Database Design I: The Entity-Relationship Model

Chapter 4

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Database Design

- Goal: specification of database schema
- Methodology:
  - Use *E-R model* to get a high-level graphical view of essential components of enterprise and how they are related
  - Convert E-R diagram to DDL
- *E-R Model*: enterprise is viewed as a set of
  - *Entities*
  - *Relationships* among entities

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Entities

- *Entity*: an object that is involved in the enterprise
  - Ex: John, CSE305
- *Entity Type*: set of similar objects
  - Ex: students, courses
- *Attribute*: describes one aspect of an entity type
  - Ex: *name*, *maximum enrollment*

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Entity Type

- Entity type described by set of attributes
  - Person: *Id*, *Name*, *Address*, *Hobbies*
- *Domain*: possible values of an attribute
  - Value can be a set (in contrast to relational model)
    - (111111, John, 123 Main St, {stamps, coins})
- *Key*: minimum set of attributes that uniquely identifies an entity (candidate key)
- *Entity Schema*: entity type name, attributes (and associated domain), key constraints

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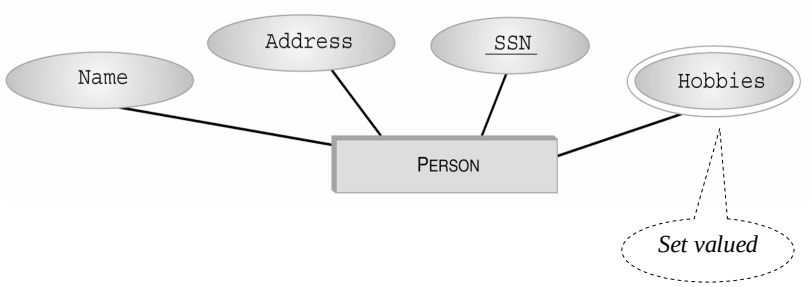
Entity Type (con't)

- Graphical Representation in E-R diagram:



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Relationships

- *Relationship*: relates two or more entities
  - John *majors in* Computer Science
- *Relationship Type*: set of similar relationships
  - Student (entity type) related to Department (entity type) by MajorsIn (relationship type).
- Distinction:
  - *relation* (relational model) - set of tuples
  - *relationship* (E-R Model) – describes relationship between entities of an enterprise
  - Both entity types and relationship types (E-R model) may be represented as relations (in the relational model)

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Attributes and Roles

- *Attribute* of a relationship type describes the relationship
  - e.g., John majors in CS *since* 2000
    - John and CS are related
    - 2000 describes relationship - value of SINCE attribute of MajorsIn relationship type
- *Role* of a relationship type names one of the related entities
  - e.g., John is value of *Student* role, CS value of *Department* role of MajorsIn relationship type
  - (John, CS; 2000) describes a relationship

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Relationship Type

- Described by set of attributes and roles
  - e.g., MajorsIn: *Student*, *Department*, *Since*
  - Here we have used as the role name (*Student*) the name of the entity type (Student) of the participant in the relationship, but ...

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Roles

- *Problem*: relationship can relate elements of same entity type
  - e.g., *ReportsTo* relationship type relates two elements of Employee entity type:
    - Bob reports to Mary since 2000
  - We do not have distinct names for the roles
  - It is not clear who reports to whom

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Roles (con't)

- *Solution*: role name of relationship type need not be same as name of entity type from which participants are drawn
  - ReportsTo has roles *Subordinate* and *Supervisor* and attribute *Since*
  - Values of *Subordinate* and *Supervisor* both drawn from entity type Employee

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Schema of a Relationship Type

- *Role names*, R_i, and their corresponding entity sets. Roles must be single valued (number of roles = degree of relationship)
- *Attribute names*, A_j, and their corresponding domains. Attributes may be set valued
- *Key*: Minimum set of roles and attributes that uniquely identify a relationship
- *Relationship*: $<e_1, \ldots e_n; a_1, \ldots a_k>$
  - e_i is an entity, a value from R_i's entity set
  - a_j is a set of attribute values with elements from domain of A_j

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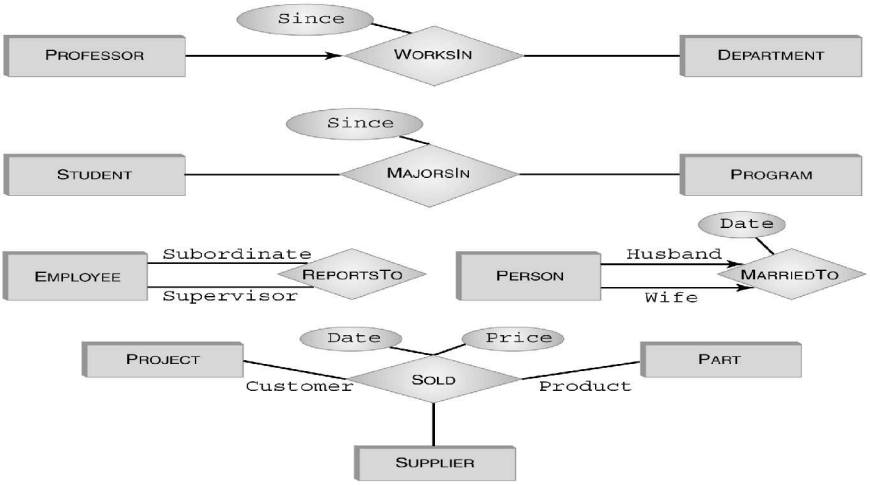
Graphical Representation

- Roles are edges labeled with role names (omitted if role name = name of entity set). Most attributes have been omitted.



Single-role Key Constraint

- If, for a particular participant entity type, each entity participates in *at most* one relationship, corresponding role is a key of relationship type
  - E.g., *Professor* role is unique in WorksIn
- Representation in E-R diagram: arrow

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Entity Type Hierarchies

- One entity type might be subtype of another
  - Freshman is a subtype of Student
- A relationship exists between a Freshman entity and the corresponding Student entity
  - e.g., Freshman John is related to Student John
- This relationship is called *IsA*
  - Freshman IsA Student
  - The two entities related by IsA are always descriptions of the same real-world object

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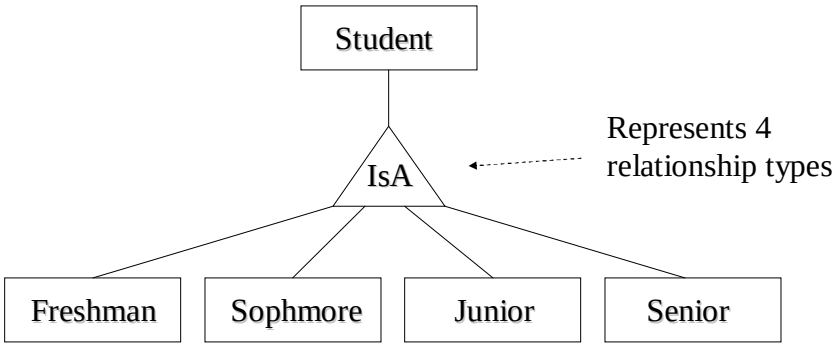
IsA



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Properties of IsA

- *Inheritance* - Attributes of supertype apply to subtype.
  - E.g., *GPA* attribute of Student applies to Freshman
  - Subtype *inherits* all attributes of supertype.
  - Key of supertype is key of subtype
- *Transitivity* - Hierarchy of IsA
  - Student is subtype of Person, Freshman is subtype of Student, so Freshman is also a subtype of Student

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Advantages of IsA

- Can create a more concise and readable E-R diagram
  - Attributes common to different entity sets need not be repeated
  - They can be grouped in one place as attributes of supertype
  - Attributes of (sibling) subtypes can be different

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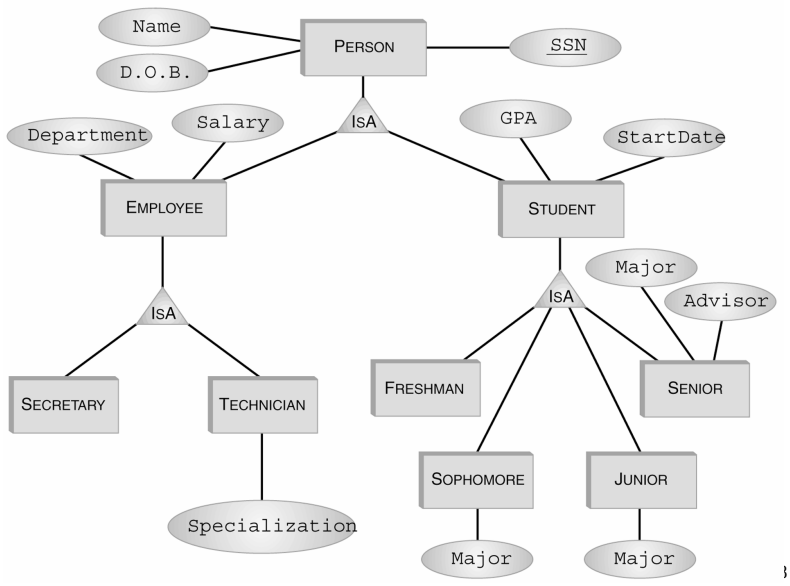
IsA Hierarchy - Example



Constraints on Type Hierarchies

- Might have associated constraints:
  - *Covering constraint*: Union of subtype entities is equal to set of supertype entities
    - Employee is either a secretary or a technician (or both)
  - *Disjointness constraint*: Sets of subtype entities are disjoint from one another
    - Freshman, Sophomore, Junior, Senior are disjoint set

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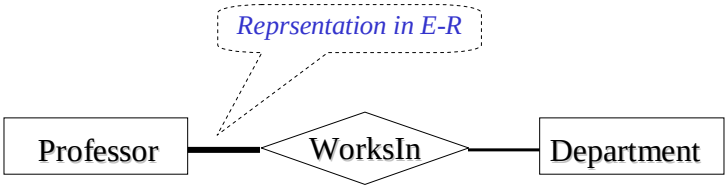
Participation Constraint

- If every entity participates in *at least* one relationship, a *participation constraint* holds:
  - A participation constraint of entity type E having role ρ in relationship type R states that for *e* in E there is an *r* in R such that ρ(*r*) = *e*.
  - e.g., every professor works in *at least* one department



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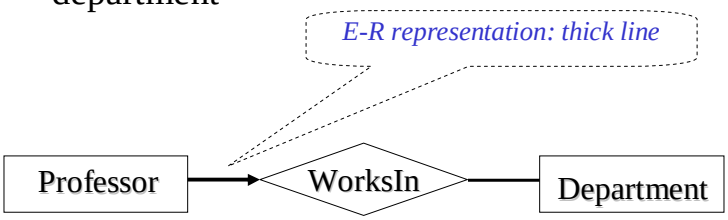
Participation *and* Key Constraint

- If every entity participates in *exactly* one relationship, both a participation and a key constraint hold:
  - e.g., every professor works in *exactly one* department



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Representation of Entity Types in the Relational Model

- An entity type corresponds to a relation
- Relation's attributes = entity type's attributes
  - *Problem*: entity type can have set valued attributes, e.g.,

    Person: *Id*, *Name*, *Address*, *Hobbies*
  - *Solution*: Use several rows to represent a single entity
    - (111111, John, 123 Main St, stamps)
    - (111111, John, 123 Main St, coins)
  - Problems with this solution:
    - Redundancy
    - Key of entity type (Id) not key of relation
    - Hence, the resulting relation must be further transformed (Chapter 6)

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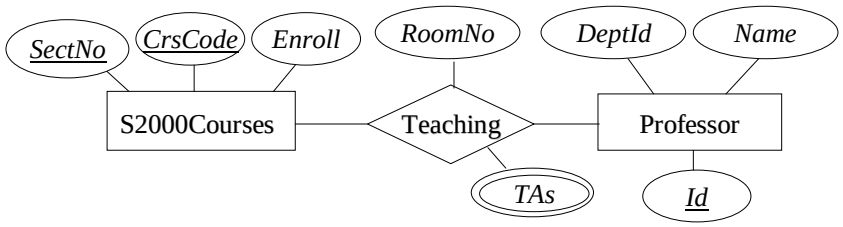
Representation of Relationship Types in the Relational Model

- Typically, a relationship becomes a relation in the relational model
- Attributes of the corresponding relation are
  - Attributes of relationship type
  - For each role, the primary key of the entity type associated with that role
- *Example*:



  - S2000Courses (*CrsCode*, *SectNo*, *Enroll*)
  - Professor (*Id*, *DeptId*, *Name*)
  - Teaching (*CrsCode*, *SecNo*, *Id*, *RoomNo*, *TAs*)

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Representation of Relationship Types in the Relational Model

- Candidate key of corresponding table = candidate key of relation
  - Except when there are set valued attributes
  - Example: Teaching (*CrsCode, SectNo, Id, RoomNo, TAs*)
    - Key of relationship type = (*CrsCode, SectNo*)
    - Key of relation = (*CrsCode, SectNo, TAs*)

CrsCode	*SectNo*	*Id*	*RoomNo*	*TAs*
CSE305	1	1234	Hum 22	Joe
CSE305	1	1234	Hum 22	Mary

Set valued

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Representation in SQL

- Each role of relationship type produces a foreign key in corresponding relation
  - Foreign key references table corresponding to entity type from which role values are drawn

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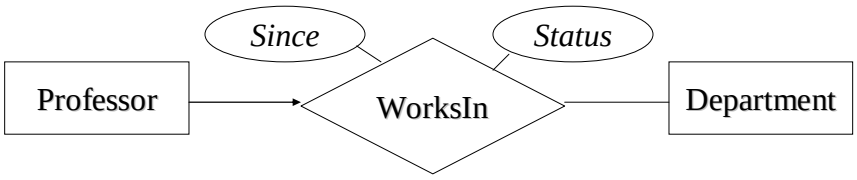
Example 1




```
CREATE TABLE WorksIn  (
   Since DATE,              -- attribute
   Status  CHAR (10),       -- attribute
   ProfId  INTEGER,         -- role (key of  Professor)
   DeptId  CHAR (4),        -- role (key of  Department)
   PRIMARY KEY (ProfId),  -- since a professor works in at most one department
   FOREIGN KEY (ProfId) REFERENCES Professor (Id),
   FOREIGN KEY (DeptId) REFERENCES Department )
```

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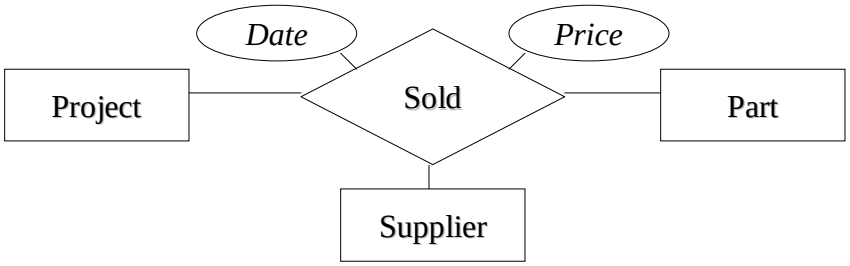
Example 2




```
CREATE TABLE  Sold  (
   Price  INTEGER,              -- attribute
   Date  DATE,                  -- attribute
   ProjId  INTEGER,             -- role
   SupplierId  INTEGER,         -- role
   PartNumber  INTEGER,         -- role
   PRIMARY KEY (ProjId, SupplierId, PartNumber, Date),
   FOREIGN KEY (ProjId) REFERENCES Project,
   FOREIGN KEY (SupplierId) REFERENCES Supplier (Id),
   FOREIGN KEY (PartNumber) REFERENCES Part (Number)  )
```

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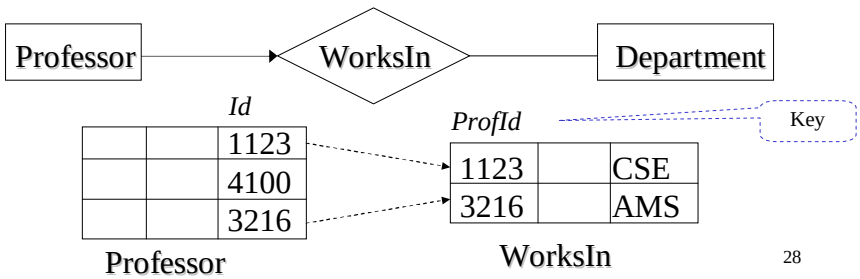
Representation of Single Role Key Constraints in the Relational Model

- *Relational model representation*: key of the relation corresponding to the entity type is key of the relation corresponding to the relationship type
  - *Id* is primary key of Professor; *ProfId* is key of WorksIn. Professor 4100 does not participate in the relationship.
  - Cannot use foreign key in Professor to refer to WorksIn since some professors may not work in any dept. (But *ProfId* is a foreign key in WorksIn that refers to Professor.)



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Representing Type Hierarchies in the Relational Model

- Supertypes and subtypes can be realized as separate relations
  - Need a way of identifying subtype entity with its (unique) related supertype entity
    - *Choose a candidate key and make it an attribute of all entity types in hierarchy*

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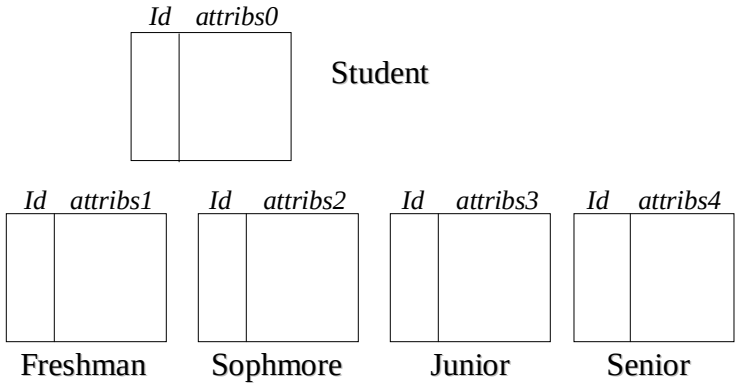
Type Hierarchies and the Relational Model

• Translated by adding the primary key of supertype to all subtypes. Plus foreign key from subtypes to the supertype.



FOREIGN KEY *Id* REFERENCES Student

in Freshman, Sophomore, Sunior, Senior

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Type Hierarchies and the Relational Model

- Redundancy eliminated if IsA is not disjoint
  - For individuals who are both employees and students, Name and DOB are stored only once

Person

SSN	*Name*	*DOB*
1234	Mary	1950

Employee

SSN	*Department*	*Salary*
1234	Accounting	35000

Student

SSN	*GPA*	*StartDate*
1234	3.5	1997

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Type Hierarchies and the Relational Model

- Other representations are possible in special cases, such as when all subtypes are disjoint
- See in the book

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Representing Participation Constraints in the Relational Model

- *Inclusion dependency*: Every professor works in *at least* one dep't.
  - in the relational model: (easy)
    - Professor (*Id*) references WorksIn (*ProfId*)
  - in SQL:
    - Simple case: *If ProfId is a key in* **WorksIn** (i.e., every professor works in *exactly one* department) then it is easy:
      - FOREIGN KEY *Id* REFERENCES WorksIn (*ProfId*)
    - General case – *ProfId* is *not* a key in **WorksIn**, so can't use foreign key constraint (not so easy):

```
CREATE ASSERTION ProfsInDepts
  CHECK ( NOT EXISTS (
    SELECT * FROM Professor P
    WHERE NOT EXISTS (
      SELECT * FROM WorksIn W
      WHERE P.Id = W.ProfId ) ) )
```

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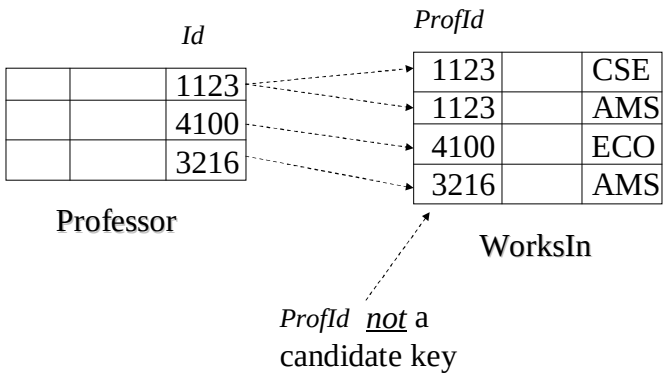
Representing Participation Constraint in the Relational Model

- Example (can't use foreign key in Professor if ProfId is not a candidate key in WorksIn)



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Representing Participation *and* Key Constraint in SQL

- If both participation and key constraints apply, use foreign key constraint in entity table (but beware: if candidate key in entity table is not primary, presence of nulls violates participation constraint).

```
CREATE TABLE Professor  (
   Id   INTEGER,
        ……
   PRIMARY KEY (Id),      -- Id can't be null
   FOREIGN KEY (Id) REFERENCES WorksIn  (ProfId)
                          --all professors participate
)
```

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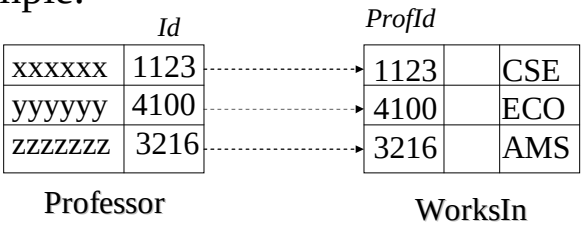
Participation *and* Key Constraint in the Relational Model

- Example:



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Participation *and* Key Constraint in Relational Model (again)

- Alternative solution if both key and participation constraints apply: merge the tables representing the entity and relationship sets
  - Since there is a 1-1 and onto relationship between the rows of the entity set and the relationship sets, might as well put all the attributes in one table

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Participation *and* Key Constraint in Relational Model

- Example

Name	*Id*		*DeptId*
xxxxxxx	1123		CSE
yyyyyyy	4100		ECO
zzzzzzzz	3216		AMS

Prof_WorksIn

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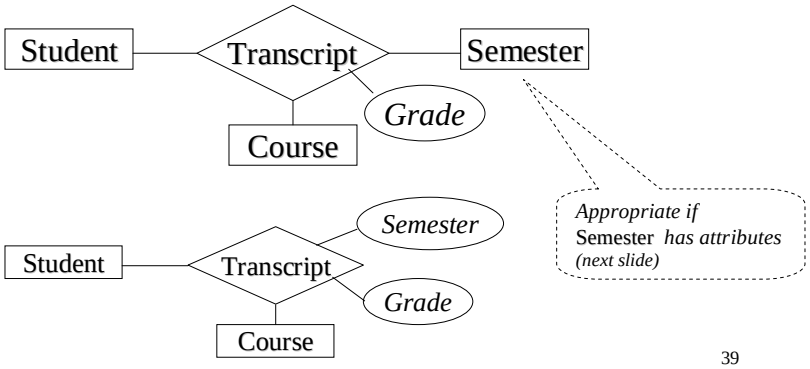
Entity or Attribute?

- Sometimes information can be represented as either an entity or an attribute.



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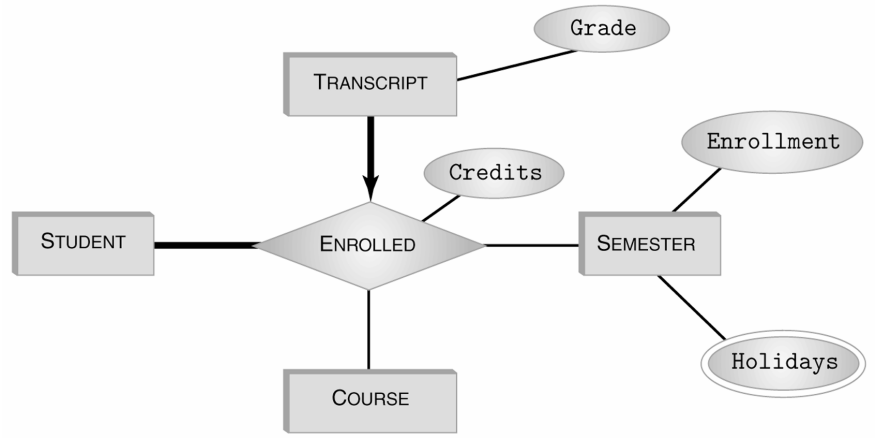
Entity or Relationship?



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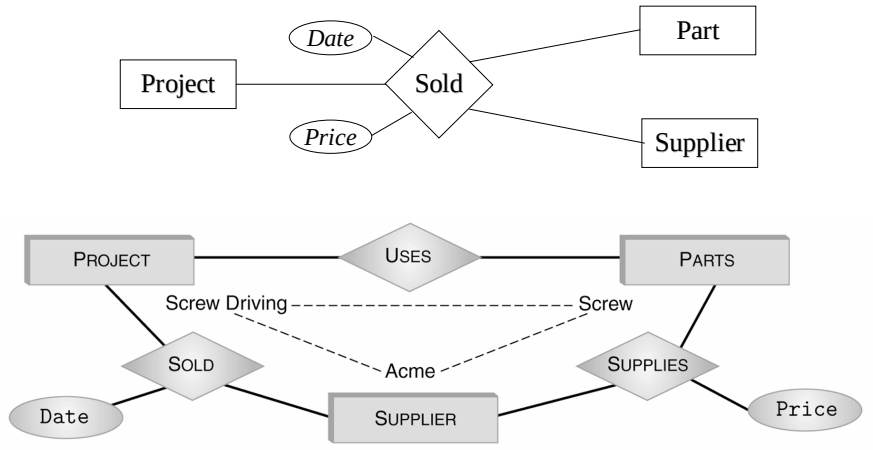
(Non-) Equivalence of Diagrams

- Transformations between binary and ternary relationships.



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