Constraints in Entity-Relationship Models

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Types of Constraints

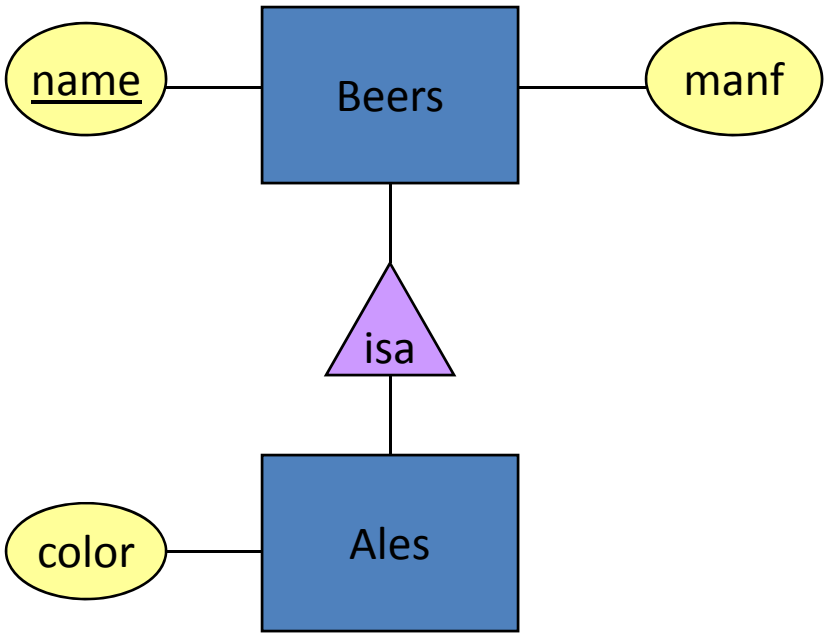
- Keys are attributes or sets of attributes that uniquely identify an entity within its entity set.
- Single-value constraints require that a value be unique in certain contexts.
- Referential integrity constrains require that a value referred to actually exists in the database.
- Domain constraints specify what set of values an attribute can take.
- General constraints are arbitrary constraints that should hold in the database. We will study some examples in the second half of the semester.
- **Constraints are part of the schema of a database.**

Keys

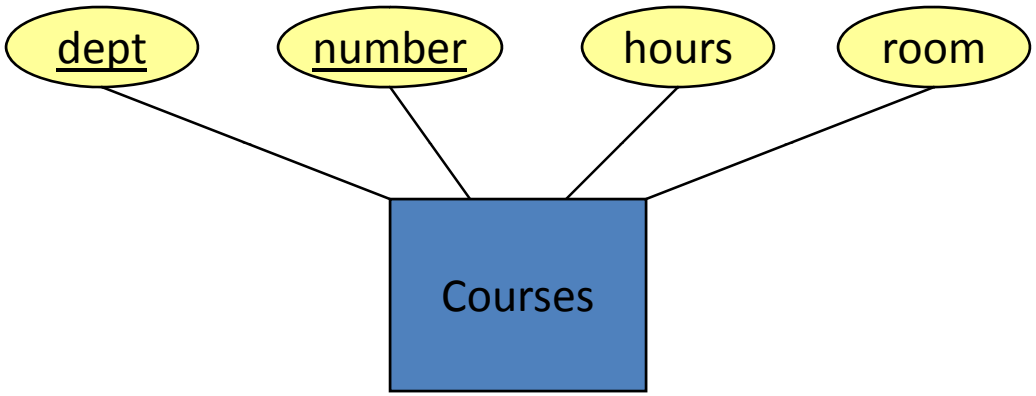
- A *key* is a set of attributes for one entity set such that no two entities in this set agree on all the attributes of the key.
  - It is allowed for two entities to agree on some, but not all, of the key attributes.
- A key for an entity set E is a set K of one or more attributes such that given any two entities e1 and e2 in E, e1 and e2 cannot have identical values for all the attributes in K.
- E can have multiple keys. We usually designate one as the primary key.
- We must designate a key for every entity set.

Keys in E/R Diagrams

- Underline the key attribute(s).
- In an Isa hierarchy, only the root entity set has a key, and it must serve as the key for all entities in the hierarchy.

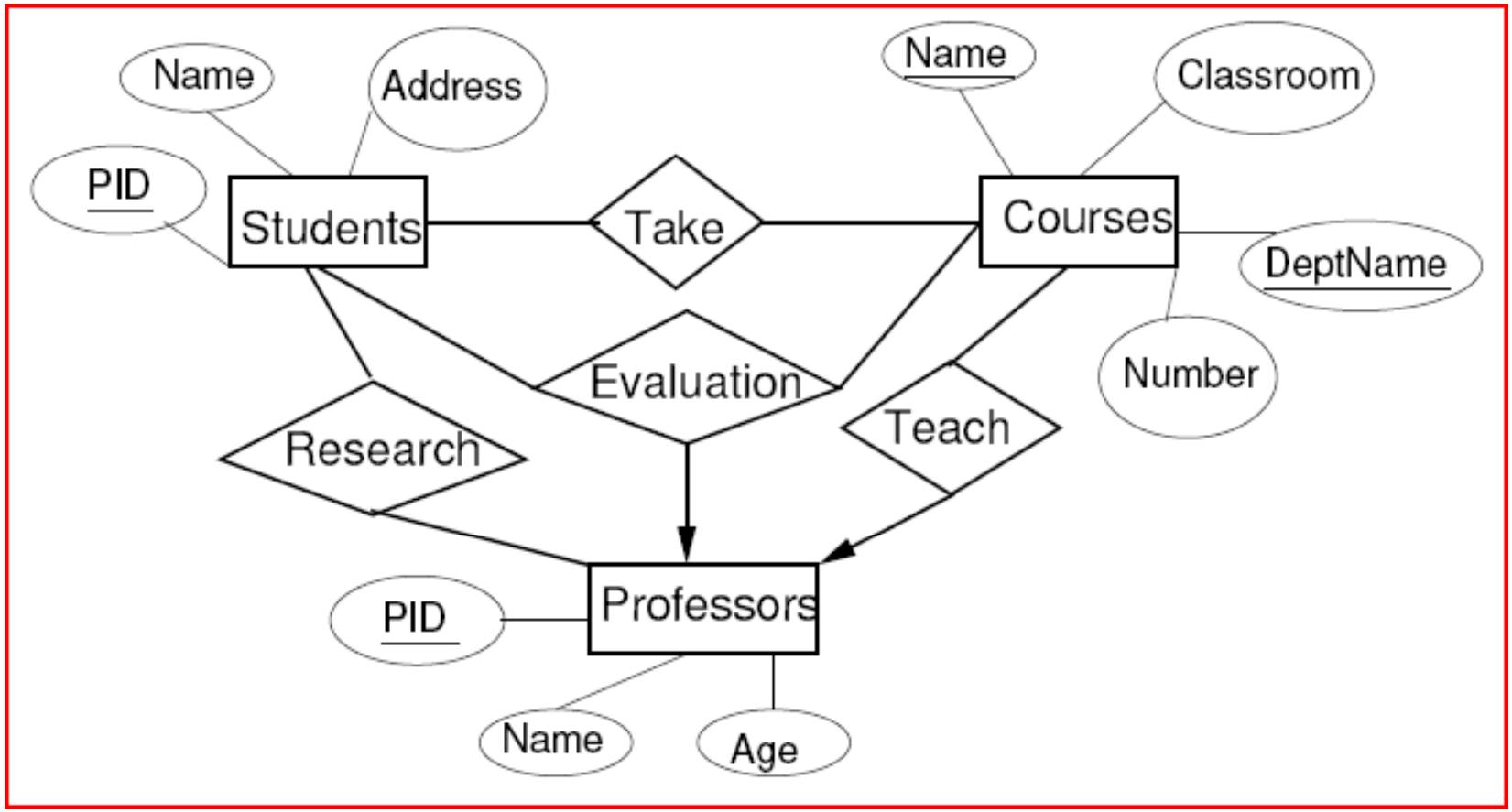


Example: a Multi-attribute Key



- Note that *hours* and *room* could also serve as a key, but we must select only one key.

Examples of Keys



Single-Value Constraint

- There is at most one value in a given context.

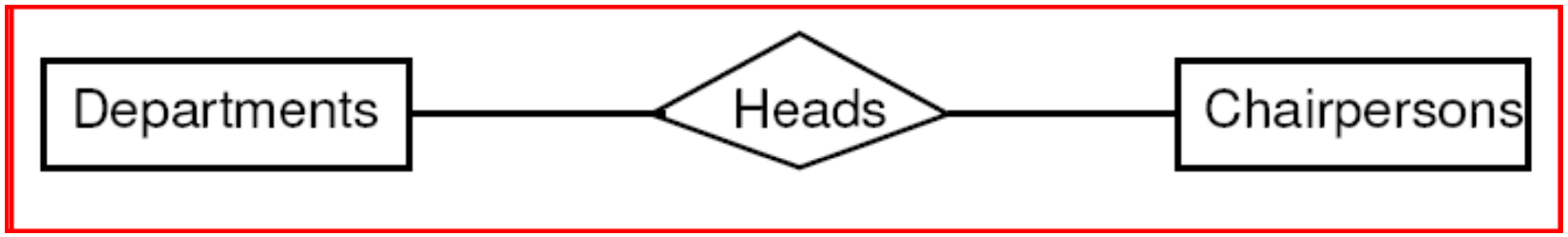
1. Each attribute of an entity set has a single value.
   - If the value is missing, we can invent a “null” value.
   - E/R models cannot represent the requirement that an attribute cannot have a null value.
2. A many-one relationship implies a single value constraint.

Referential Integrity Constraint

- Asserts that exactly one value exists in a given context.
- Usually used in the context of relationships.
- Example: Many-one Advises relationship between Students and Professors.
  - Many-one requirement says that no student may have more than one advising professor.
  - Referential integrity constraint says that each student must have exactly one advising professor and that professor must be present in the database.
- If R is a (many-to-one or one-to-one) relationship from E to F, we use a rounded arrowhead pointing to F to indicate that we require that the entity in F related by R to an entity in E must exist.

Example

- Each department has at most one chairperson who is its head (there are times when a department may not have a chairperson).
- Each chairperson can be the head of at most one department and this department must exist in the database.
- Where do we put the arrows?



Enforcing Referential Integrity Constraints

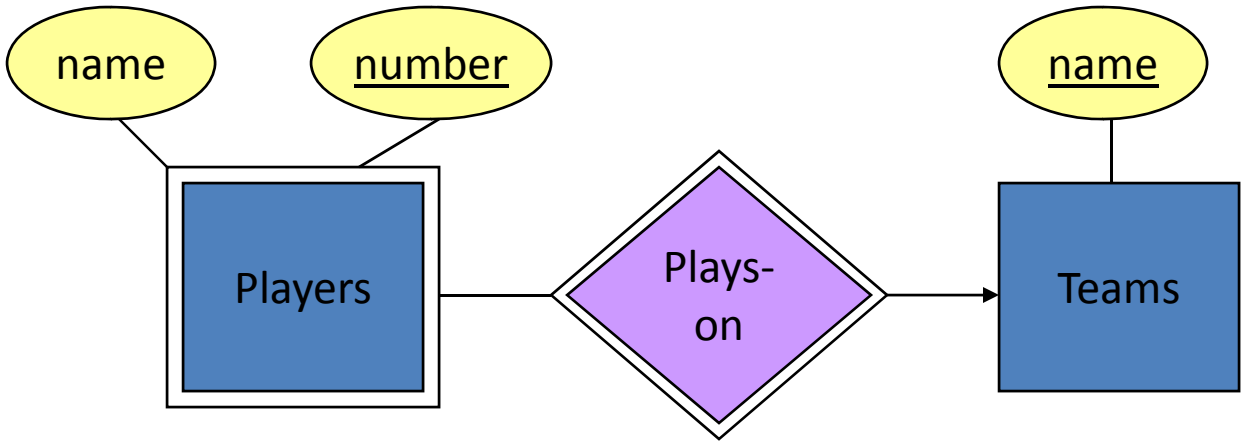
- We forbid the deletion of a referenced entity (e.g., a professor) until the professor advises no students.
- We require that if we delete a referenced entity, we delete all entities that reference it.
- When we insert a student entity, we must specify an existing professor entity connected to the student by the Advises relationship.

Weak Entity Sets

- Occasionally, entities of an entity set need "help" to identify them uniquely.
- Entity set *E* is said to be *weak* if in order to identify entities of *E* uniquely, we need to follow one or more many-one relationships from *E* and include the key of the related entities from the connected entity sets.

Example

- *name* is almost a key for football players, but there might be two with the same name.
- *number* is certainly not a key, since players on two teams could have the same number.
- But *number*, together with the *Team* related to the player by *Plays-on* should be unique.



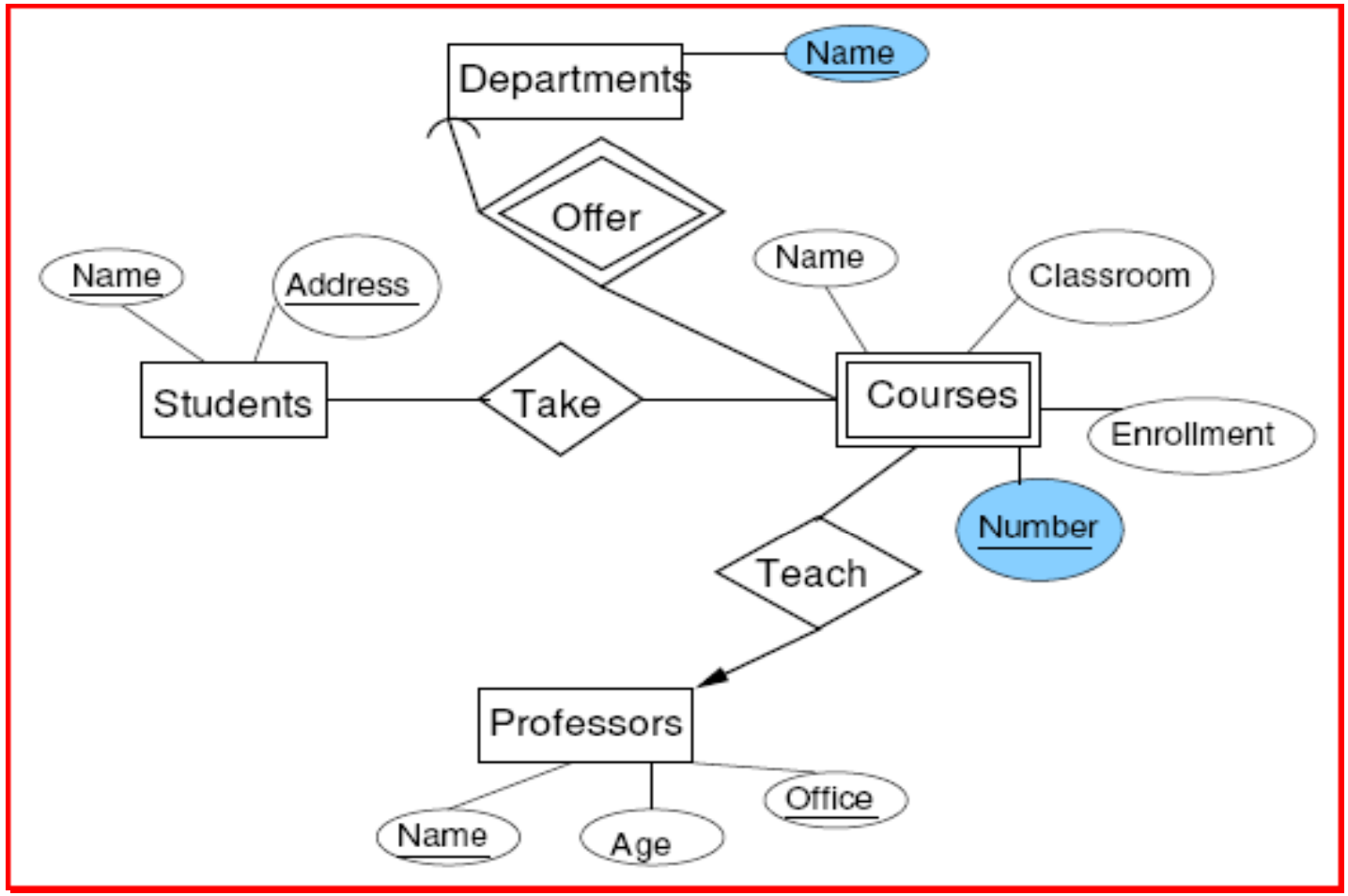
- Double diamond for *supporting* many-one relationship.
- Double rectangle for the weak entity set.

Weak Entity-Set Rules

- A weak entity set has one or more many-one relationships to other (supporting) entity sets.
  - Not every many-one relationship from a weak entity set need be supporting.
- The key for a weak entity set is its own underlined attributes and the keys for the supporting entity sets.
  - E.g., player-*number* and team-*name* is a key for *Players* in the previous example.

Example of Weak Entity Set

- Each department teaches multiple courses. Each course has a number. What is the key for the entity set Courses?



Design Techniques

- Be faithful to the specification of the application.
- Avoid redundancy.
- Keep the entities and relationship simple.
  - Don’t use an entity set when an attribute will do.
- Select the right relationships.
- Select the right type of element.
- Limit the use of weak entity sets.

Be Faithful

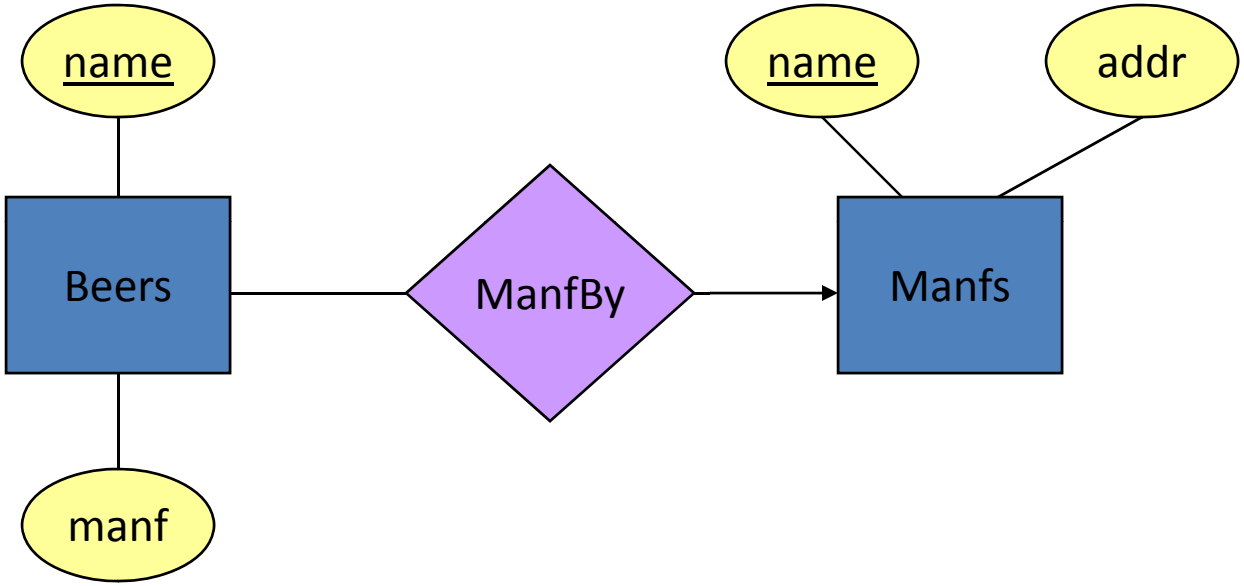
- Do not use meaningless or unecessary attributes.

- Define the multiplicity of a relationship appropriately.
  - What is the multiplicity of the relationship Take between Students and Courses?
  - What is the multiplicity of the relationship Teach between Professors and Courses?

Avoiding Redundancy

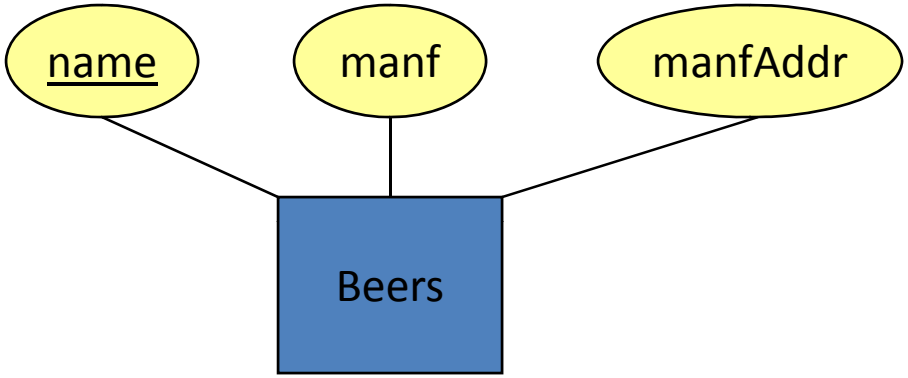
- Redundancy occurs when we say the same thing in two different ways.
- Redundancy wastes space and (more importantly) encourages inconsistency.
  - The two instances of the same fact may become inconsistent if we change one and forget to change the other, related version.

Example: Bad



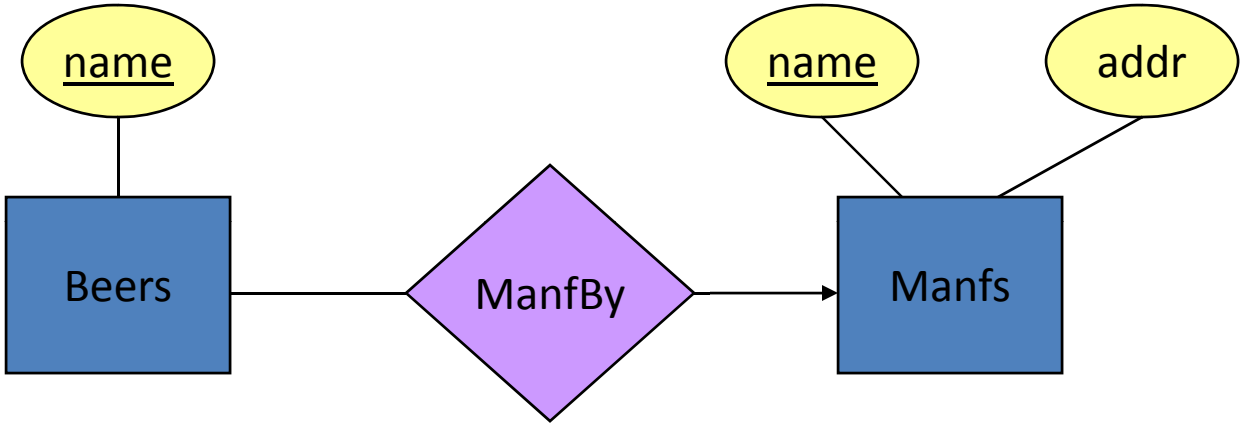
This design states the manufacturer of a beer twice: as an attribute and as a related entity.

Example: Bad



This design repeats the manufacturer's address once for each beer; loses the address if there are temporarily no beers for a manufacturer.

Example: Good



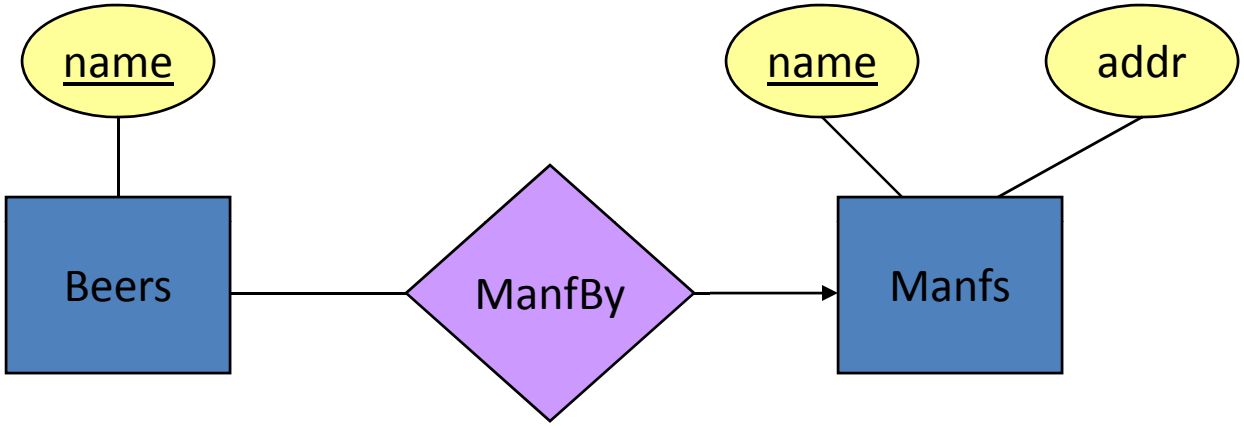
This design gives the address of each manufacturer exactly once.

Entity Sets Versus Attributes

- An entity set should satisfy at least one of the following conditions:
  - It is more than the name of something; it has at least one nonkey attribute.

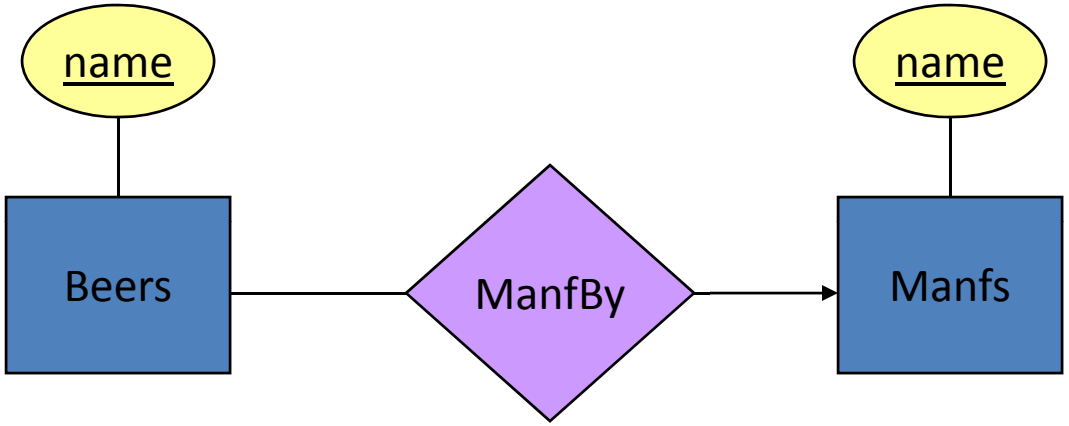
    or
  - It is the "many" in a many-one or many-many relationship.

Example: Good



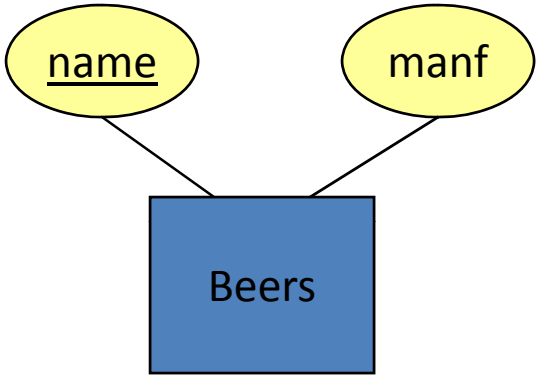
- *Manfs* deserves to be an entity set because of the nonkey attribute *addr*.
- *Beers* deserves to be an entity set because it is the "many" of the many-one relationship *ManfBy*.

Example: Bad



Since the manufacturer is nothing but a name, and is not at the "many" end of any relationship, it should not be an entity set.

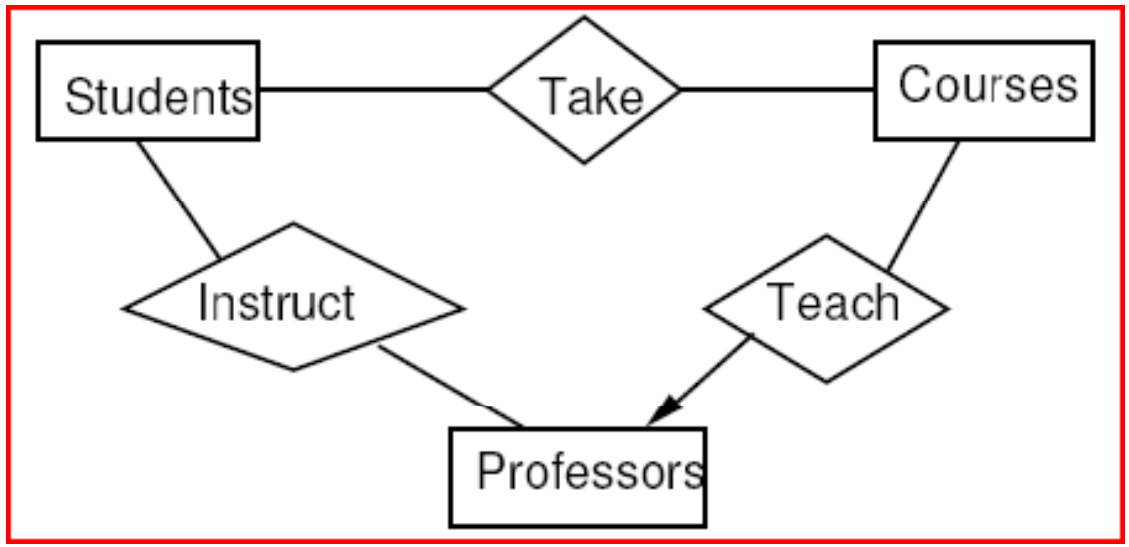
Example: Good



There is no need to make the manufacturer an entity set, because we record nothing about manufacturers besides their name.

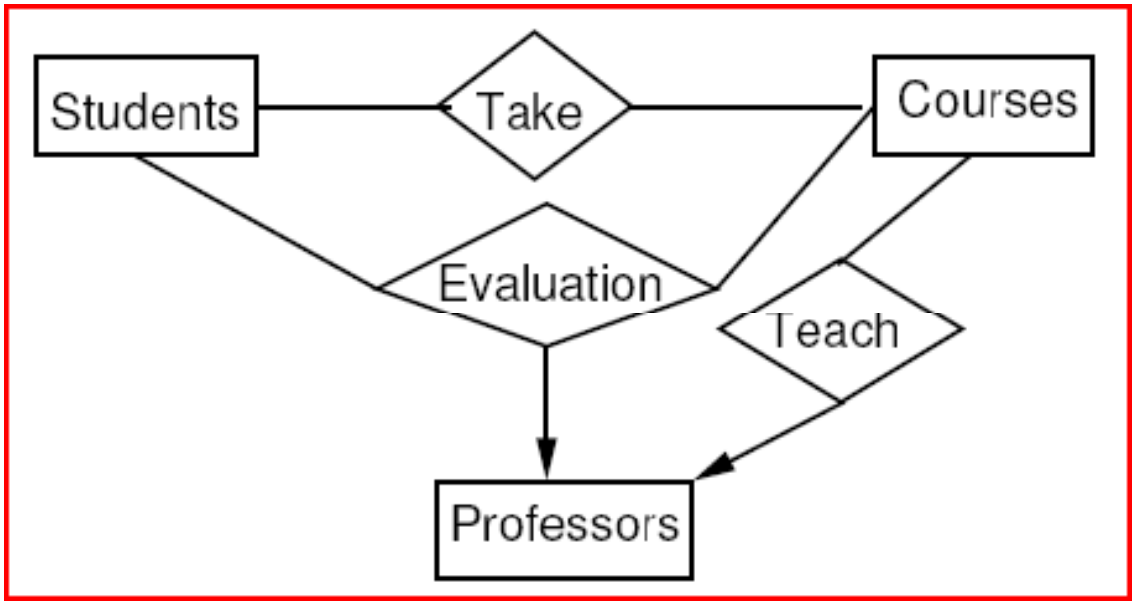
Design

- Do not add unnecessary relationships.
- It may be possible to deduce one relationship from another.
- Do we need the relationship Instruct between Professors and Students?
  - No. We can deduce this relationship from Take and Teach.



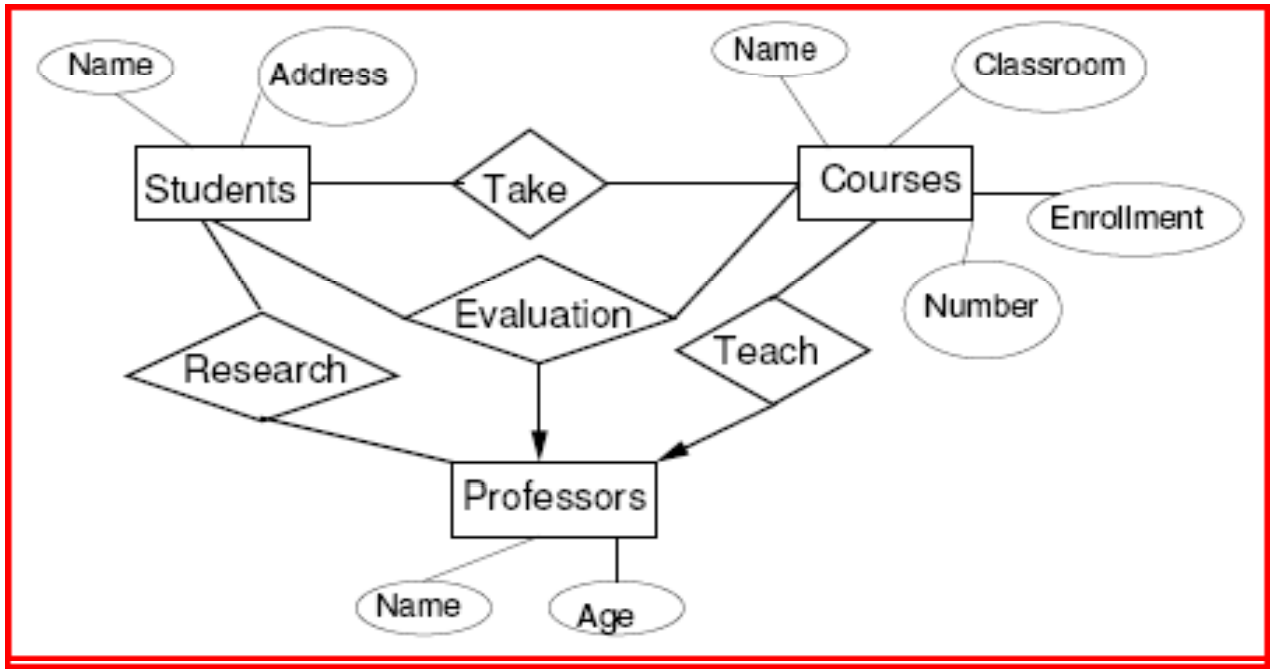
Design

- Do not add unnecessary relationships.
- It may be possible to deduce one relationship from another.
- Do we need the relationships Take and Teach?
  - Yes. Why?



Select the Right Type of Element

- Attribute or Entity or Relationship?
- Can we make Professor an attribute of Courses and remove the relationship Teach?
- What if we add the relationship Evaluation?
- What if we add the relationship Research signifying a research project the student is working on with a professor?



Converting an Entity Set into an Attribute

- If an entity set E satisfies the following properties:
  1. All relationships involving E have arrows entering E.
  2. The attributes of E collectively identify an entity (i.e., no attribute depends on another).
  3. No relationship involves E more than once
- then we can replace E as follows:
  1. If there is a many-one relationship R from an entity set F to E, remove R and make the attributes of E be attributes of F.
  2. If there is a multi-way relationship R with an arrow to E, make the attributes of E be new attributes of R and remove the arrow from R to E.

Don’t Overuse Weak Entity Sets

- Beginning database designers often doubt that anything could be a key by itself.
  - They make all entity sets weak, supported by all other entity sets to which they are linked.
- In reality, we usually create unique ID’s for entity sets.
  - Examples include social-security numbers, automobile VIN’s etc.

When Do We Need Weak Entity Sets?

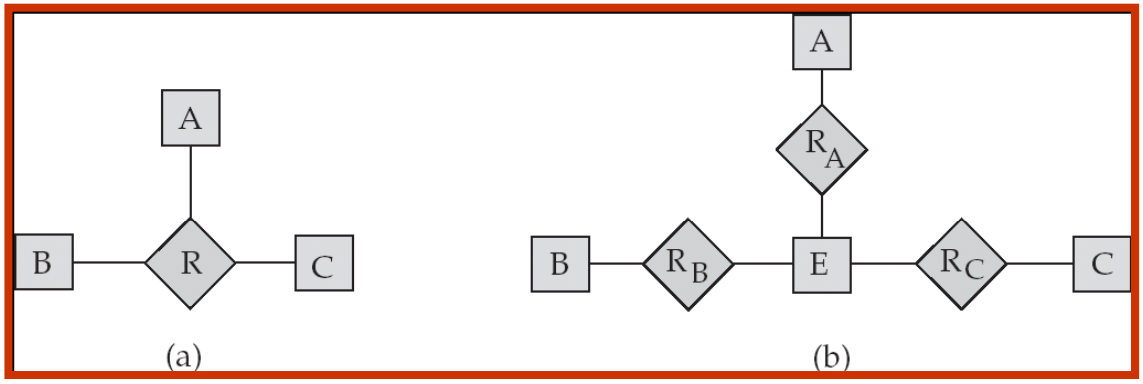
- The usual reason is that there is no global authority capable of creating unique ID's.
- Example: it is unlikely that there could be an agreement to assign unique player numbers across all football teams in the world.

Binary vs. Non-Binary Relationships

- 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 known)
  - But there are some relationships that are naturally non-binary
    - Example: *works_on*

Converting Non-Binary Relationships to Binary Form

- 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 three 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



From E/R Diagrams to Relations

- Entity set $\longrightarrow$ relation.
  - Attribute of an entity set $\longrightarrow$ attribute of a relation.
- Relationship $\longrightarrow$ relation whose attributes are
  - Attribute of the relationship itself.
  - Key attributes of the connected entity sets.
- Several special cases:
  - Weak entity sets.
  - Combining relations (especially for many-one relationships).
  - *Isa* relationships and subclasses.

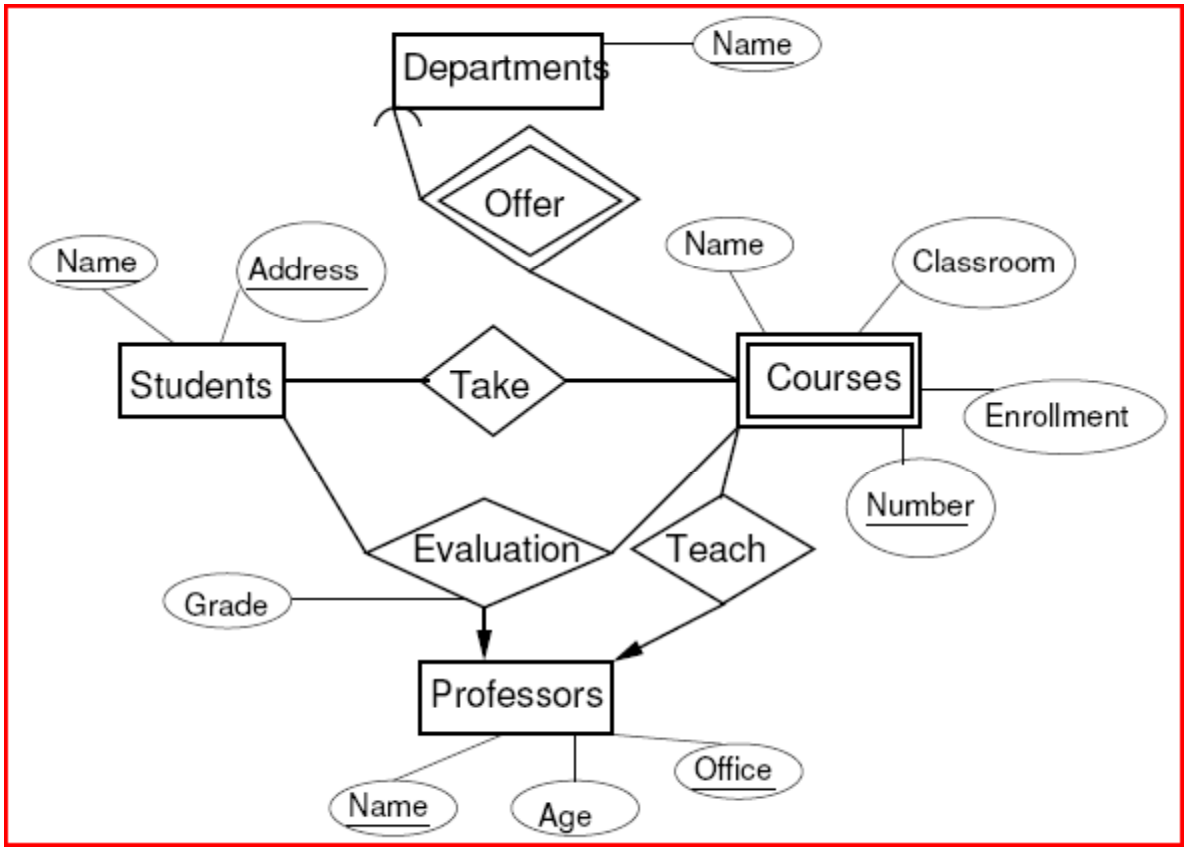
Schemas for Non-Weak Entity Sets

- For each entity set, create a relation with the same name and with the same set of attributes.

Students(Name, Address)

Professors(Name, Office, Age)

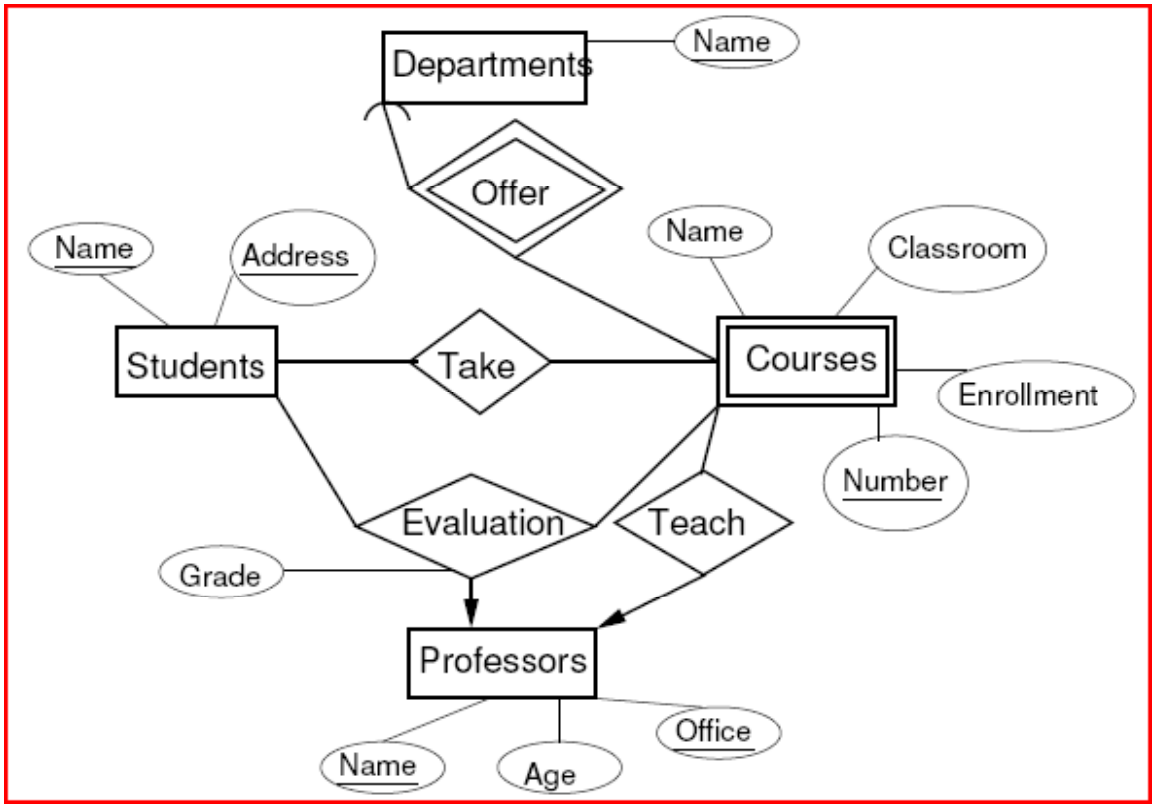
Departments(Name)



Schemas for Weak Entity Sets

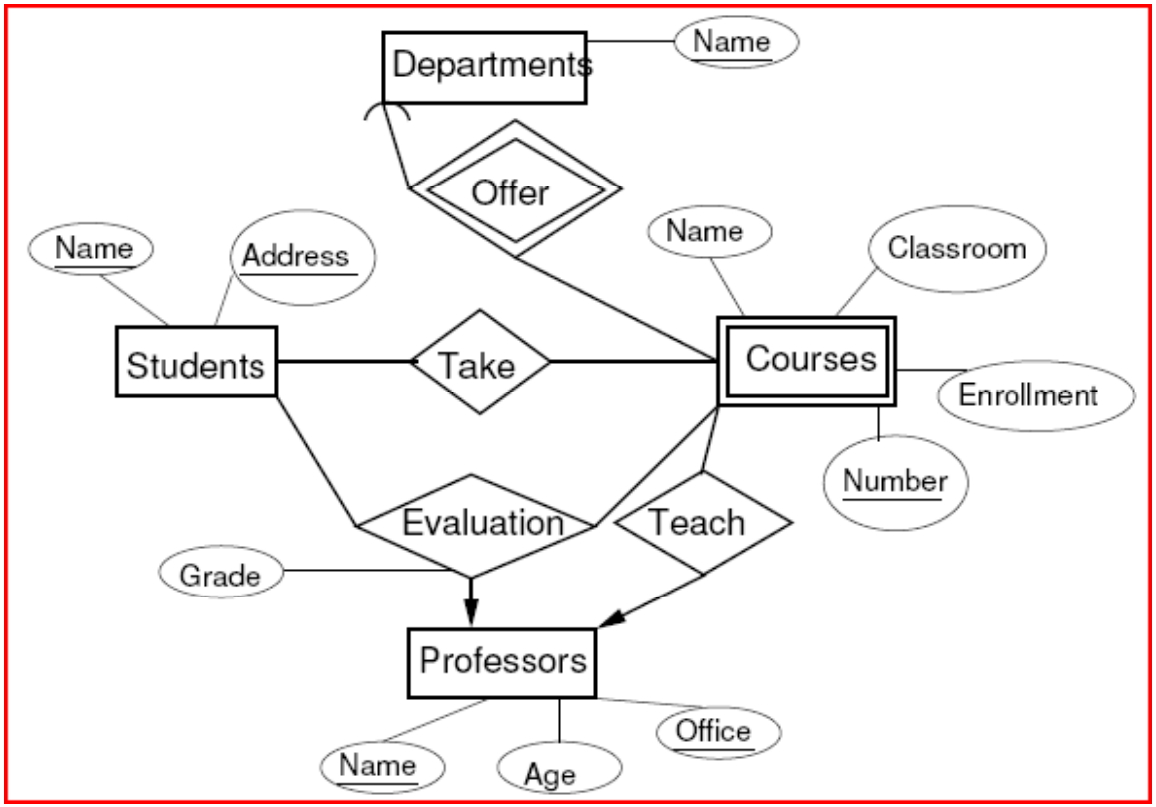
- For each weak entity set W, create a relation with the same name whose attributes are
  - Attributes of W and
  - Key attributes of the other entity sets that help form the key for W.

Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)



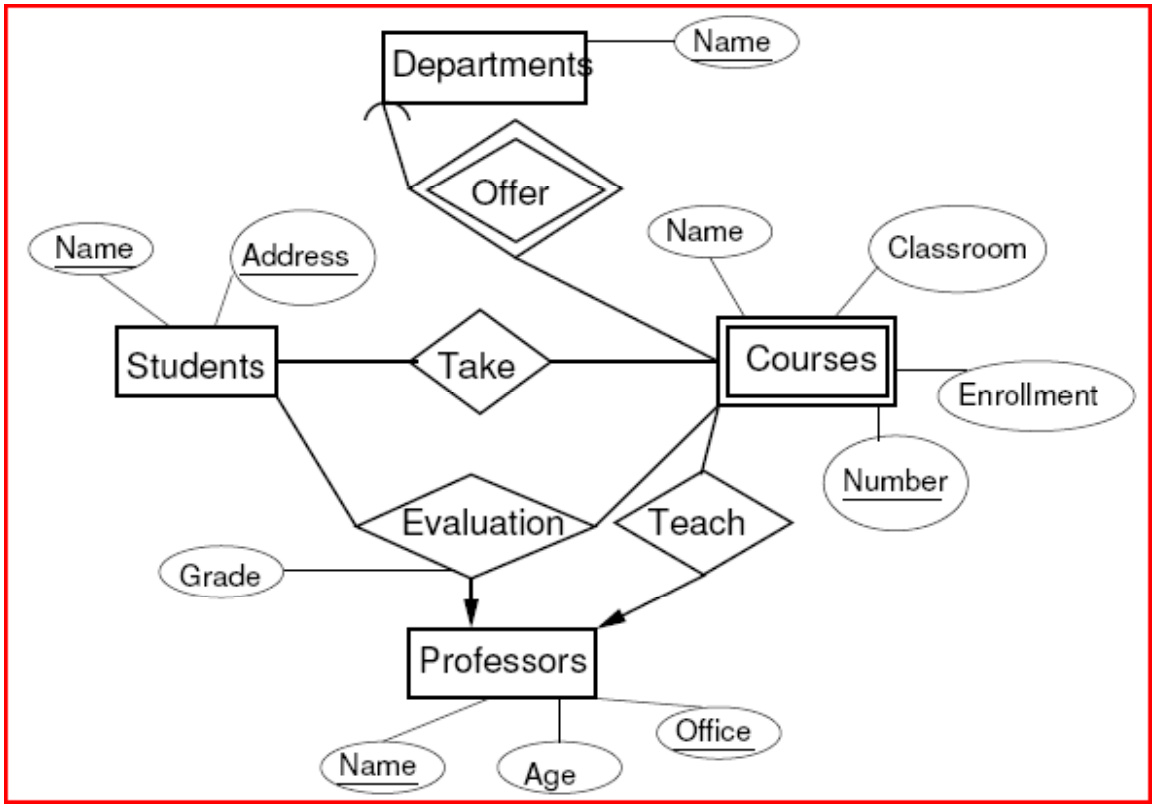
Schemas for Non-Supporting Relationships

- For each relationship, create a relation with the same name whose attributes are
  - Attributes of the relationship itself.
  - Key attributes of the connected entity sets (even if they are weak).

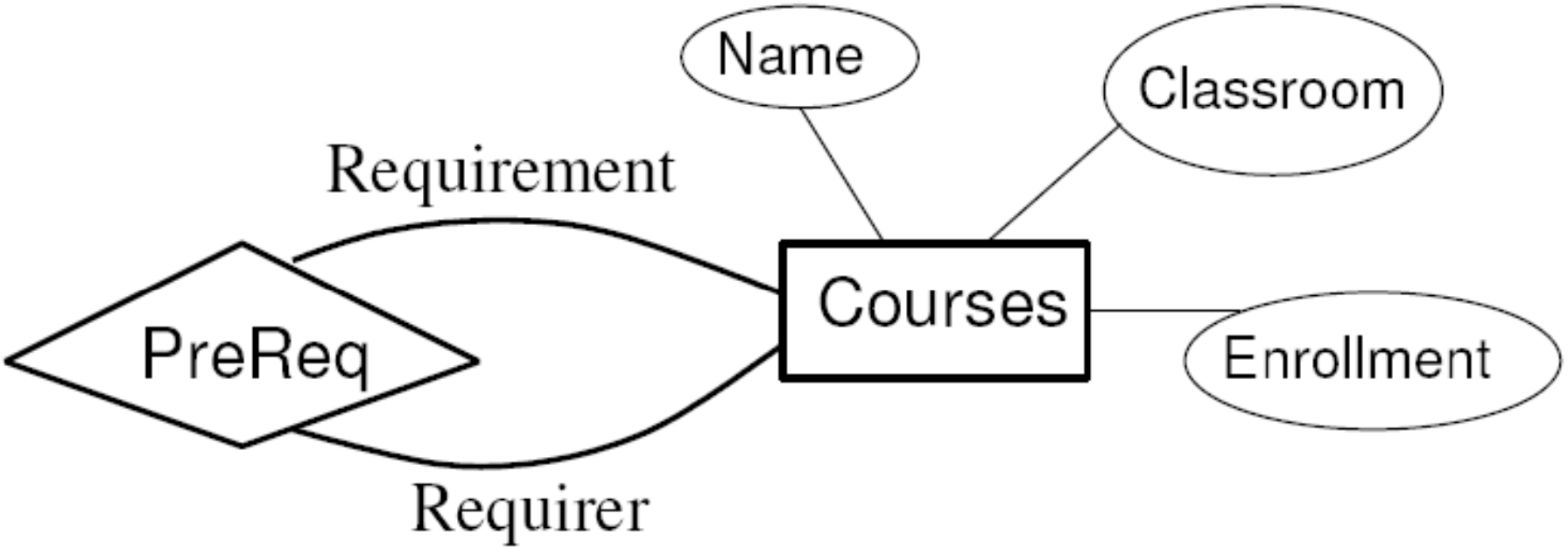


Schemas for Non-Supporting Relationships

- Take(StudentName, Address, Number, DepartmentName)
- Teach(ProfessorName, Office, Number, DepartmentName)
- Evaluation(StudentName, Address, ProfessorName, Office, Number, DepartmentName, Grade)



Roles in Relationships



- If an entity set E appears $k > 1$ times in a relationship R (in different roles), the key attributes for E appear k times in the relation for R, appropriately renamed.

  `PreReq(RequirerNumber, RequirerDeptName, RequirementNumber, RequirementDeptName)`

Combining Relations

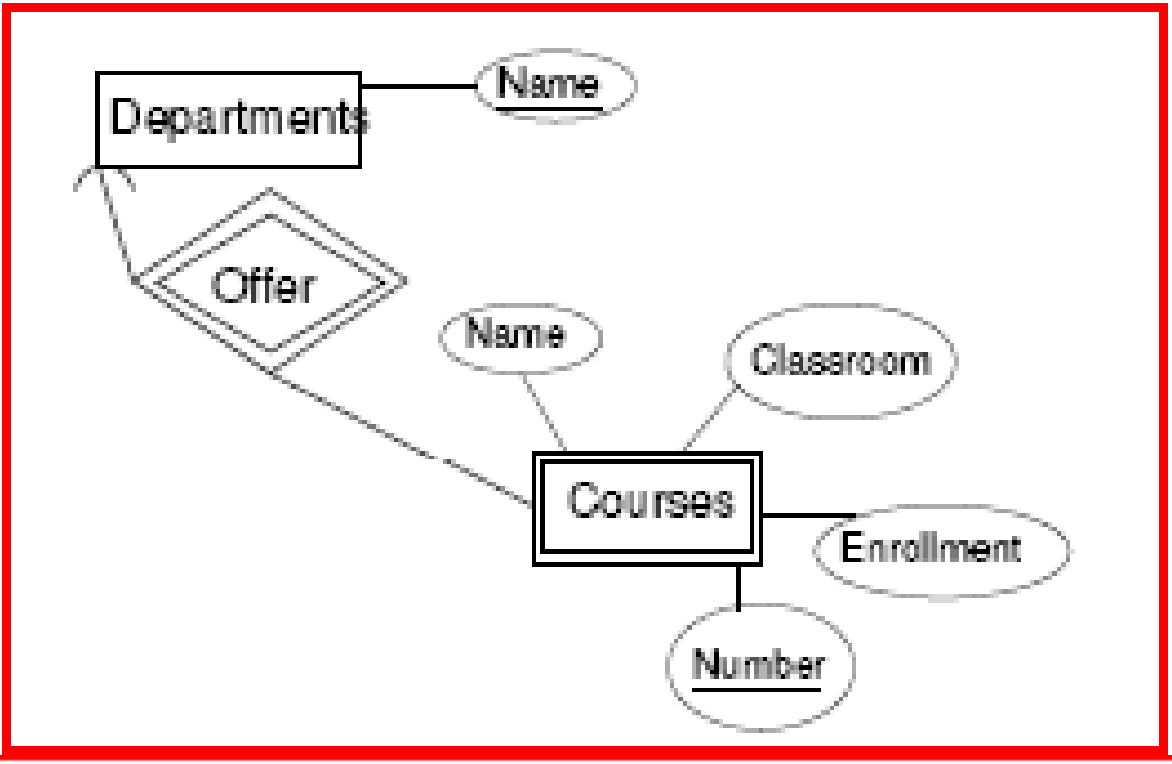
- Consider many-one `Teach` relationship from `Courses` to `Professors`.
- Schemas are

  `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`
  `Professors(Name, Office, Age)`
  `Teach(Number, DepartmentName, ProfessorName, Office)`
- The key for `Courses` uniquely determines all attributes of `Teach`.
- We can combine the relations for `Courses` and `Teach` into a single relation whose attributes are
  - All the attributes for `Courses`,
  - Any attributes of `Teach`, and
  - The key attributes of `Professors`.

Rules for Combining Relations

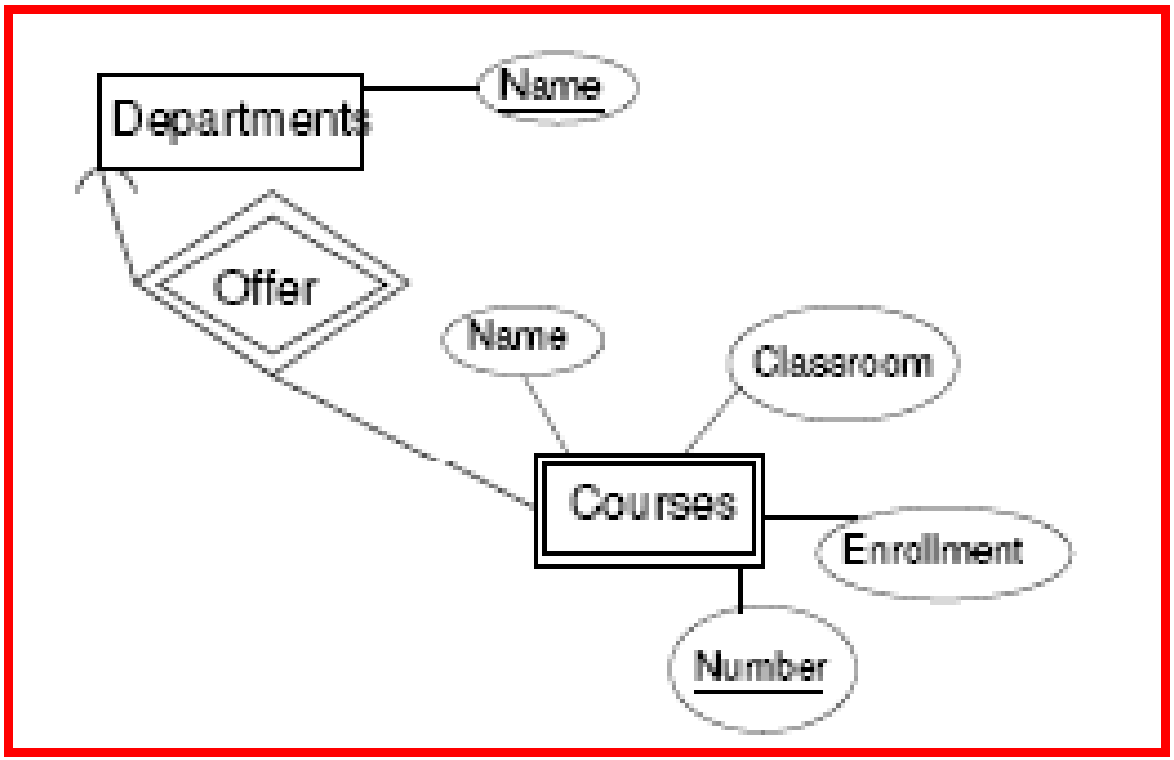
- We can combine into one relation Q
  - The relation for an entity set E and
  - all many-to-one relationships $R_1, R_2, \ldots R_k$ from E to other entity sets $E_1, E_2, \ldots, E_k$, respectively.
- The attributes of Q are
  - all the attributes of E,
  - any attributes of $R_1, R_2, \ldots R_k$, and
  - the key attributes of $E_1, E_2, \ldots, E_k$.

Supporting Relationships



- Schema for `Departments` is `Departments(Name)`.
- Schema for `Courses` is `Courses(Number, DepartmentName, CourseName, Classroom, Enrollment)`.
- What is the schema for `Offer`?

Supporting Relationships



- Offer(Name, Number, DepartmentName).
- But Name and DepartmentName are identical, so the schema for Offer is
  Offer(Number, DepartmentName).

The schema for Offer is a subset of the schema for the weak entity set, so we can dispense with the relation for Offer.

End of E/R Diagrams