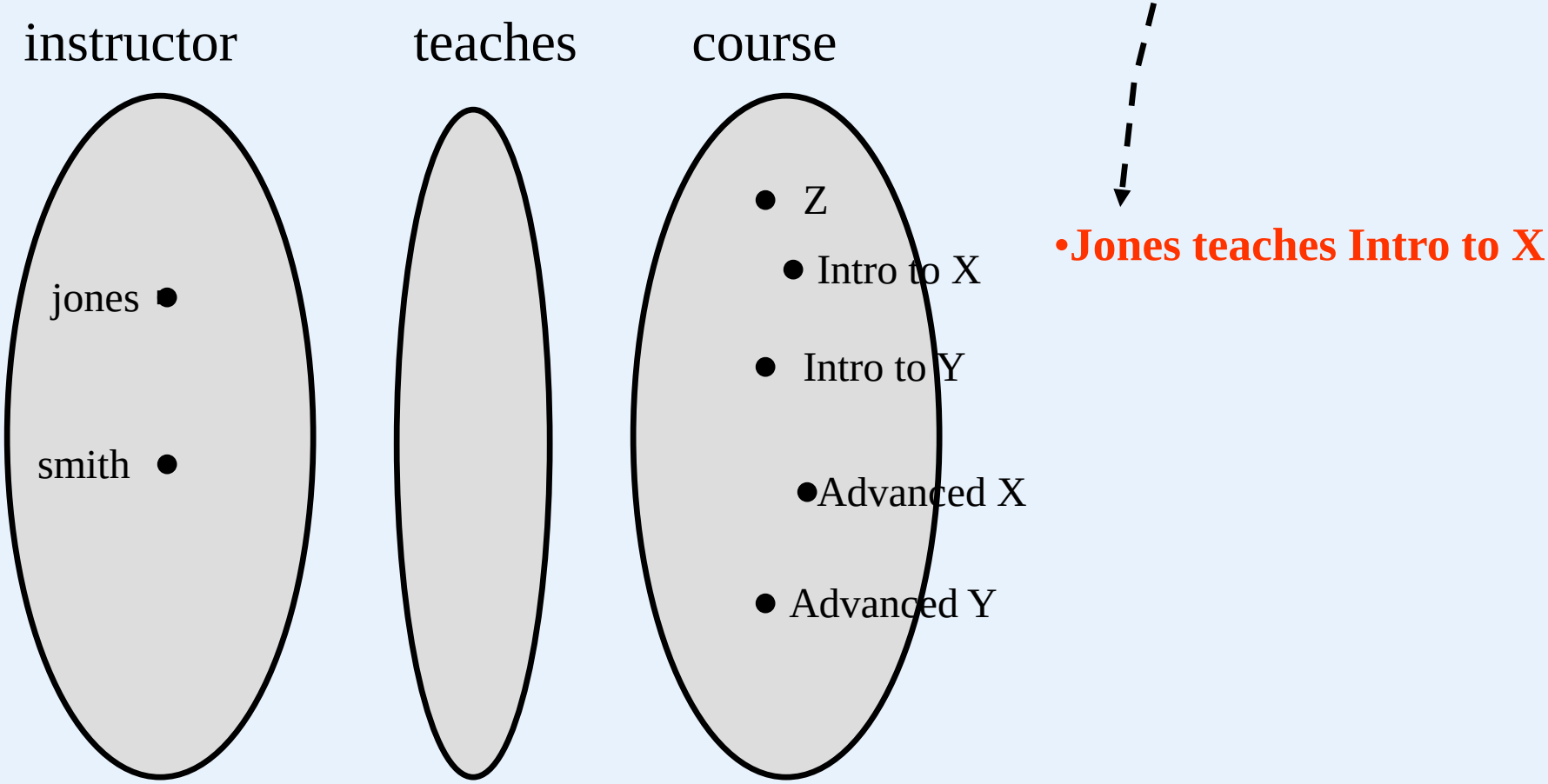


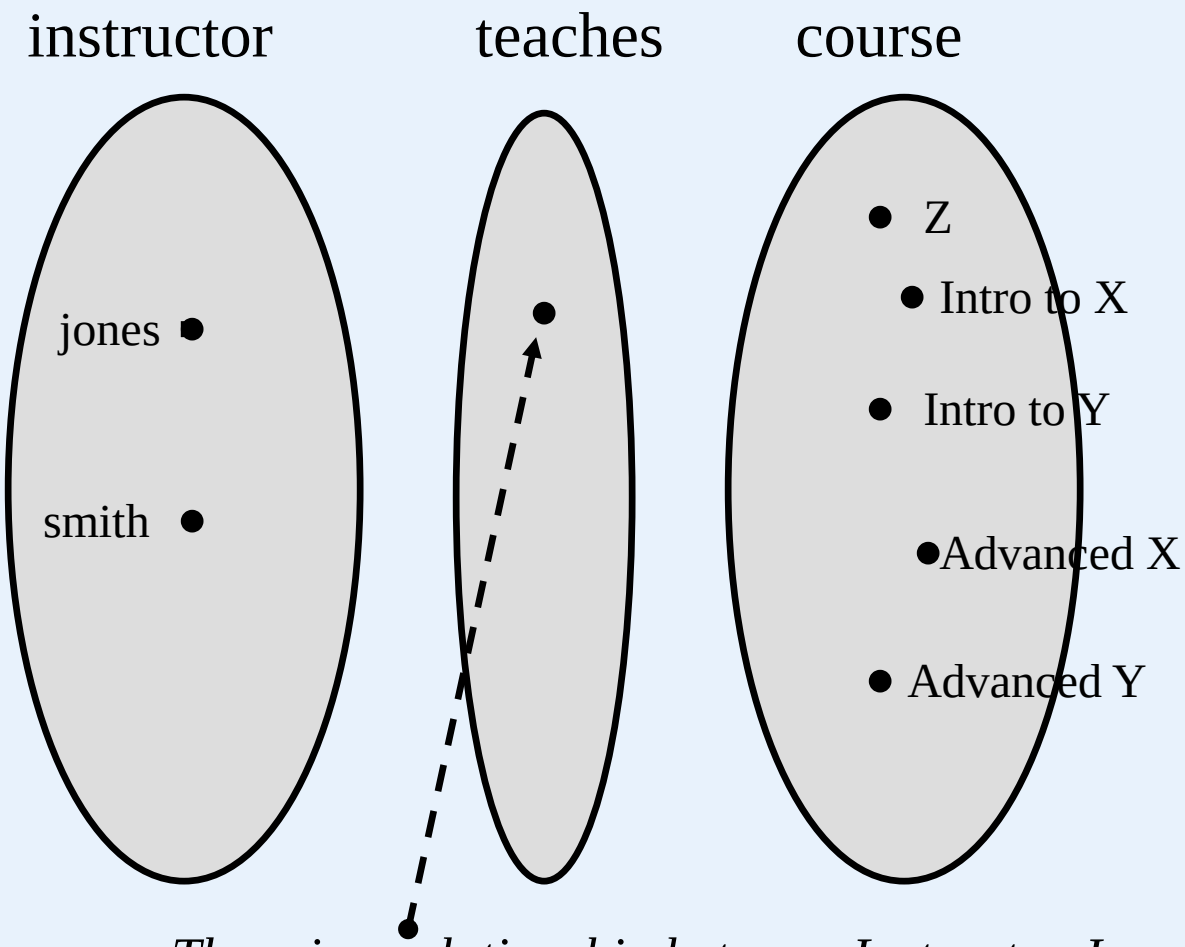
textbook




instructor
jones
smith
Jones and Smith are Instructors
course
Z
Intro to X
Intro to Y
Advanced X
Advanced Y
Courses offered are
Intro to X,
Intro to Y,
Z,
Advanced X,
Advanced Y

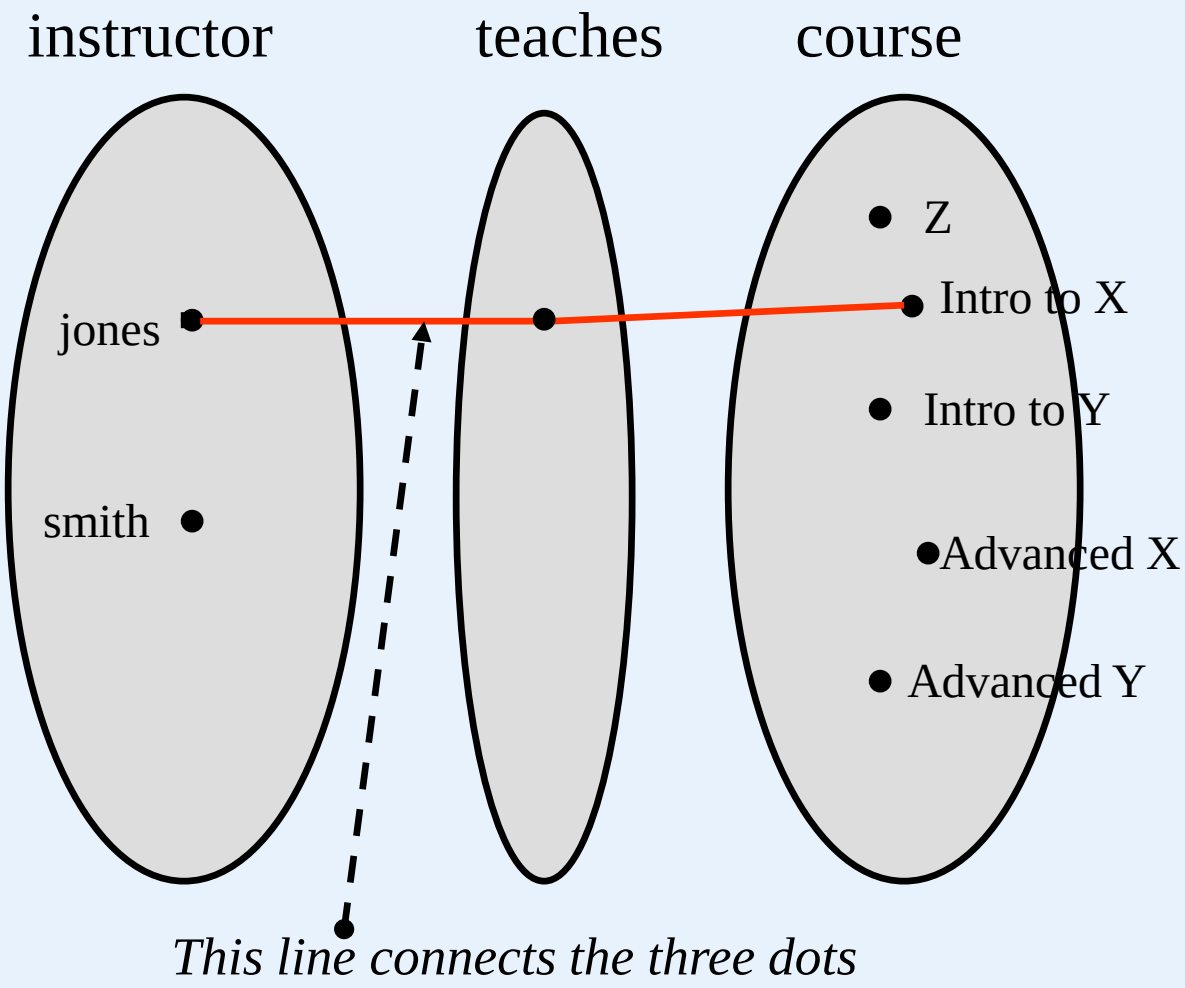
Consider instances of *Instructor teaches Course*



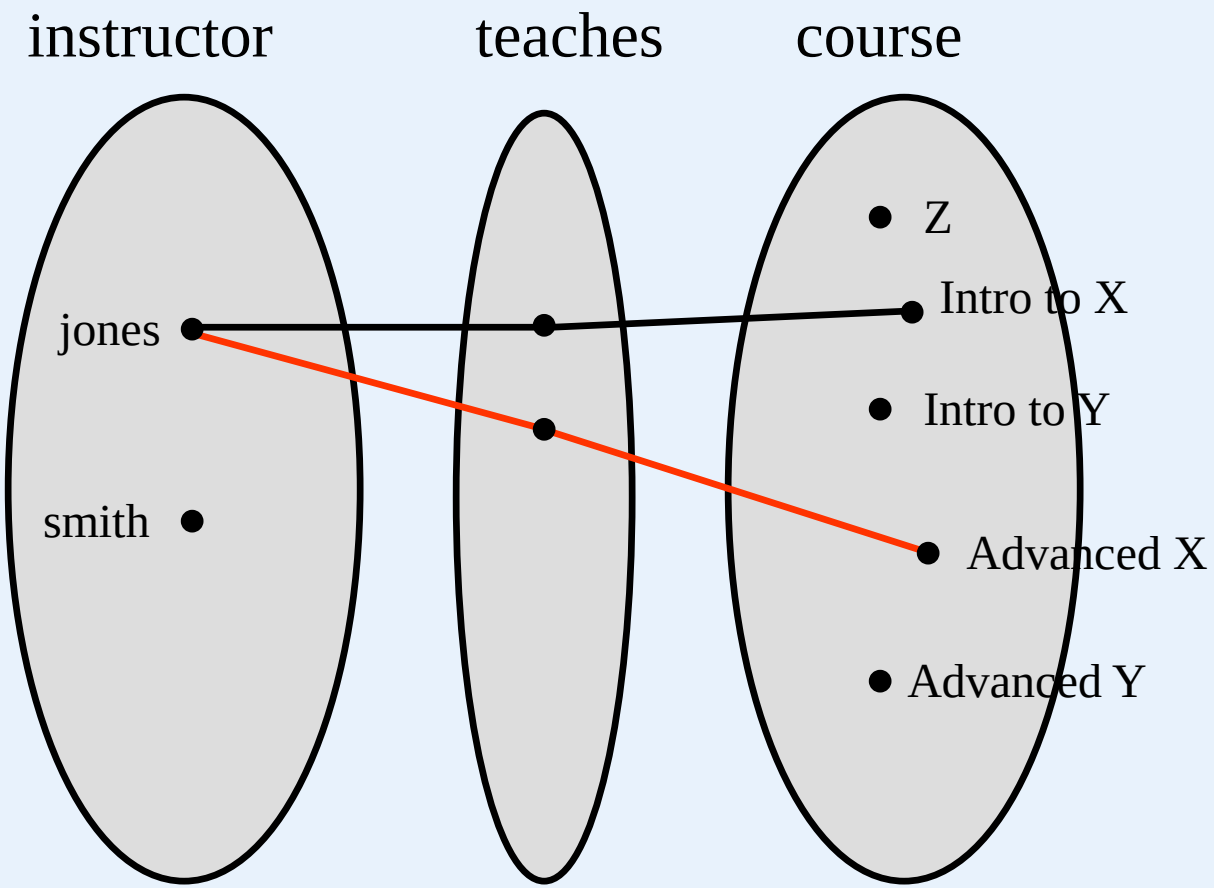


- **Jones teaches Intro to X**

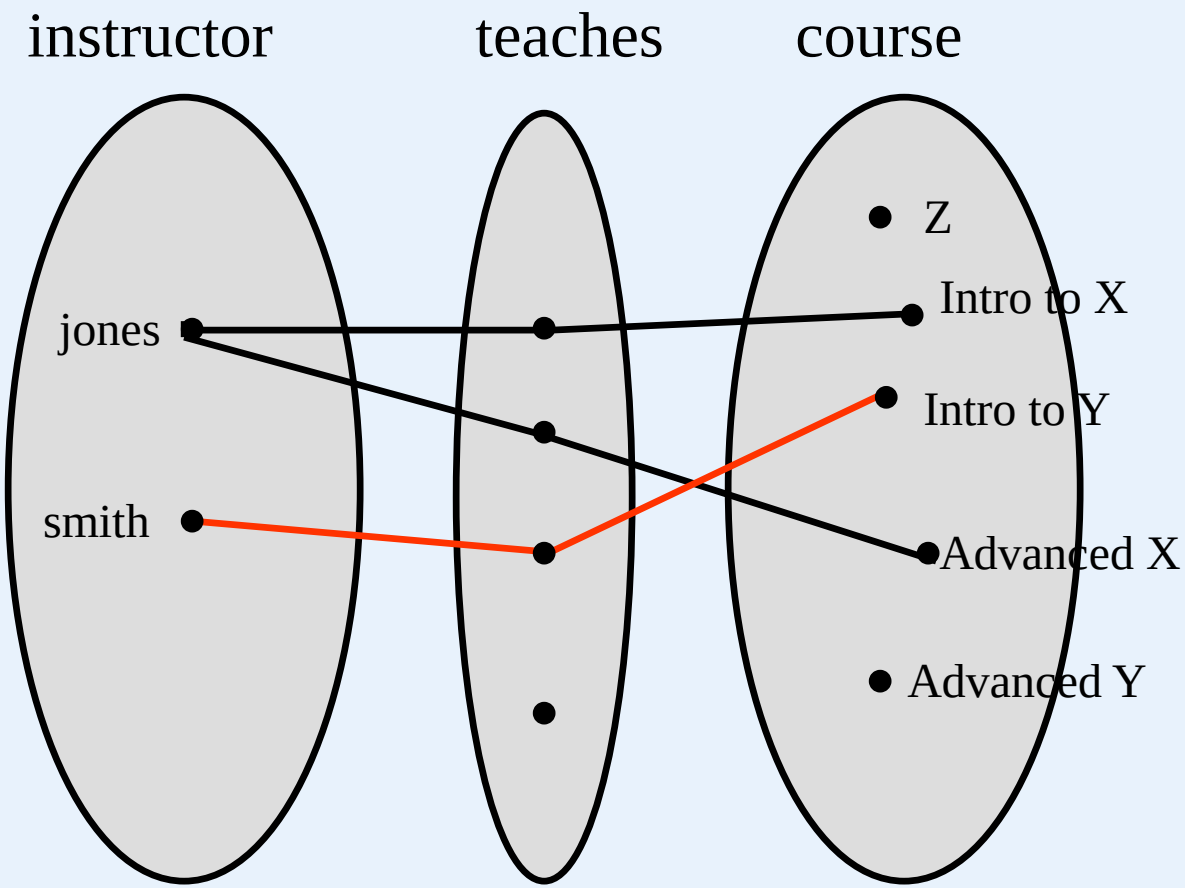
There is a relationship between Instructor Jones and Course Intro to X



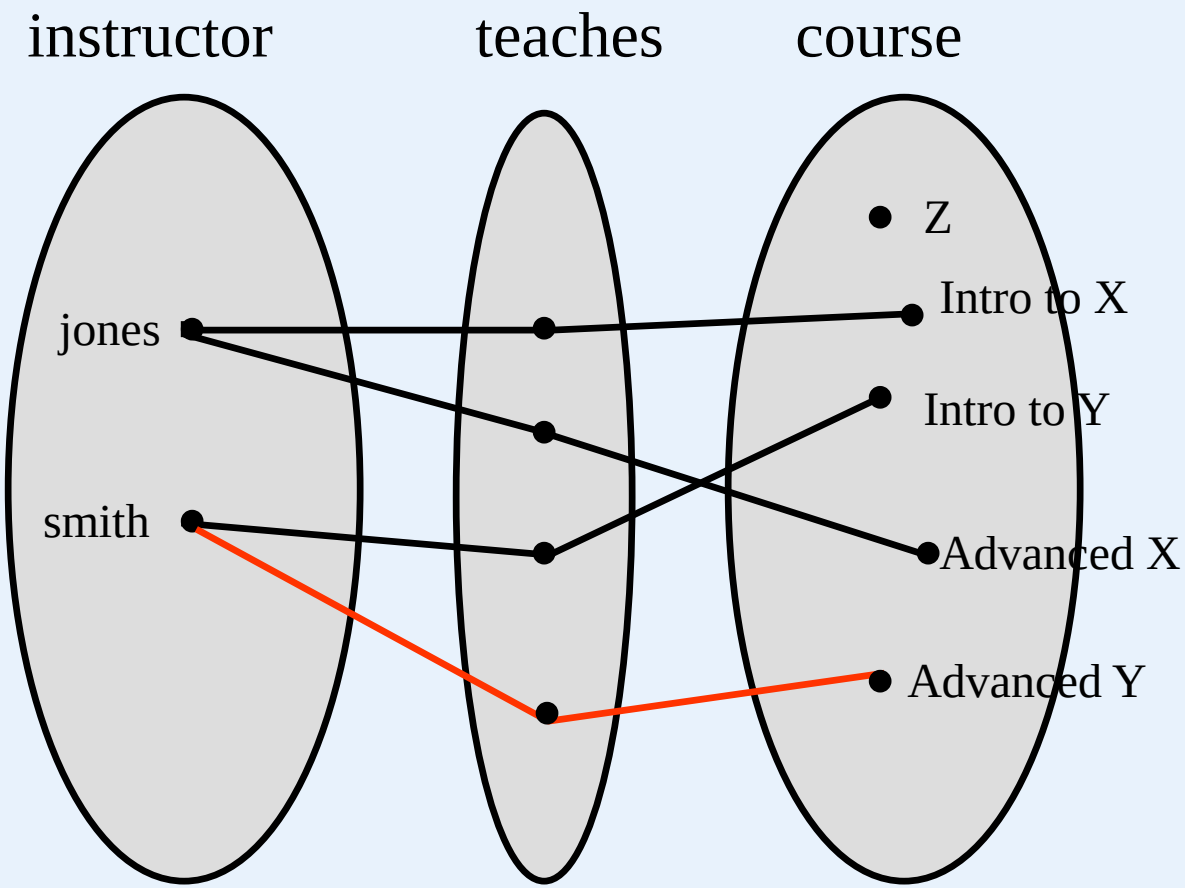
- **Jones teaches Intro to X**



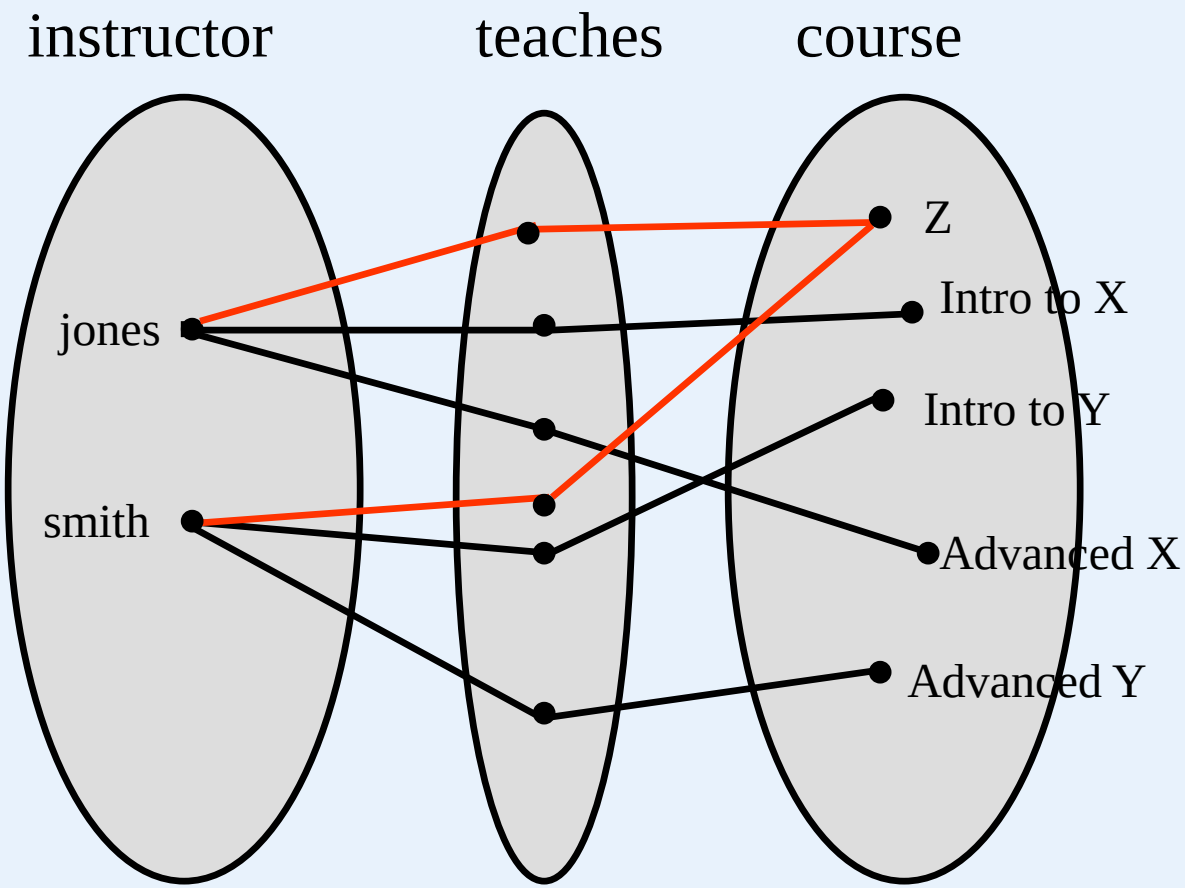
- Jones teaches Intro to X
- **Jones teaches Advanced X**



- Jones teaches Intro to X
- Jones teaches Advanced X
- **Smith teaches Intro to Y**



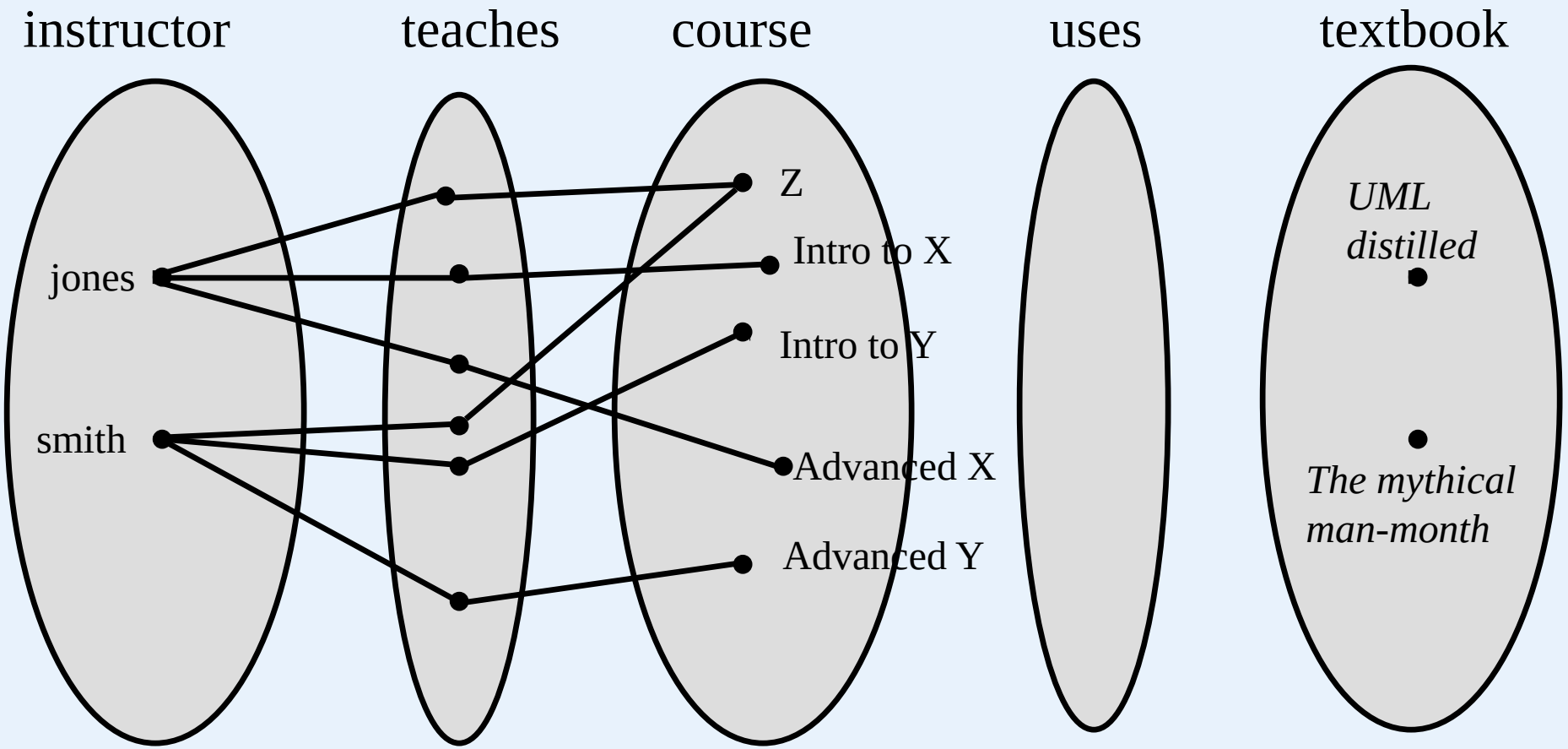
- Jones teaches Intro to X
- Jones teaches Advanced X
- Smith teaches Intro to Y
- **Smith teaches Advanced Y**



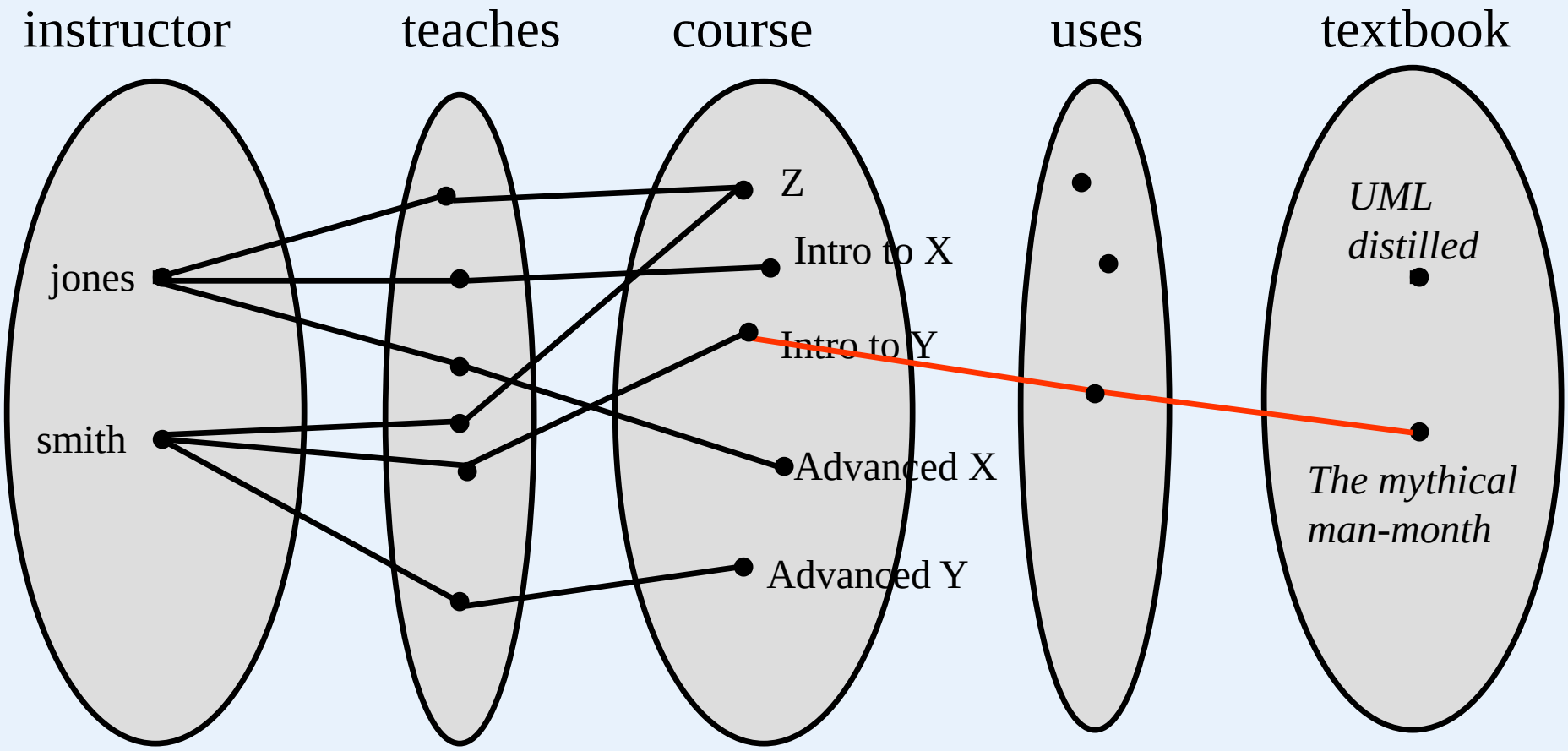
- Jones teaches Intro to X
- Jones teaches Advanced X
- Smith teaches Intro to Y
- Smith teaches Advanced Y
- **Smith and Jones teach Z together**

There are two relationships: one between Jones and Z; the other between Smith and Z

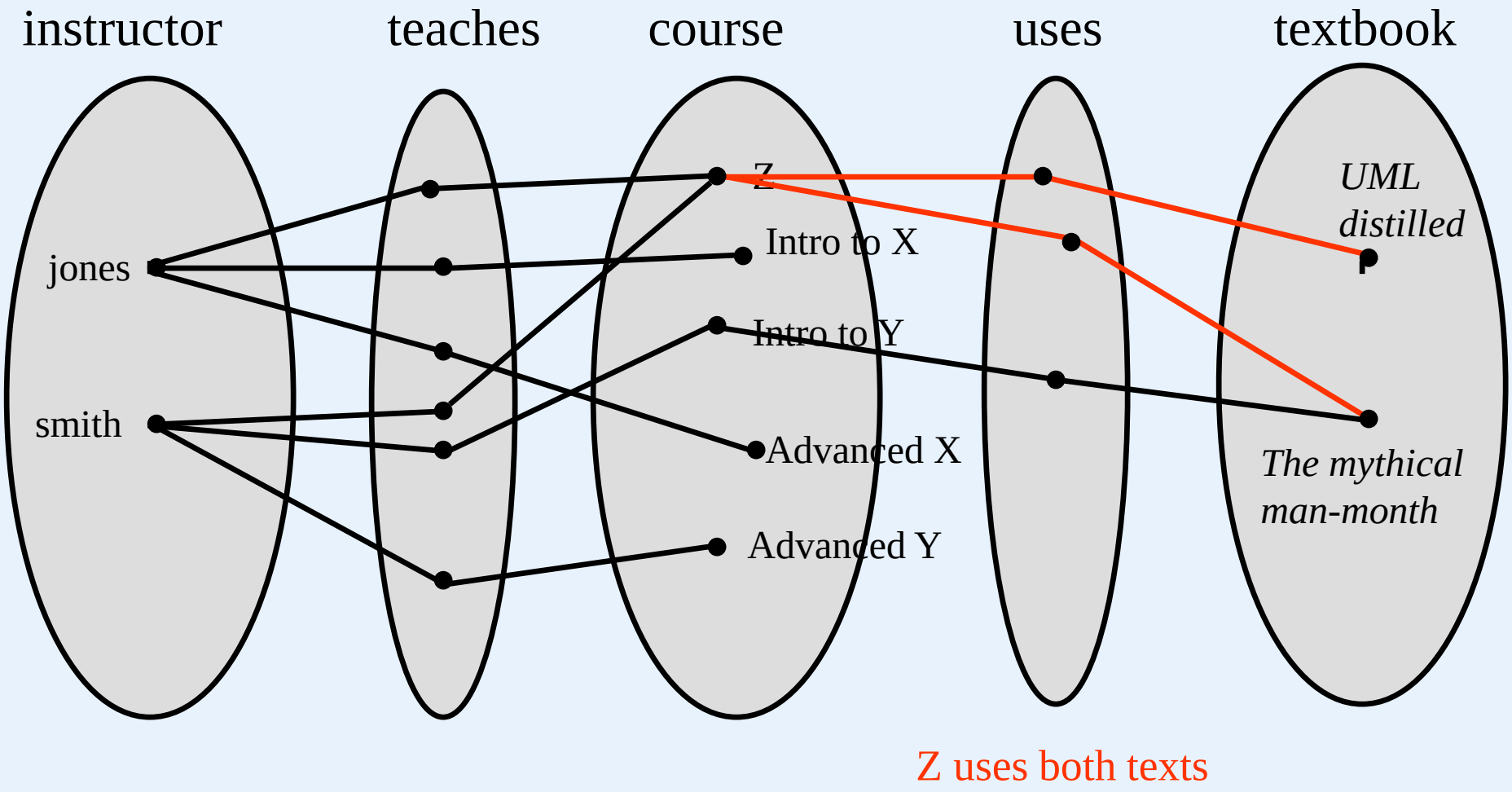
Now let us examine *Course uses Textbook*



Suppose we have two textbooks: *The mythical man-month*, and *UML distilled*



Intro to Y uses *The mythical man-month*


instructor
teaches
course
uses
textbook
jones
smith
Z
Intro to X
Intro to Y
Advanced X
Advanced Y
UML distilled
The mythical man-month
Z uses both texts

- **ER-to-Relational mapping**

1. Create a relation for each strong entity type
   - For each atomic attribute associated with the entity type, an attribute in the relation will be created.
   - Composite attributes are not included. However the atomic attributes comprising the composite attribute must appear in the pertinent relation.
2. Create a relation for each weak entity type
   - include primary key of owner (an FK - foreign key)
   - owner's PK + partial key becomes PK
3. For each binary *1:1* relationship choose an entity and include the other's PK in it as an FK. Include any attributes of the relationship

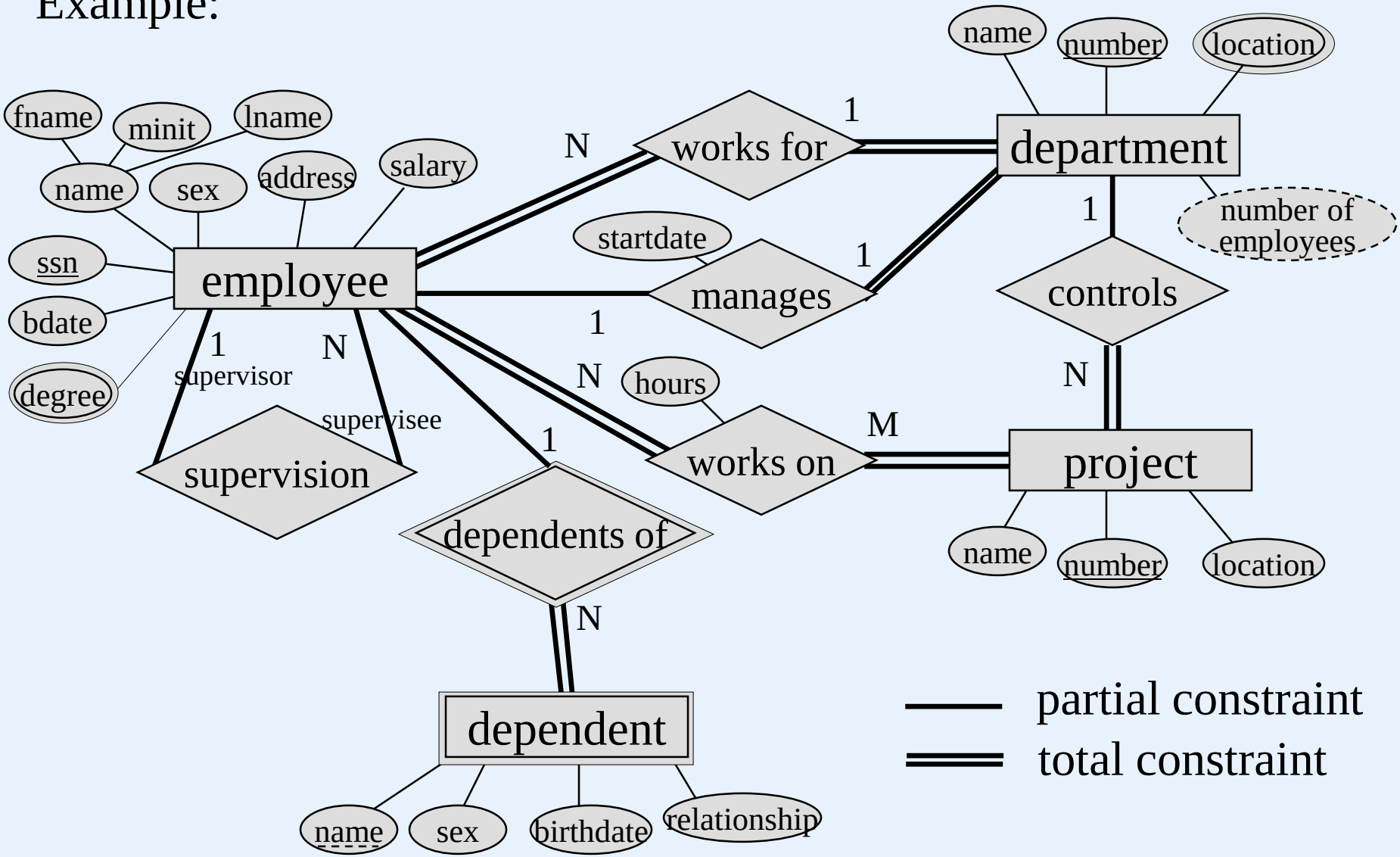
4. For each binary *1:n* relationship, choose the *n*-side entity and include an FK with respect to the other entity. Include any attributes of the relationship

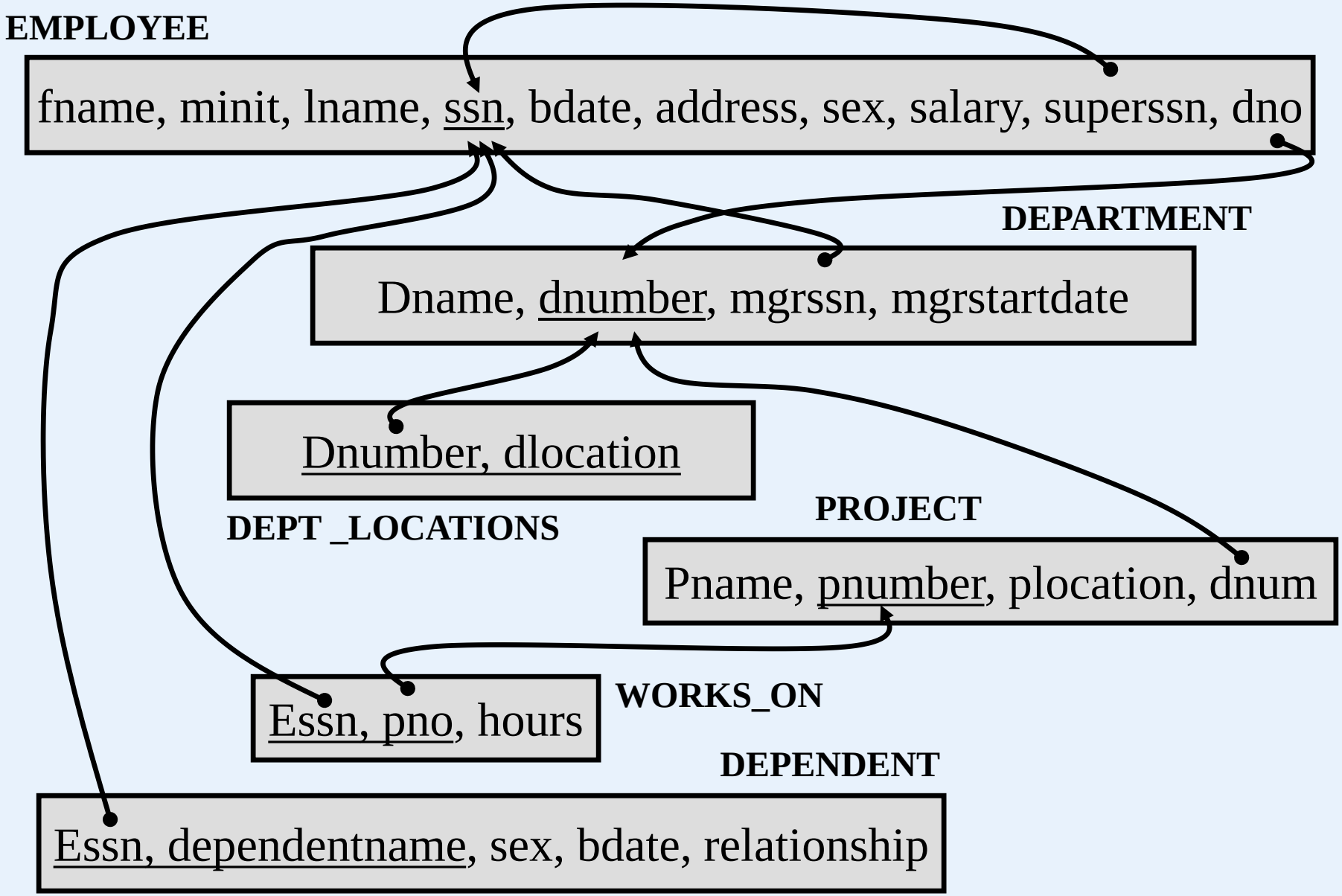
5. For each binary *M:N* relationship, create a relation for the relationship
   - include PKs of both participating entities and any attributes of the relationship
   - PK is the concatenation of the participating entity PKs

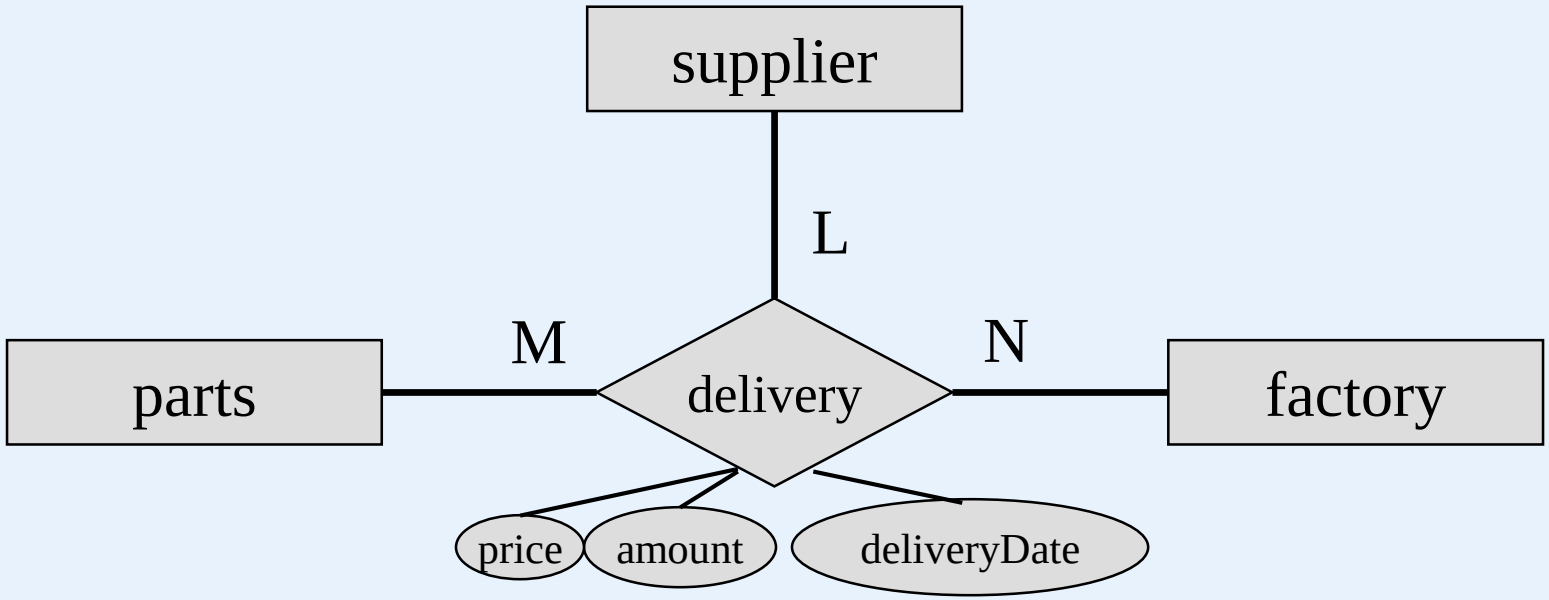
6. For each multivalued attribute create a new relation
   - include the PK attributes of the entity type
   - PK is the PK of the entity type and the multivalued attribute

7. For each *n*-ary relationship, create a relation for the relationship
   - include PKs of all participating entities and any attributes of the relationship
   - PK is the concatenation of the participating entity PKs

Example:


name
number
location
fname
minit
lname
name
sex
address
salary
ssn
bdate
degree
employee
works for
1
N
department
1
number of employees
startdate
manages
1
1
controls
1
supervisor
N
N
hours
N
supervisee
1
M
supervision
works on
project
dependents of
name
number
location
N
dependent
name
sex
birthdate
relationship
partial constraint
total constraint


EMPLOYEE
fname, minit, lname, ssn, bdate, address, sex, salary, superssn, dno
DEPARTMENT
Dname, dnumber, mgrssn, mgrstartdate
Dnumber, dlocation
DEPT _LOCATIONS
PROJECT
Pname, pnumber, plocation, dnum
Essn, pno, hours
WORKS_ON
DEPENDENT
Essn, dependentname, sex, bdate, relationship

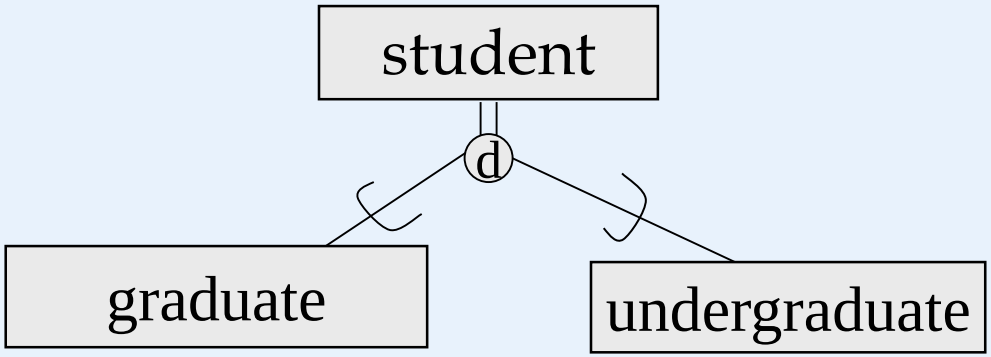


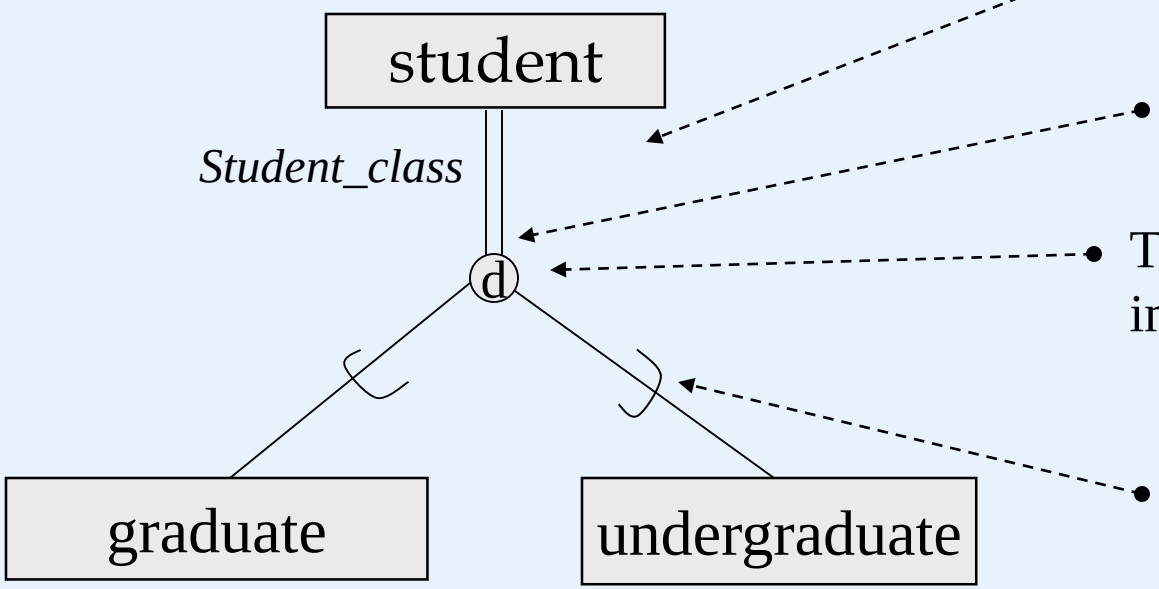
Delivery

sNum, pNum, fNum, price, amount, deliveryDate

- **Specialization and Generalization**

- Specialization is the process of defining a set of sub-entities of some entity type. Generalization is the opposite approach/process of determining a supertype based on certain entities having common characteristics.
  - e.g. employees may be paid by the hour or a salary (part vs full-time)
  - e.g. students may be part-time or full-time; graduate or undergraduate
- these are similar to 1:1 relationships, but they always involve entities of one (super)type
- these are *'is-a'* relationships

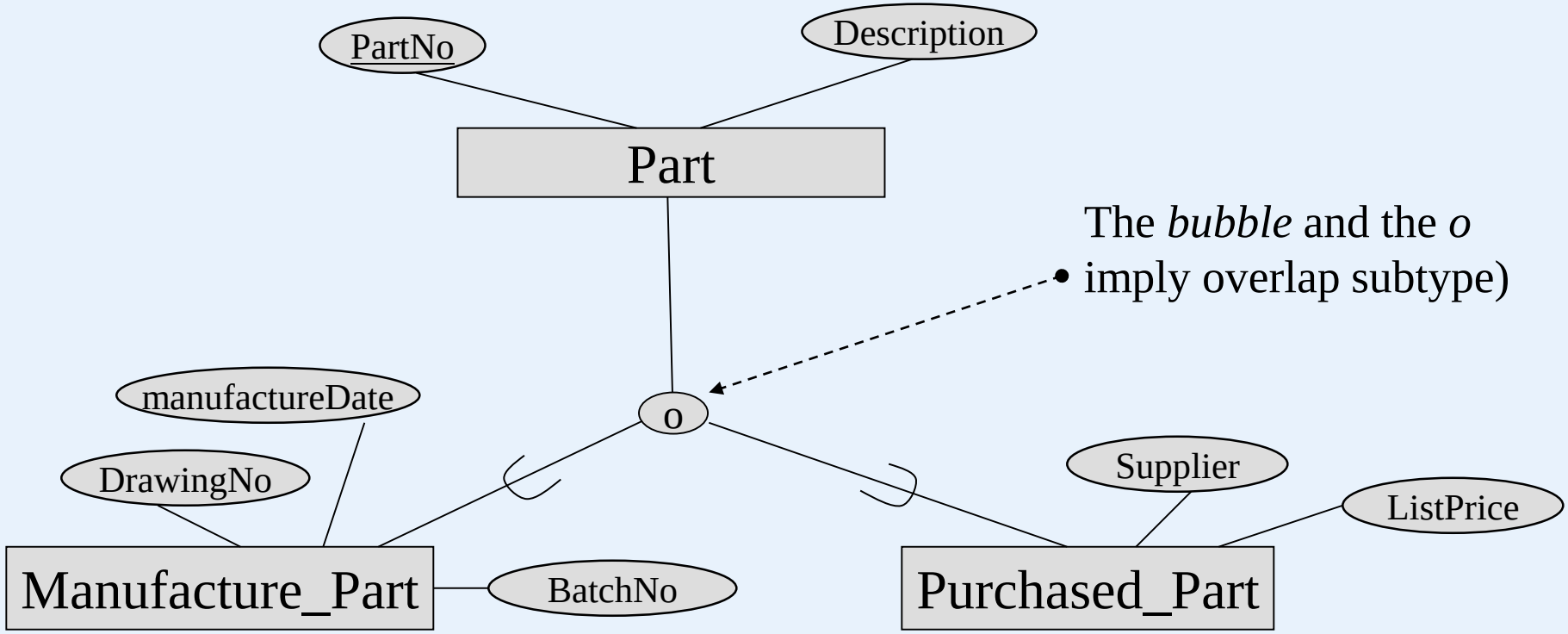




- Subtype is determined by the *student_class* attribute
- A *student* must be a *graduate* or *undergraduate*
- The *bubble* and the *d* imply disjoint subtypes
- The arc implies *graduate* and *undergraduate* are subtypes of *student*

- Participation of supertype may be mandatory or optional
- Subtypes may be disjoint or overlapping
- a predicate (on an attribute) determines the subtype: e.g. attribute Student_class

  Student_class = ‘graduate’; Student_class = ‘undergraduate’


PartNo
Description
Part
The *bubble* and the *o* imply overlap subtype)
manufactureDate
o
DrawingNo
Supplier
ListPrice
Manufacture_Part
BatchNo
Purchased_Part

- **Mapping to a relational database**

  4 choices:

  1. Create separate relations for the supertype and each of the subtypes.

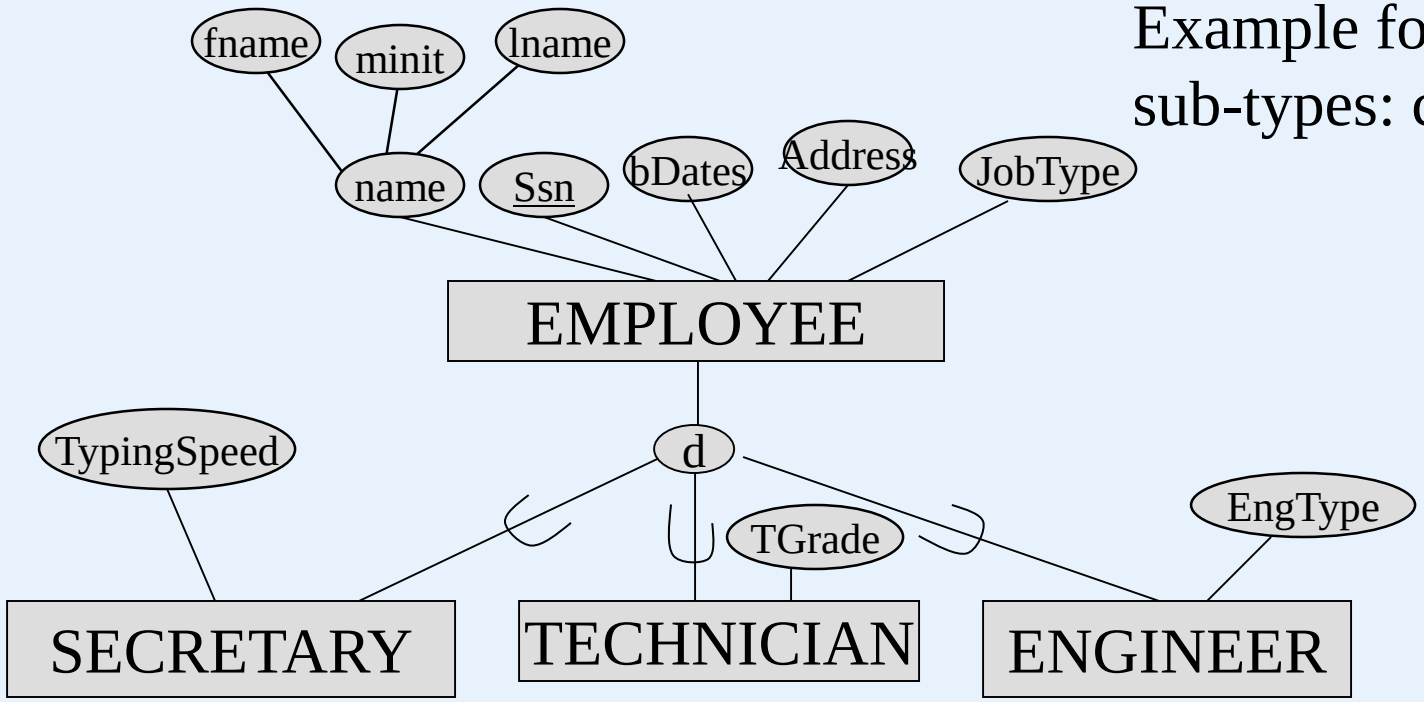
  2. Create relations for the subtypes only - each contains attributes from the supertype.

  3. (**disjoint** subtypes) Create only one relation - includes all of the attributes for the supertype and all for the subtypes, and one discriminator attribute.

  4. (**overlapping** subtypes) Create only one relation - includes all of the attributes for the supertype and all for the subtypes, and one logical discriminator attribute per subtype.

  PK is always the same - determined from the supertype

Example for super- & sub-types: choice 1



EMPLOYEE

fname, minit, lname, ssn, bdate, address, JobType

SECRETARY

Essn, TypingSpeed

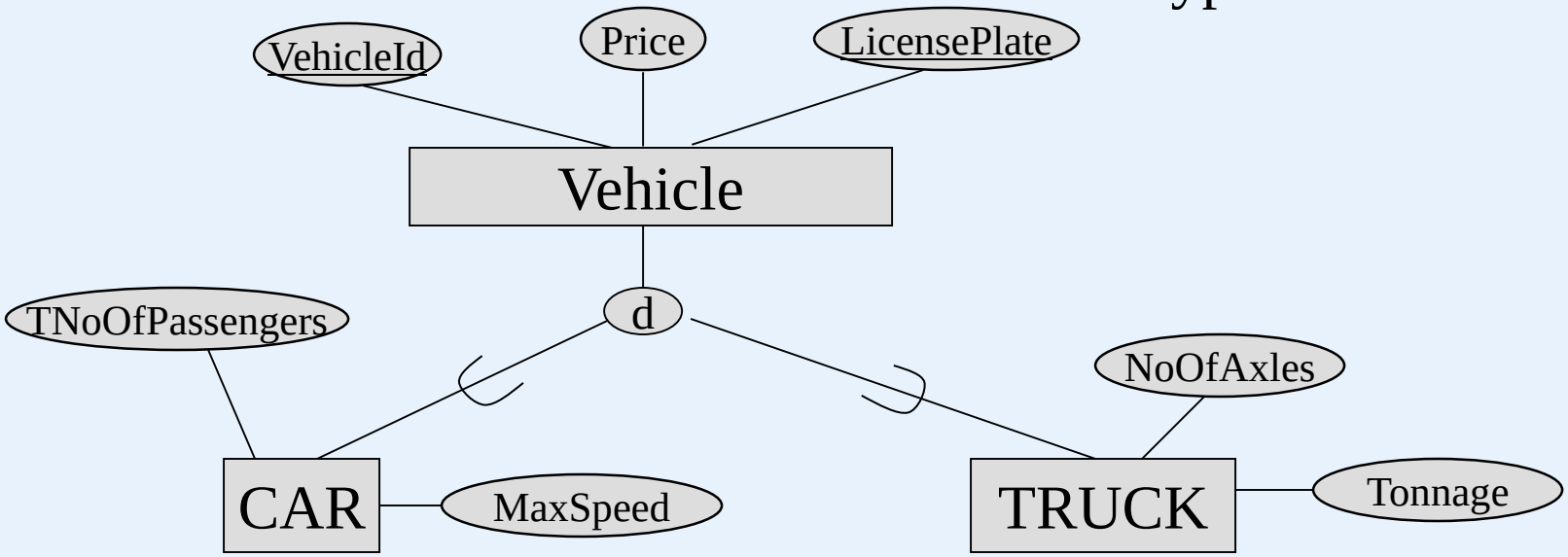
TECHNICIAN

Essn, TGrade

ENGINEER

Essn, EngType

Example for super- & sub-types: choice 2



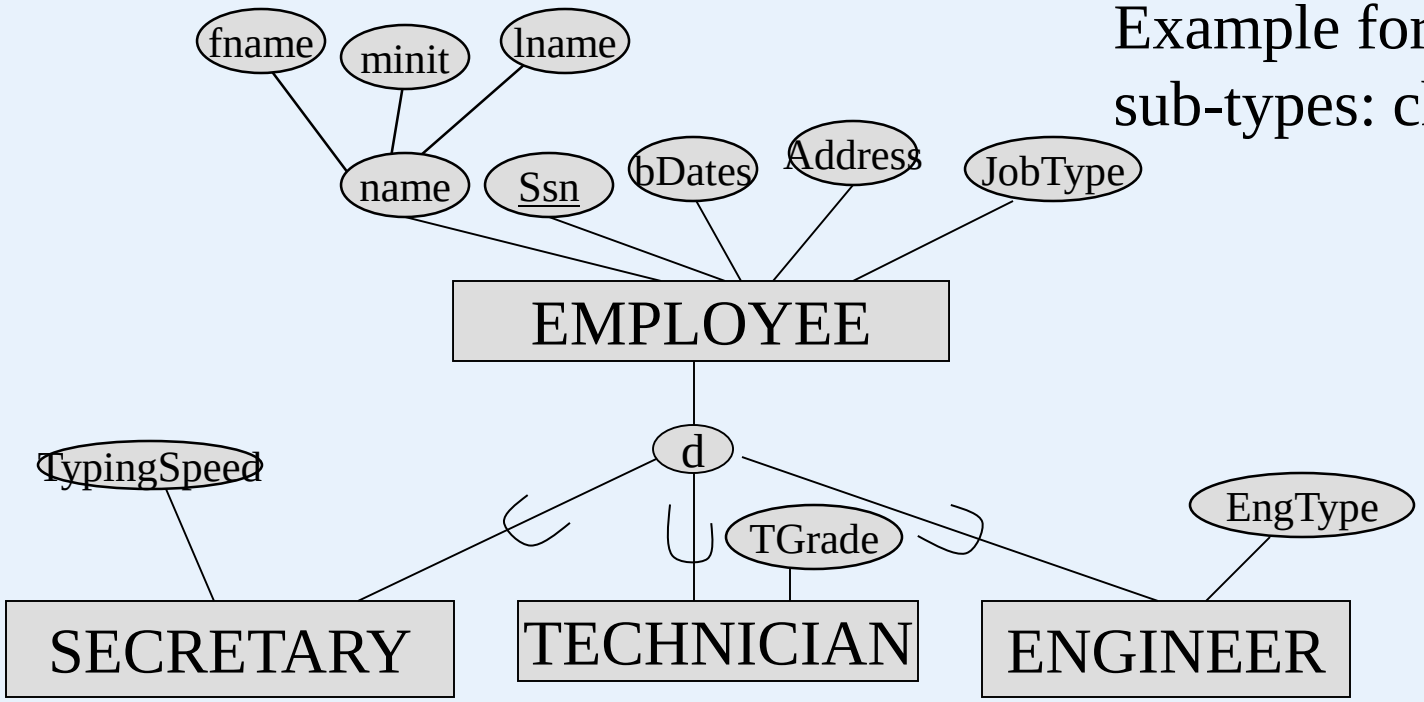
CAR

VehicleId, LicensePlate, Price, MaxSpeed, NoOfPassenger

TRUCK

VehicleId, LicensePlate, Price, NoOfAxles, Tonnage

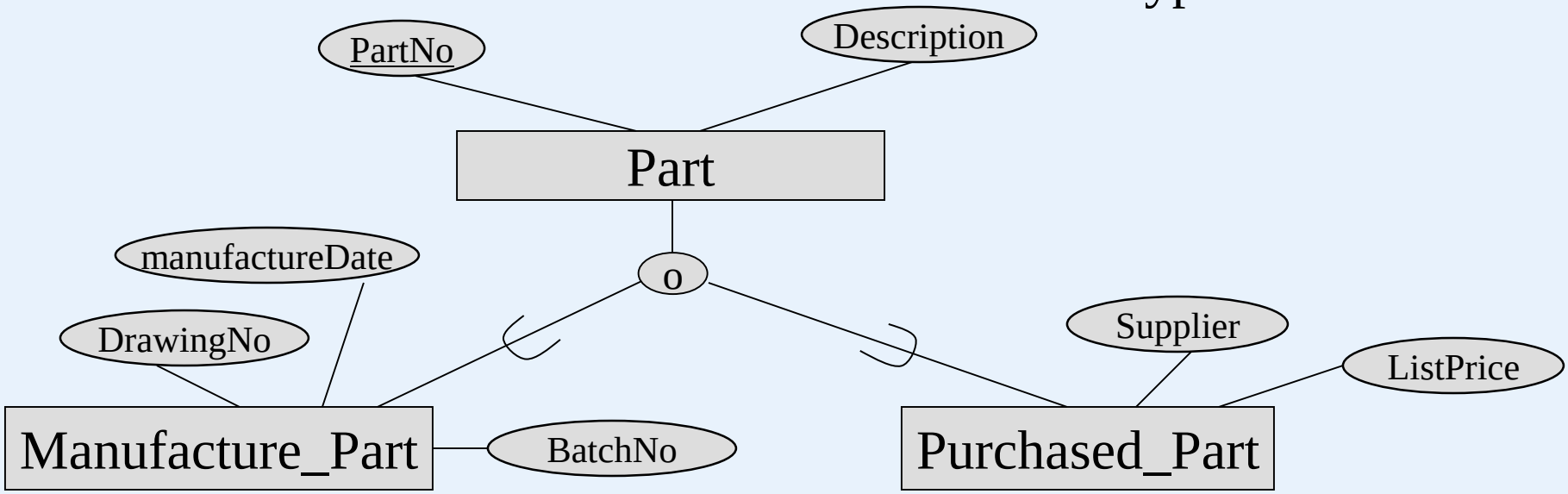
Example for super- & sub-types: choice 3



EMPLOYEE

fname, minit, lname, ssn, bdate, address, JobType, TypingSpeed, Tgrade, EngType							
12345	…	…	1	…	…		
56463	…	…	2	…	…		
55554	…		3	…	…		

Example for super- & sub-types: choice 4

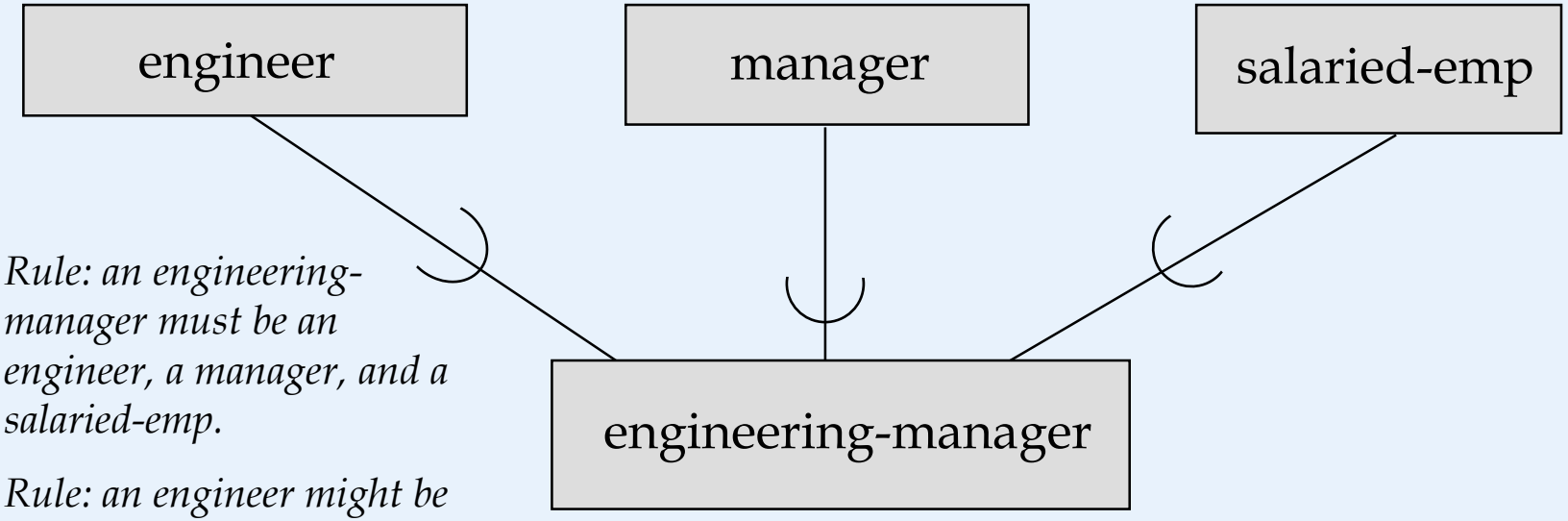


Part

PartNo, Desription, MFlag, Drawing, ManufactureDate, BatchNo, Pflag, Supplier, ListPrice

1	screw	1	…	…		…	…
2	bolt		…	…	1	…	…
3	axes	1	…	…	1		

- Shared SubClass
  - a subclass with more than one superclass
  - leads to the concept of multiple inheritance: engineering manager inherits attributes of engineer, manager, and salaried employee

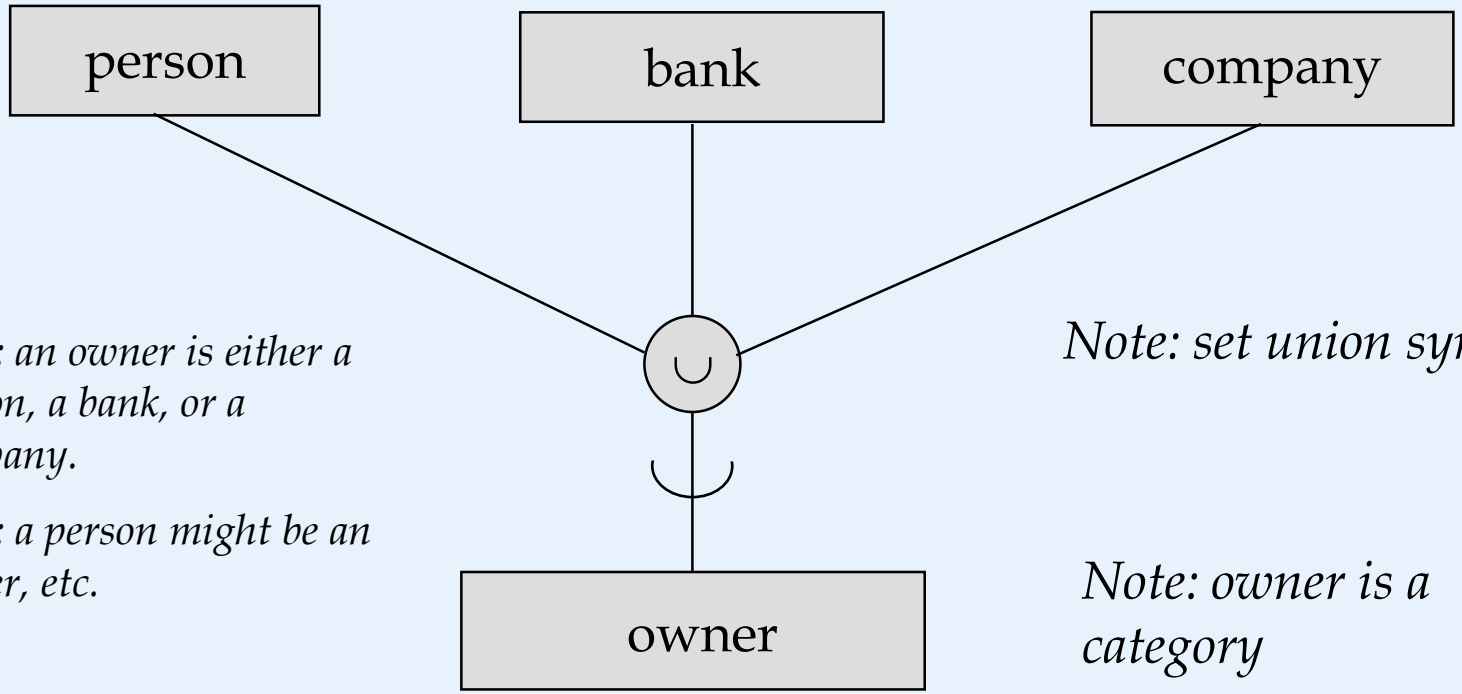


Rule: an engineering-manager must be an engineer, a manager, and a salaried-emp.

Rule: an engineer might be an engineering manager, etc.

Categories

- Models a single class/subclass with more than one super class of different entity types



Rule: an owner is either a person, a bank, or a company.

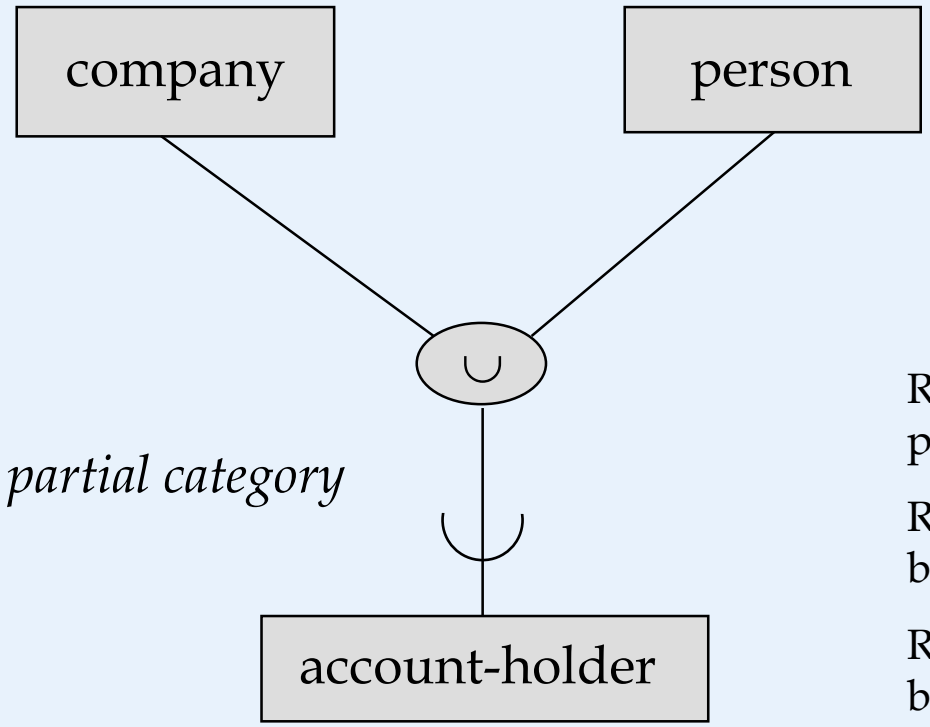
Rule: a person might be an owner, etc.

Note: set union symbol

Note: owner is a category

Categories

- A category can be either total or partial



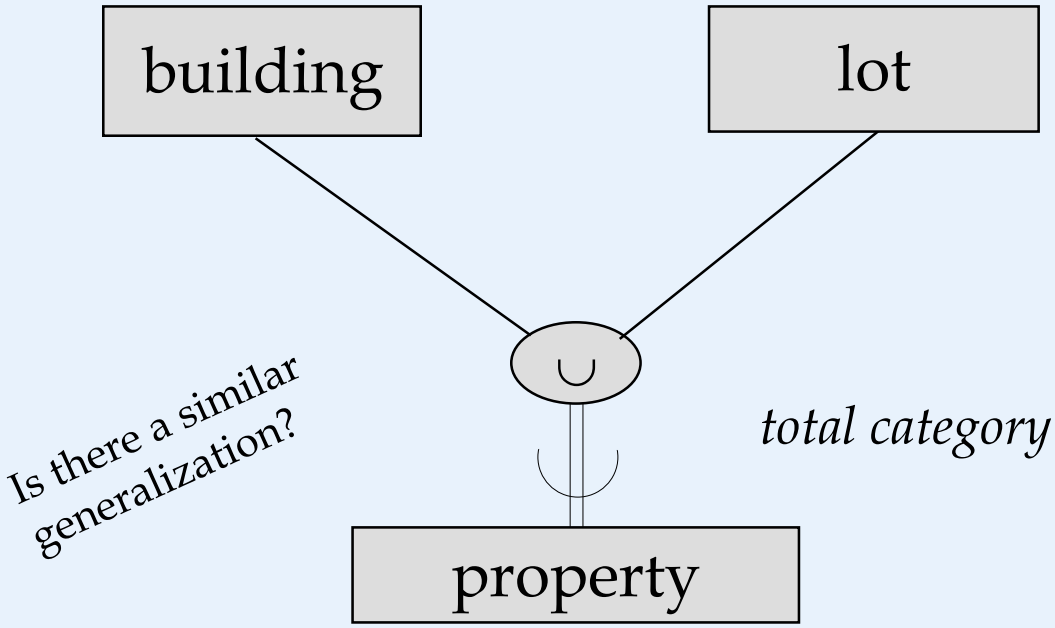
Rule: an account holder is either a person or a company.

Rule: a person may, or may not, be an account owner

Rule: a company may, or may not, be an account holder

Categories

- A category can be either total or partial



Rule: a property is either a building or a lot

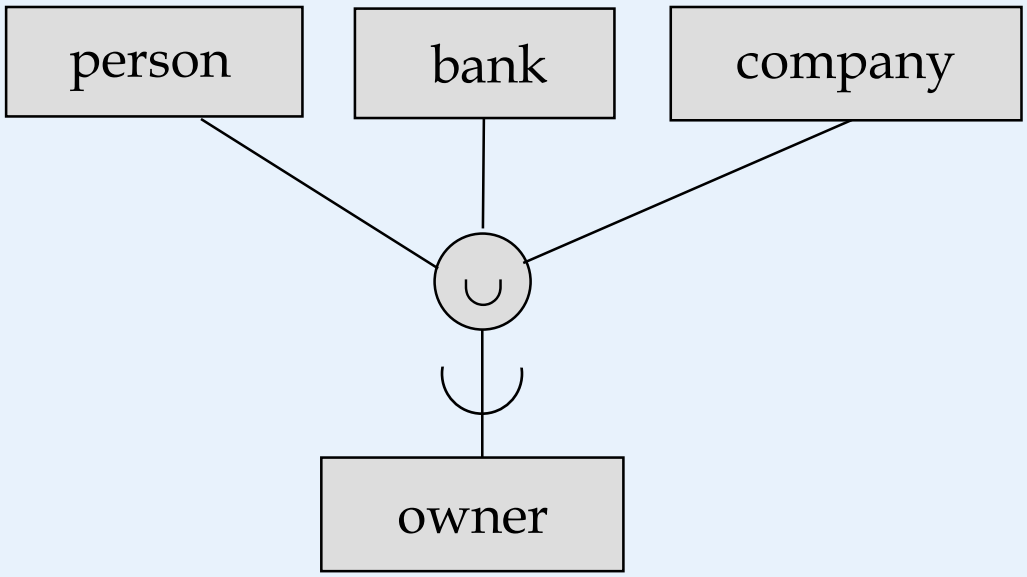
Rule: a building is a property

Rule: a lot is a property

- Mapping of Categories
  - Generate a table for each entity type involved
  - Superclasses with different key
  - Specify a new key called surrogate key for the category, which will also be included in the tables for the superclasses as foreign keys
  - Superclasses with the same keys

    No need of a surrogate key

- Categories - Superclasses with different keys



Person (SSN, DrLicNo, Name, Address, *Ownerid*)

Bank (Bname, BAddress, *Ownerid*)

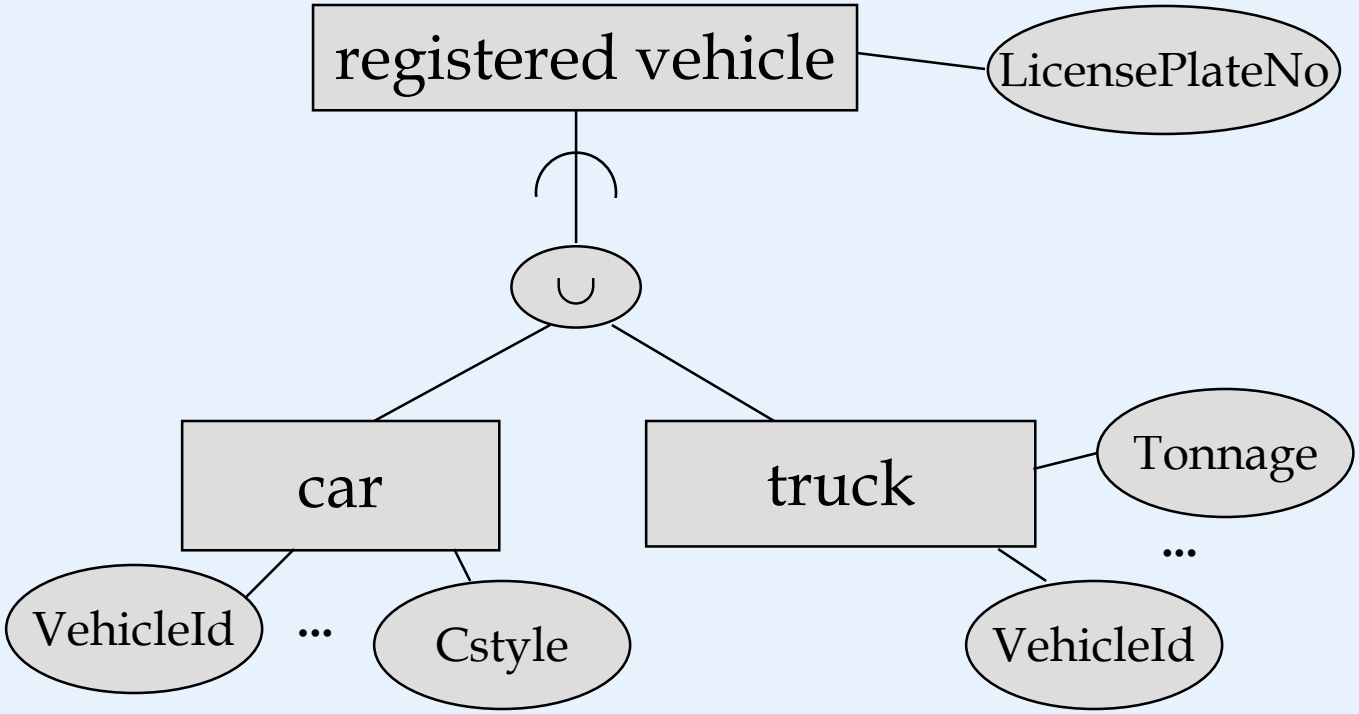
Company (CName, CAddress, *Ownerid*)

Owner (*Ownerid*)

Note the Foreign Keys

Surrogate key

- Categories - Superclasses with the same keys



Registered Vehicle (*VehicleID*, LicensePlateNo,)

Car (*VehicleID* , Cstyle, CMake, CModel,CYear)

Truck (*VehicleID* , TMake, TModel,TYear, Tonnage)

Note there are no Foreign Keys