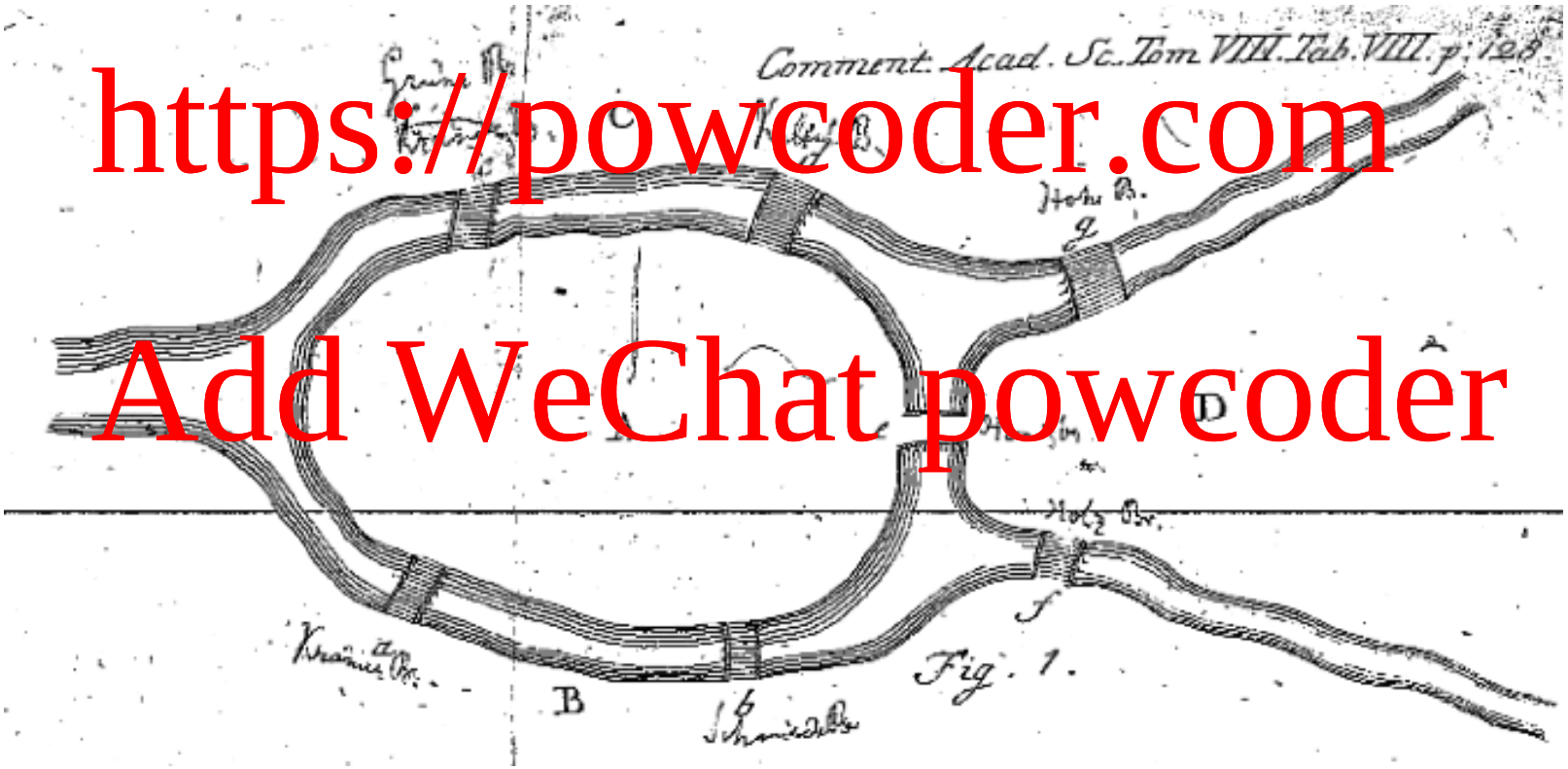
# Week 4 Workshop





## Housekeeping information



- SQL Assessment (Assignment 1) will be available on Wattle 23:59 tonight, and the submission via Wattle is due 23:59 Sep 3 (Friday, Week 6)
  - **Individual, no group work!**
  - **Do not post any idea/partial solution/result on Wattle.**
  - **Do not wait until the last minute to check/submit your solution.**
- Sample SQL questions/solutions will be available on Wattle.
- The correctness of queries does not depend on any database state.
- Partial marks may be awarded.

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  - Sample SQL questions/solutions will be available on Wattle.
  - The correctness of queries does not depend on any database state.
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- Drop in sessions for Assignment 1 (Week 5 and Week 6)
  - Aug 23 (Mon) 2-3 pm (NEW)
  - Aug 24 (Tue) 2-3 pm
  - Aug 25 (Wed) 8-9 pm (NEW)
  - Aug 30 (Mon) 2-3 pm (NEW)
  - Aug 31 (Tue) 2-3 pm
  - Sep 1 (Wed) 8-9 pm (NEW)

## Database Design – Four Phases



- The database design process has **four phases**:



1. **Requirements Collection and Analysis**
2. **Conceptual Design**
   **Entity-Relationship Model**



3. **Logical Design**
   **From Entity-Relationship Model to Relation Schemas**
4. **Physical Design**

## Phase 2: Conceptual Design



- **Conceptual design** is the process of constructing a conceptual data model that is
  - modeled at a high-level of abstraction;
  - sufficiently simple and often graphical;
  - used to communicate the requirements of a database with nontechnical users.





- A conceptual data model is built using the information in users' requirements specification.

**Note:** The conceptual design is based on the **Entity-Relationship Model** in this course.

## Model and Modeling

- What is a model?

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- often a graphical depiction of data
- associated with a modeling language

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- **What does modeling do?**

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- **What does modeling do?**

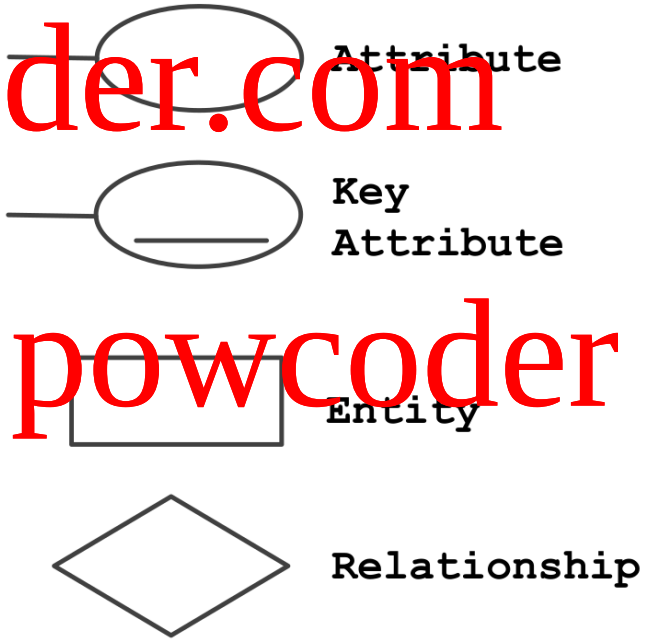
  **Modeling**

  - creates an understanding and relationships of components of a system
  - helps in conceptualising and visualising the structure of a system that we may want to build.
  - facilitates specifications of the behaviour of a system
  - gives rise to a template that guides us in constructing a system
  - . . .

## Entity-Relationship (ER) Model



- ER diagrams (Peter Chen in 1976):
  - **Attribute** as *oval*;
  - **Key attribute** with *underlined*;
  - **Entity** as *rectangles*;
  - **Relationship** as *diamonds*.



(Exercise 1) Consider the following data requirements for a university student database that is used to keep track of students' transcripts.

- The university keeps track of each student's name, student number, social security number, address, phone, and birthdate. Both social security number and student number have unique values for each student.
- Each student has exactly one major, and may have a minor (if any) with departments.
- Each department has name, department code, office number, office phone, and college. Both name and code have unique values for each department.
- Each course has a course name, description, course number, number of semester hours, level, and offering department. The value of course number is unique for each course.
- Each section of a course has an instructor, semester, year, and section number and the section number distinguishes different sections of the same course that are taught during the same semester/year; its values are 1, 2, 3, ..., up to the number of sections taught during each semester.
- A grade record refers to each student and a particular section, consisting of a final mark and a letter grade from (F, D, C, B, A).

## Entities, Relationships and Attributes



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**Question:** What are the entities, relationships and attributes?

- **Entities:** STUDENT
- **Relationships:**
- **Attributes**: name, student number, social security number, address, phone and birthdate for STUDENT

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**Question:** What are the entities, relationships and attributes?



- **Entities:** STUDENT, DEPARTMENT
- **Relationships:** has_major_with between STUDENT and DEPARTMENT, has_minor_with between STUDENT and DEPARTMENT
- **Attributes**: name for has_major_with, name for has_minor_with

## Constraints on Relationships



- **Cardinality ratios**: Specifies the *maximum* number of relationships that an entity can participate in.
- **Participation constraints** (total, partial): Specifies whether the existence of any entity depends *on* its being related to another entity via the relationship type.

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**Participation constraints**: Every student **must** have one major (**total**) and each department **must** (typically) offer one major (**total**).

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**Question:** What are the constraints on relationship "**has_minor_with**"?

**Cardinality ratios**: Every student has at most **one** minor and a department may offer **many** minor (to different students)

**Participation constraints**: Every student **may or may not** have one minor (**partial**) and each department **must** (typically) offer one minor (**total**).

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**Question:** What are the entities, relationships and attributes?

- **Entities:** course, department
- **Relationships:** offer (between **department** and **course**)
- **Attributes**: course name, description, course number, number of semester hours and level (of the entity **course**)

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**Question**: What are the constraints on relationship "**offer**"?



**Cardinality ratios**: Every course is offered by at most **one** department and a department may offer **many** courses

**Participation constraints**: Every course **must** be offered by some department (**total**) and each department **may (or may not)** offer any courses (**partial**).

# Entities, Relationships and Attributes



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  Each section of a course has an instructor, semester, year, and section number; the section number distinguishes different sections of the same course that are taught during the same semester/year; its values are 1, 2, 3, ..., up to the number of sections taught during each semester.

  A grade record refers to each student and a particular section, consisting of a final mark and a letter grade from (F, D, C, B, A).

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- **Relationships:** section_taught (between **section** and **course**), grade_record (between **student** and **section**)

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- **Relationships:** section_taught (between **section** and **course**), grade_record (between **student** and **section**)
- **Attributes**: instructor, semester, year, and section number (of the **weak** entity **section**), final mark and letter grade (of the relationship **grade_record**)

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## Constructing an ER or EER Model



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- Identify the relationships
  - **has_major** (between **student** and **department**)
  - **has_major** (between **student** and **department**)
  - **offer** (between **department** and **course**)
  - **section_taught** (between **section** and **course**)
  - **grade_record** (between **student** and **section**)

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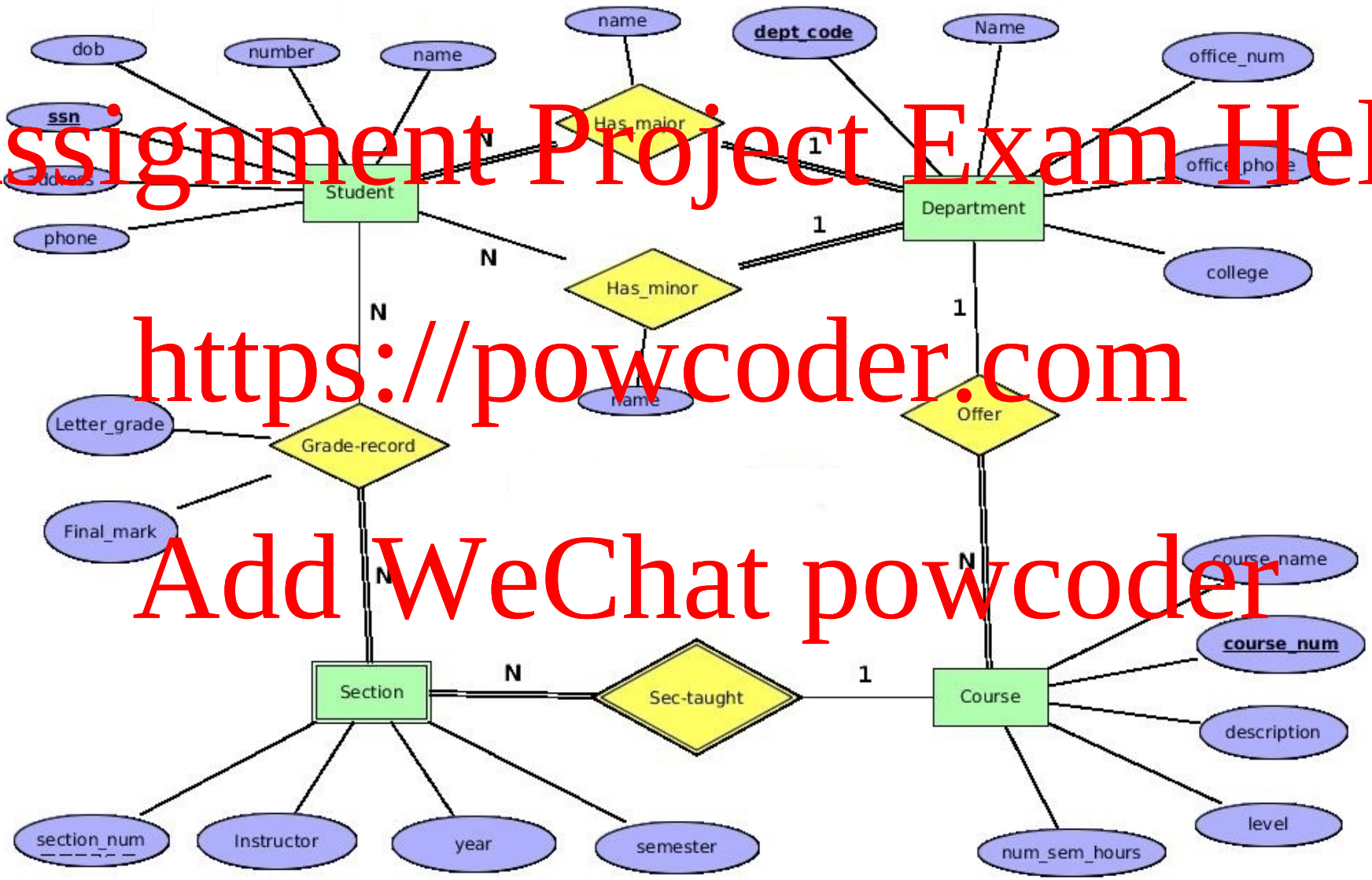
- Identify the attributes of entities and relationships and identify a primary key for each entity type
- Identify cardinality ratios and participation constraints on relationships



## Software tool to draw ER diagram



- We require students to use an academic tool, TerraER, to draw the ER diagrams.
- TerraER allows you to save your ER diagrams into xml files and export your ER diagrams as a JPEG figure.
- You can download the jar file from the following website:
  `https://github.com/rterrabh/TerraER/releases/download/TerraER3.01/TerraER3.01beta.jar`
- You can double-click that file to execute on Windows/Mac/Linux (assume that the Java Runtime Environment JRE has been installed).
- More information on how to use TerraER will be provided next week.

(Exercise 2) A retailer company wants to build a database application for managing information about its sale process. The company sells products in both local shops and webstores on the Internet. Each local shop has a name, contact details (e.g., phone number and email), and a unique location. The database application also needs to store the URL(unique), name and last updated date of each webstore. Every product has a unique productID, a description, an item price, and a quantity in stock. The database application should also record customers' details such as their name, address and email. Every customer is assigned a unique ID. A customer may place an order that consists of at least one product and each order is from either a shop or a webstore. Customers have three payment options (i.e., cash, paypal, and credit card) but for each order only one payment option can be chosen. A delivery may be requested for each order. After full-payment is received, a delivery would be sent out subject to products' availability. Every delivery has a unique tracking number.

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- Identify the relationships

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- Identify subclass/superclass and the corresponding disjointness and completeness constraints
  - subclass **shop**, **webstore**
  - superclass **store**



- Identify the relationships
  - **customer** **place** **order**
  - **order** **consists of** **product**
  - each order **is from** **store**(superclass) (either subclass **shop** or subclass **webstore**)
  - **delivery** **is for** **order**

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## Constructing an ER or EER Model



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    - Attributes for superclass **store**: **name**, **location/URL**
    - Primary key for superclass **store**: **location/URL**
    - Attributes for subclass **shop**: **phone number, email**
    - Attributes for subclass **webstore**: **last updated date**

## Constructing an ER or EER Model



- Identify the entities (including weak entity types)
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  - customer **place** order
  - ...
- Identify the attributes of entities and relationships
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    - Participation constraints: A **customer** **may or may not** **place** any orders (**Partial**). An **order** **must** **be placed by** one customer (**Total**).

## Constructing an ER or EER Model



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  - delivery is for order
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## Constructing an ER or EER Model



- Identify the entities (including weak entity types)
- Identify subclass/superclass
- Identify the relationships
  - order **consists of** product
  - ...
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## Constructing an ER or EER Model



Constructing an ER or EER Model

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Constructing an ER or EER Model

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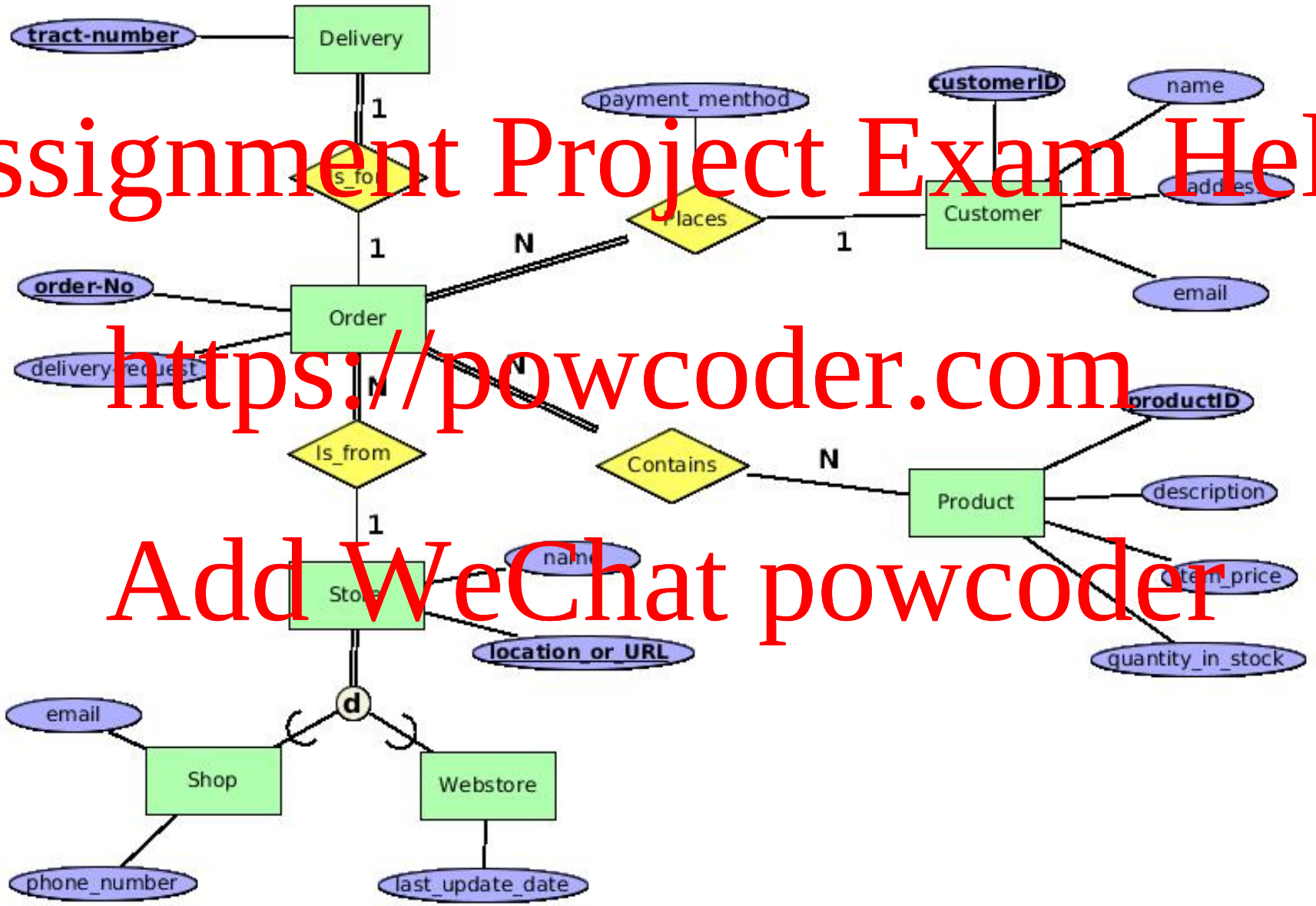
- **Not all the constraints can be expressed in the ER model**

(Exercise 2) A retailer company wants to build a database application for managing information about its sale process. The company sells products in both local shops and webstores on the Internet. Each local shop has a name, contact details (e.g., phone number and email), and a unique location. The database application also needs to store the URL(unique), name and last updated date of each webstore. Every product has a unique productID, a description, an item price, and a quantity in stock. The database application should also record customers' details such as their name, address and email. Every customer is assigned a unique ID. A customer may place an order that consists of at least one product and each order is from either a shop or a webstore. **Customers have three payment options (i.e., cash, paypal, and credit card) but for each order only one payment option can be chosen.** A delivery may be requested for each order. **After full-payment is received, a delivery would be sent out subject to products' availability**. Every delivery has a tracking number.



## Phase 3: Logical Design



- **Logical design** is the process of constructing a logical data model (e.g. relational or object-oriented).



- A conceptual data model is translated onto a logical data model, which can be further refined (e.g., normalisation) to meet the data requirements. For example,
  - **From:** An ER model



  - **To:** Relations with their primary and foreign keys, which facilitates SQL to deal with retrieving, updating and deletion.

**Note:** The logical design is based on the **relational data model** in this course.

## ER-to-Relations Algorithm



- 7-step algorithm to convert the basic ER model into relations, and more steps for the EER model.



Step 1: Mapping of Regular Entity Types

Step 2: Mapping of Weak Entity Types

Step 3: Mapping of Binary 1:1 Relationship Types

- Foreign key approach
- Merged relation approach
- Cross-reference approach



Step 4: Mapping of Binary 1:N Relationship Types

Step 5: Mapping of Binary M:N Relationship Types

Step 6: Mapping of Multi-valued Attributes

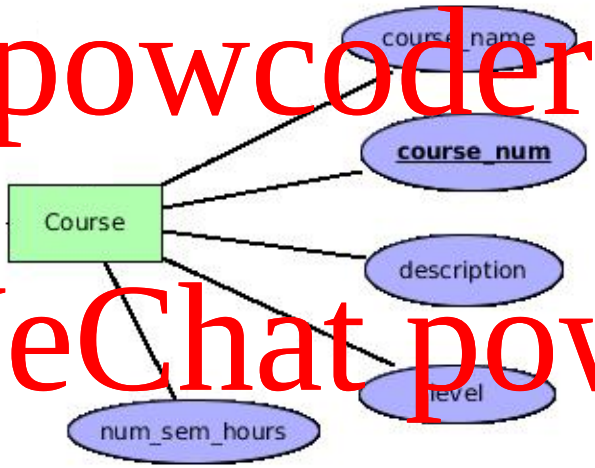
Step 7: Mapping of N-ary Relationship Types

Step 8: Mapping of Superclass/Subclass

## Step 1: Regular Entity types

- For each regular entity type $E$, **create a relation schema** with the attributes of $E$ (ignore multi-valued attributes until Step 6), where
  - **PK:** the key attributes of $E$





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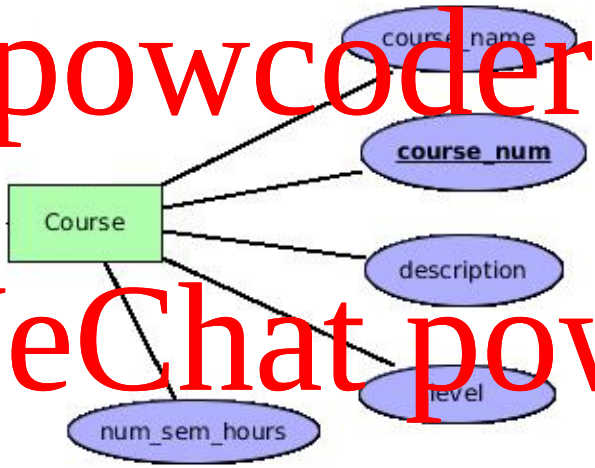




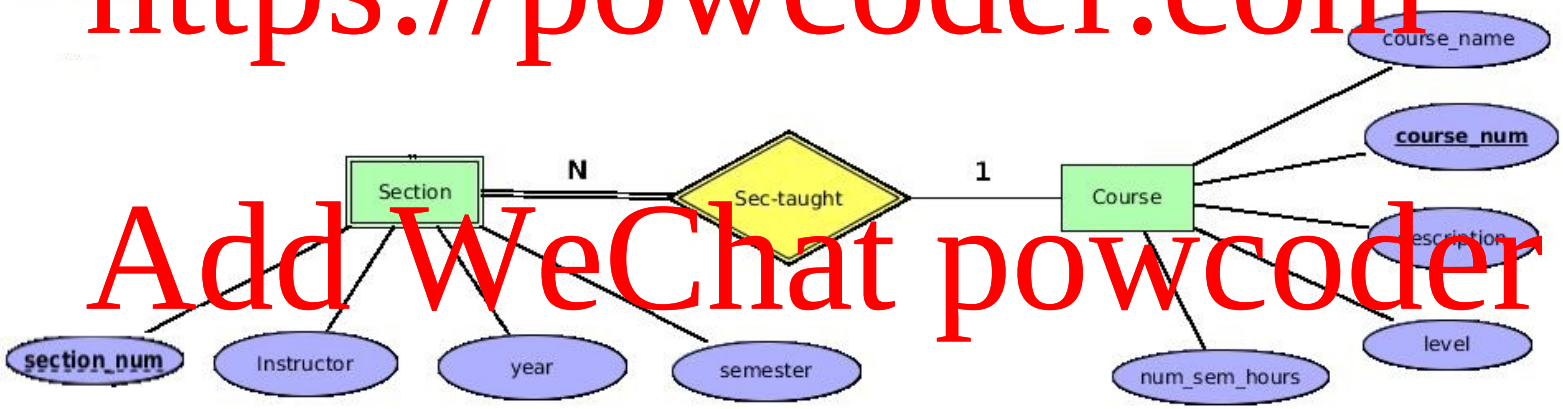

- COURSE(course_num, course_name, description, num_sem_hours, level) with PK: {course_num}
- **Note:** This is not necessarily the final relation schema of COURSE.

## Step 2: Weak Entity Types



- For each weak entity type $E_w$, **create a relation schema** with the attributes of $E_w$ plus the PK of its identifying entity type, where
  - **PK:** the partial key attributes of $E_w$ plus the PK of its identifying entity type
  - **FK:** references the PK of its identifying entity type





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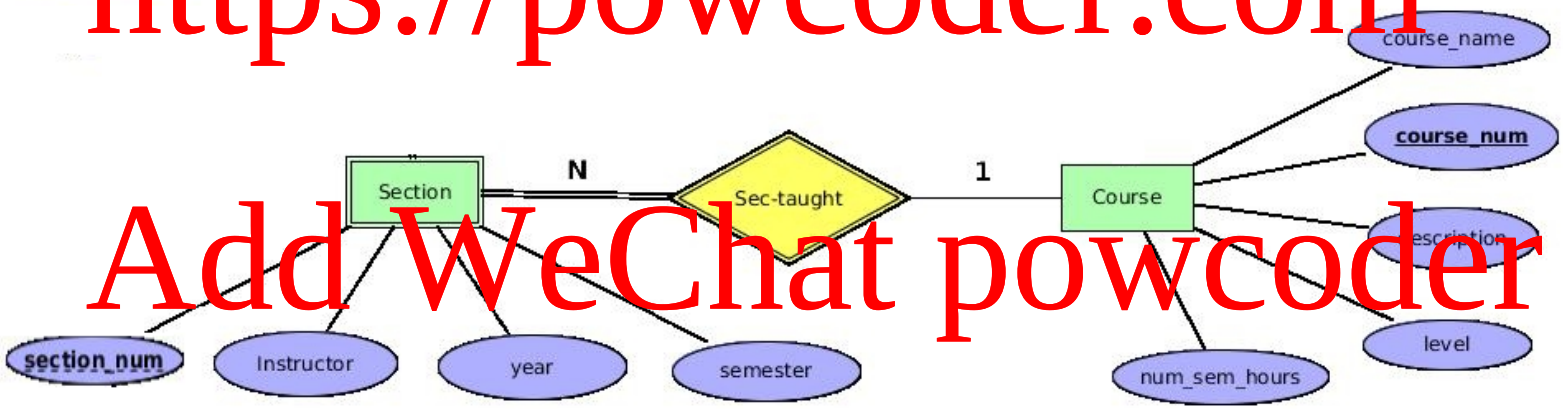




- SECTION(section_num, instructor, semester, year, course_num)
  with PK: {section_num, course_number}
  with FK: [course_num]⊆COURSE[course_num]

## Step 3: Binary 1:1 Relationship Types - (Foreign key)



- For a 1:1 relationship type $R$ with one total participation, **extend the relation schema of the total-side entity type** by the attributes of $R$ and the PK of the partial-side entity type, where
  - **PK:** still the PK of the total-side entity type
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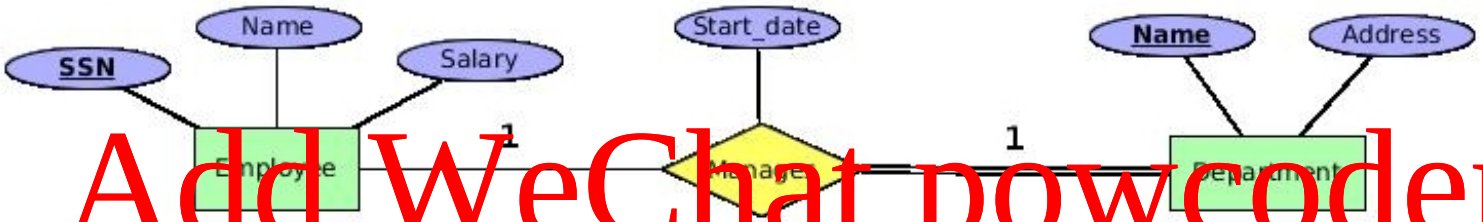

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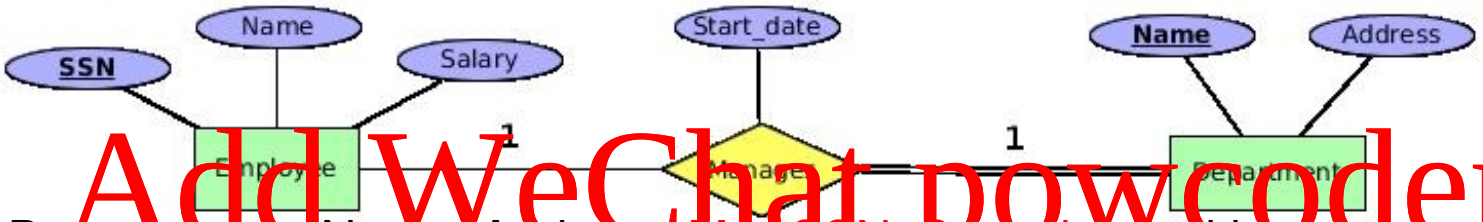




- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].

## Step 3: Binary 1:1 Relationship Types - (Foreign key)



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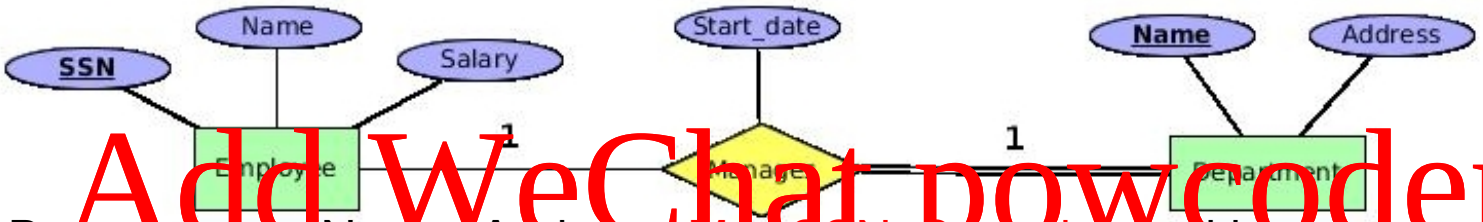




- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

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- How can we model the total participation?

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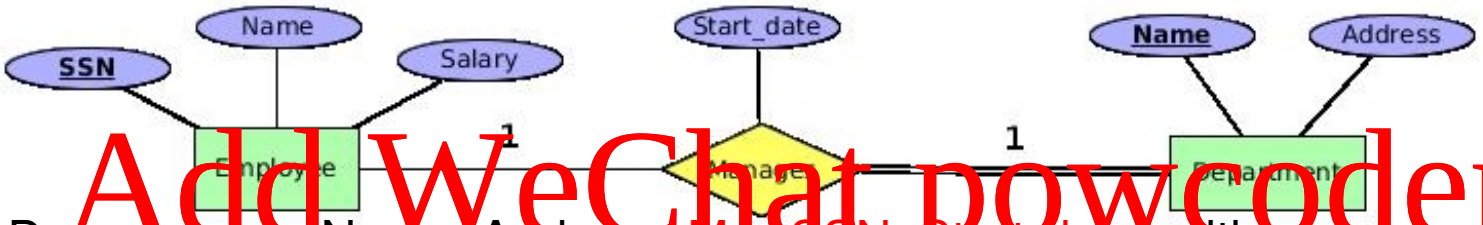




- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].
- How can we model the total participation?

  Add `NOT NULL` constraint to Mgr_SSN for total participation.

## Step 3: Binary 1:1 Relationship Types - (Foreign key)



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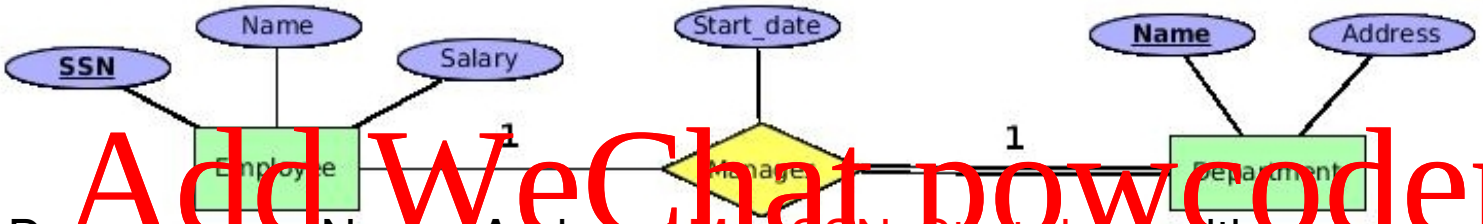




- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].
- Why don't we extend the relation schema of the partial-side entity type?

## Step 3: Binary 1:1 Relationship Types - (Foreign key)



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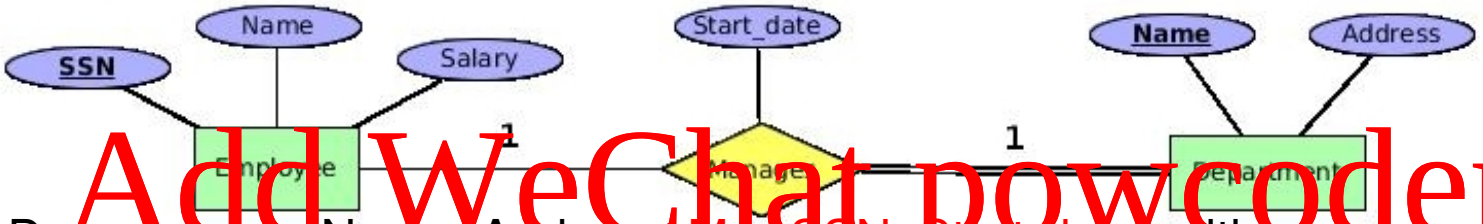




- DEPARTMENT(Name, Address, Mgr_SSN, Start_date) with

  PK: {Name}

  FK: [Mgr_SSN]⊆EMPLOYEE[SSN].
- Why don't we extend the relation schema of the partial-side entity type?

  This may cause many NULL values.

## Step 3: Binary 1:1 Relationship Types - (Merged relation)

- How can we translate the following kind of 1:1 relationship type?

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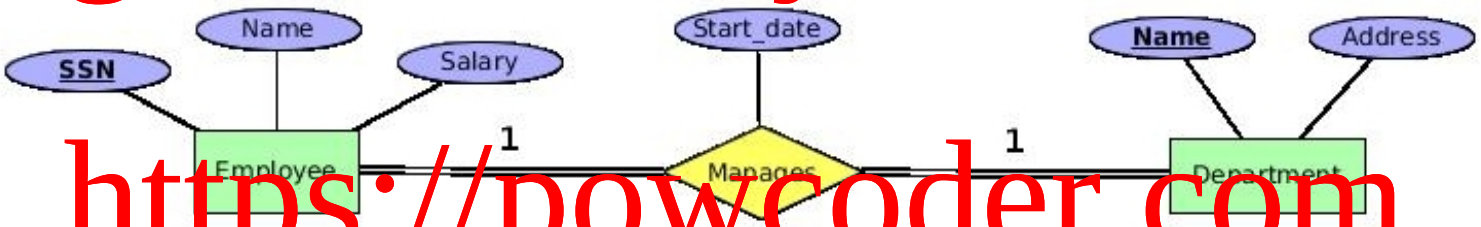





- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.

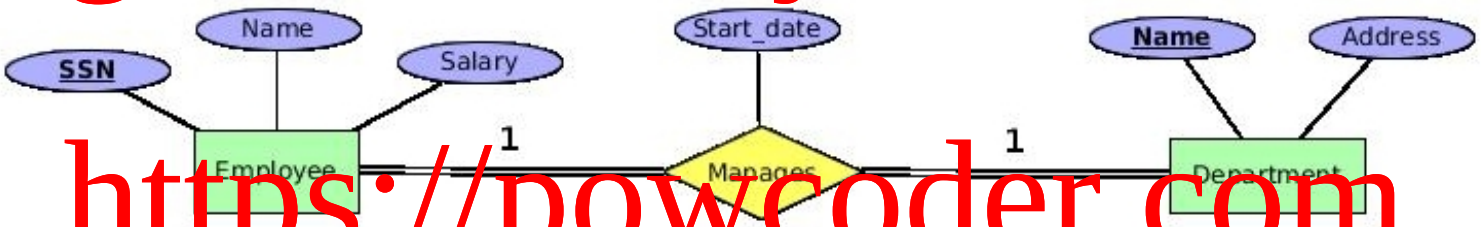


- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}

## Step 3: Binary 1:1 Relationship Types - (Merged relation)



- How can we translate the following kind of 1:1 relationship type?






- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.



- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?

## Step 3: Binary 1:1 Relationship Types - (Merged relation)



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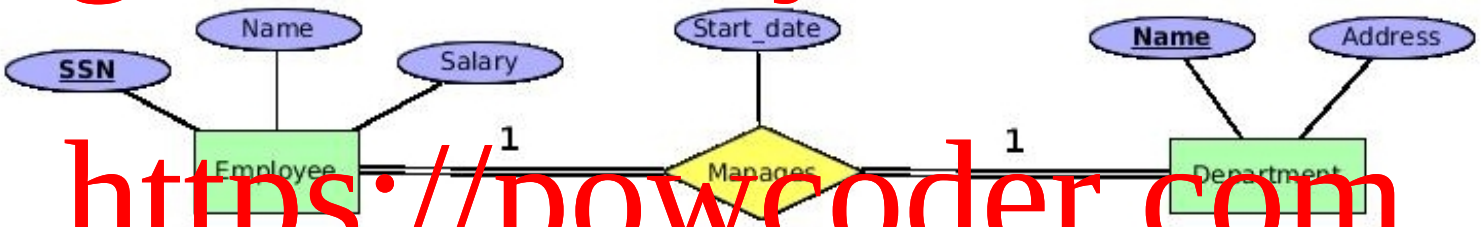




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- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?

  Add `NOT NULL` constraint to both SSN and Dname for total participations.

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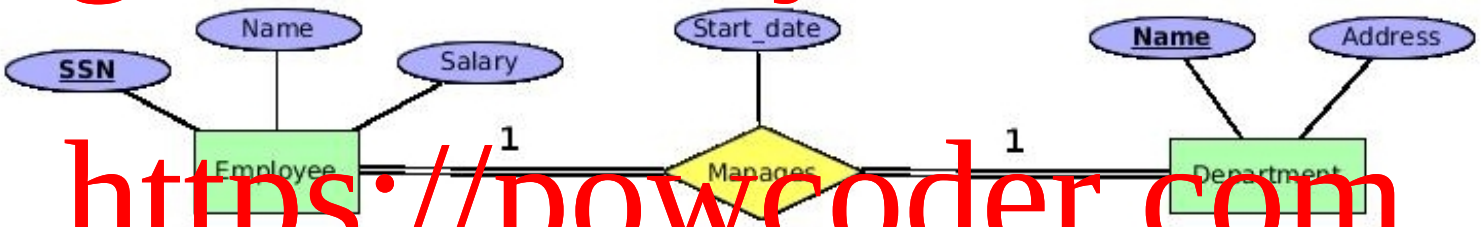




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- EMPLOYEE-DEP(SSN, Name, Salary, Start_date, Dname, Address) with PK: {SSN} or {Dname}
- How can we model the total participations?
  Add `NOT NULL` constraint to both SSN and Dname for total participations.
- **Is merging them always a good solution?**

## Step 3: Binary 1:1 Relationship Types - (Merged relation)



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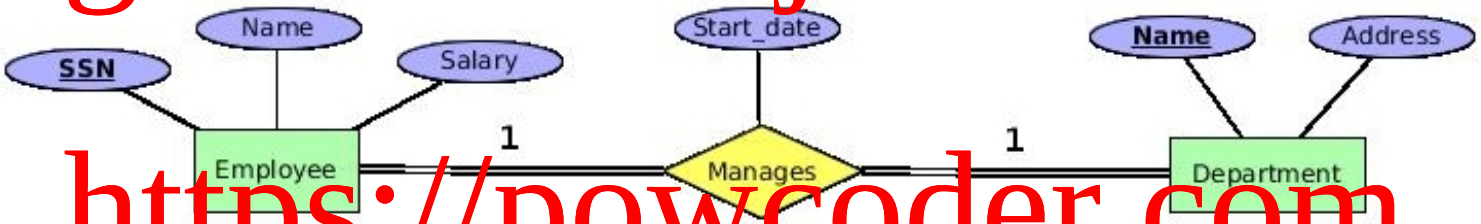




- If participation on both sides is total, we may **merge the relation schemas of both entity types and the attributes of the relationship type into a single relation**.
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## Step 3: Binary 1:1 Relationship Types - (Merged relation)



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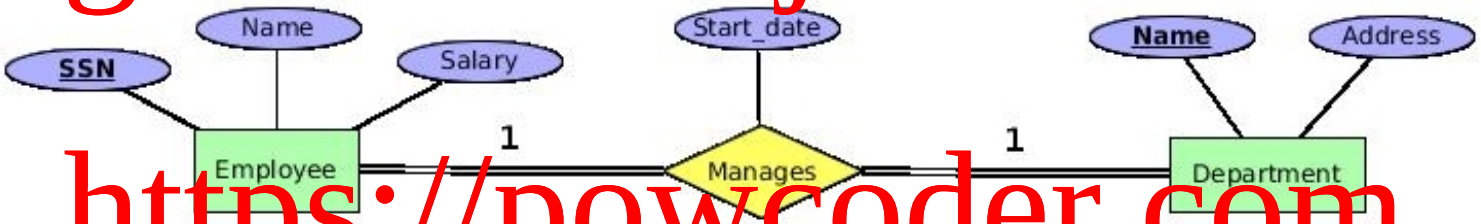




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- However, **merging them is not always a good solution**. Why?
  - (1) The two entity types represent different entities in the real world.
  - (2) The two entity types participate in different relationship types.
  - (3) Having separate relation schemas for two entity types often leads to more efficient updates than a single relation schema.
  - (4) ...

## Step 3: Binary 1:1 Relationship Types - (Cross-reference)

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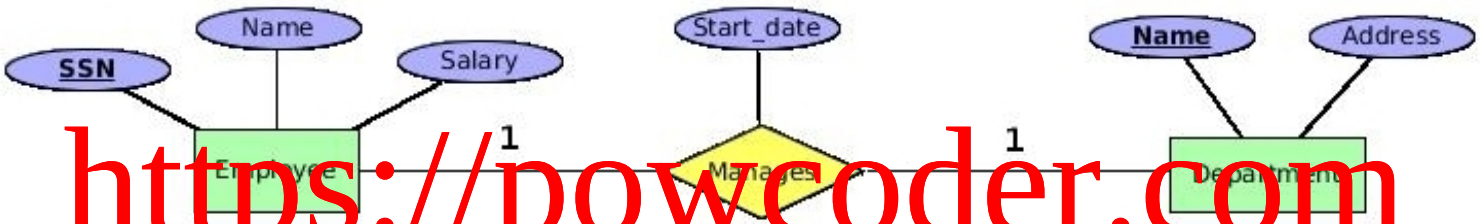




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- MANAGES(SSN, Dname, Start_date) with

  PK: {SSN} or {Dname}

  FKs: [SSN]⊆EMPLOYEE[SSN] and [Dname]⊆DEPARTMENT[Name]

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  We cannot; otherwise what would be the primary key for the merged relation schema?

# Step 4: Binary 1:N Relationship Types



- For each 1:N relationship type $R$, **extend the relation schema of the N-side entity type** by the attributes of $R$ and the PK of the 1-side entity type, where
  - **PK:** still the PK of the N-side entity type
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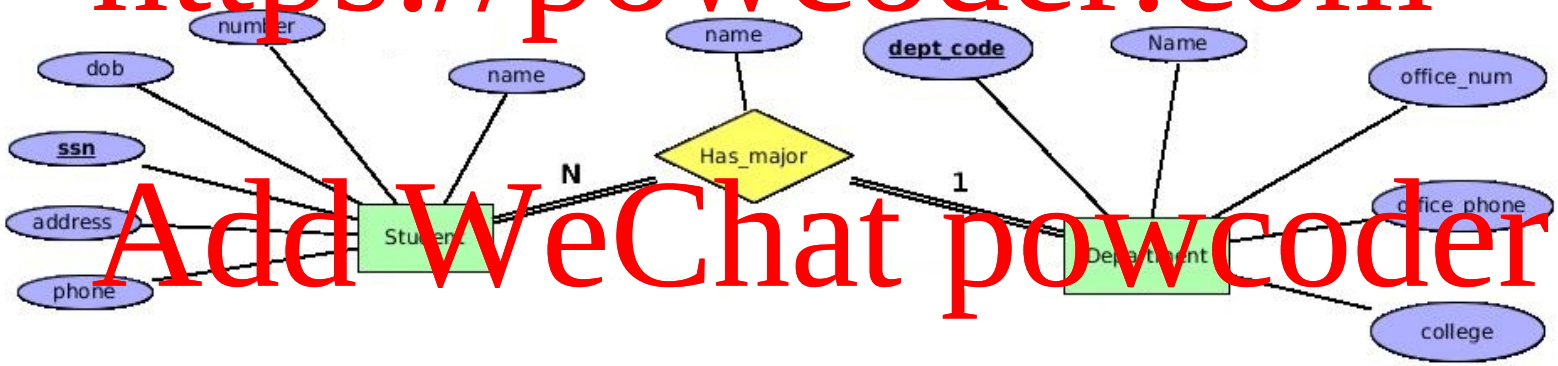

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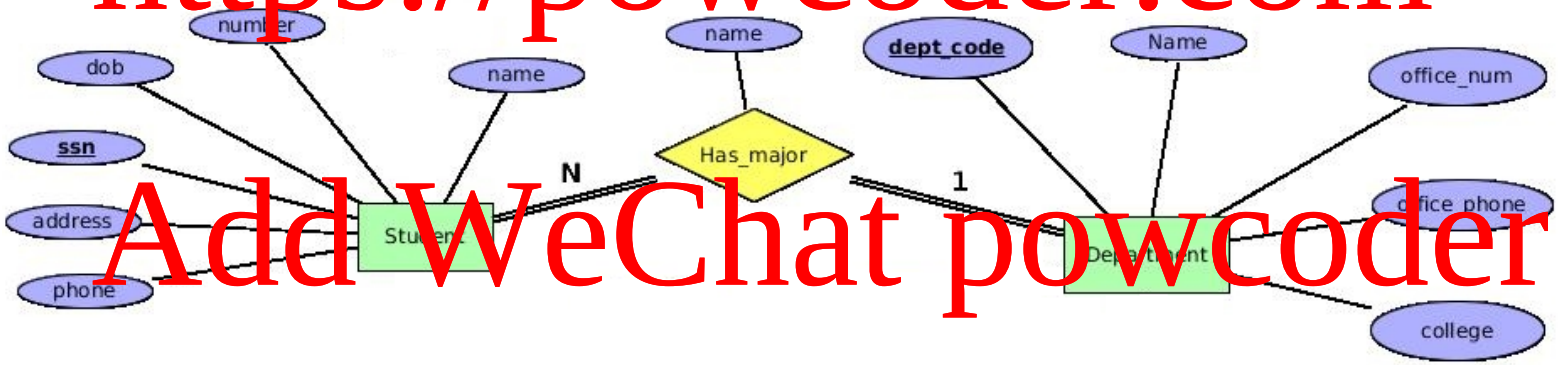





- STUDENT(SSN, Name, Number, DoB, address, phone, major_dept, major_name) with

  PK: {SSN}

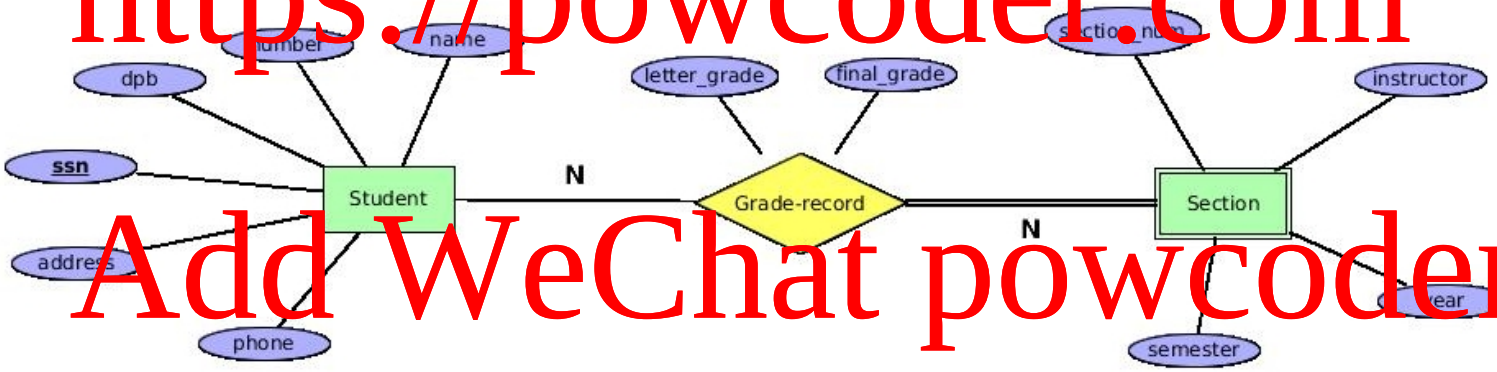
  FK: [major_dept]⊆DEPARTMENT[dept_code]

## Step 5: Binary M:N (N:N) Relationship Types



- For each M:N (N:N) relationship type $R$, **create a relation schema** with the attributes of $R$ plus the PKs of the participating entity types, where
  - **PK:** the combination of the PKs of the participating entity types
  - **FKs:** references the PKs of the participating entity types








- GRADE_RECORD(ssn, section_num, course_num, letter_grade, final_grade)

  PK: {ssn, section_num, course_num}

  FK: [ssn] $\subseteq$ STUDENT[ssn]

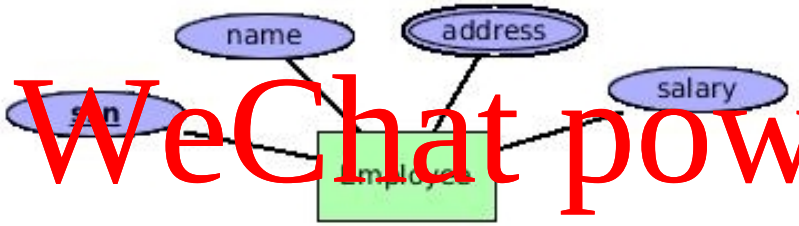
  FK: [section_num, course_num] $\subseteq$ SECTION[section_num, course_num].

## Step 6: Multi-valued Attributes



- For each multi-valued attribute *A*, **create a relation schema** with an attribute corresponding to *A* plus the PK of the entity/relationship type that has *A* as an attribute, where
  - **PK:** the combination of *A* and the PK of the entity/relationship type that has *A*
  - **FK:** references the PK of the entity/relationship type that has *A*





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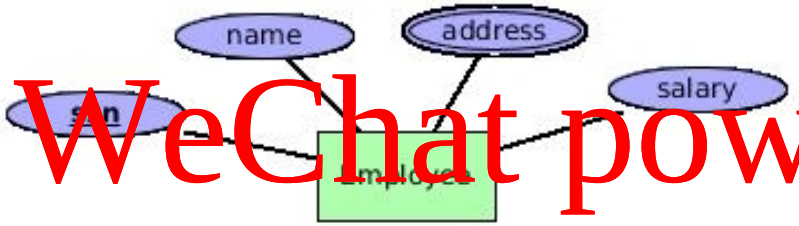





- EMPLOYEE_ADDRESS(SSN, Address) with

  PK: {SSN, Address}

  FK: [SSN]$\subseteq$EMPLOYEE[SSN]

## ER-to-Relations Algorithm (Recall)



- The algorithm to first convert the basic ER model into relations, and then convert superclass/subclass from the EER model into relations.



Step 1: Mapping of Regular Entity Types

Step 2: Mapping of Weak Entity Types

Step 3: Mapping of Binary 1:1 Relationship Types

- Foreign key approach
- Merged relation approach
- Cross-reference approach



Step 4: Mapping of Binary 1:N Relationship Types

Step 5: Mapping of Binary M:N Relationship Types

Step 6: Mapping of Multi-valued Attributes

Step 7: Mapping of N-ary Relationship Types

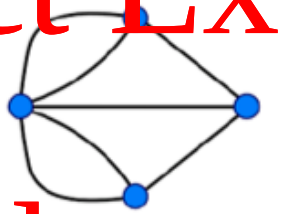
Step 8: Mapping of Superclass/Subclass

# (Credit Cookie) Graph Model and ER Diagram



Carl Gottlieb Ehler
(1685-1753)

Seven Bridges of Königsberg



Euler
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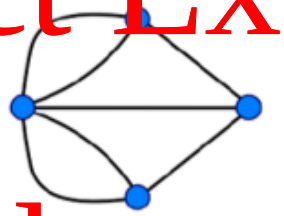

Euler
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Seven Bridges of Königsberg



- 1st paper in ACM Transactions on Database Systems in 1976
- 1st international conference on very large data bases (VLDB) in 1975



**The Entity-Relationship Model—Toward a Unified View of Data**

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