CS 411: Database Systems

Fall 2022

Homework 2 (Due by 23:59 CT on Sept 28, 2022)

Logistics

1. This homework is due on Sept 28th, 2022 at 23:59 CT. **We DO NOT accept late homework submissions.**
2. You will be using Gradescope to submit your solutions. Answer each sub-question (e.g. “a.”, “b.” etc.) on a **new page** and submit your solution as a single PDF file on Gradescope. All registered students should have received an email invitation to Gradescope. Please submit the PDF to "Homework 2".
3. ***IMPORTANT*: Please make sure to link PDF pages with the corresponding question outline on Gradescope.**
4. The answers can be written electronically or they can be hand-written, but if we cannot read your submissions, we won’t be able to grade them.
5. If you are looking for tools to create ER diagrams etc, consider draw.io.
6. Please write down any intermediate steps to receive full credit.
7. Keep your solutions brief and clear.
8. Please use Campuswire if you have questions about the homework but **do not post answers.** Feel free to use private posts or come to office hours.

Rubric (IMPORTANT!)

1. Always underline primary keys in ER diagrams and UML diagrams.
2. For the questions about ER and UML diagrams, address as many constraints implied in the problem description as possible. Explicitly state any extra assumptions you make that cannot be derived from the description.
3. Follow the question description and do not make assumptions from the real world.
4. When drawing ER diagrams or converting an ER diagram to a relational schema, have the following design principles in mind:
    a. Try not to create unnecessary entities
    b. Try not to create tables that might suffer redundancy

Section 1. ER and Relational Schema

Question 1. ER Diagram (15 pts)

You are working for Uber Eats. Your manager tasks you with designing a new database for keeping track of its service. Given the following information, draw the ER diagram:

- The database should store information about Customers, Restaurants, Dishes, Chefs, and Buildings.
- Customers are uniquely identified by their ID. Other customer attributes are name and birthday.
- A Restaurant is uniquely identified by its name and the building it's located in. Other restaurant attributes are type and size.
- A Dish is uniquely identified by its name and the restaurant that offers it. Other dish attributes are flavor and popularity.
- Chefs are uniquely identified by their SSN. Other chef attributes are name and salary.
- A Building is uniquely identified by its address. It has area as another attribute.

- A Customer may order multiple Dishes, and each Dish may be ordered by multiple Customers.
- Every time a Customer orders a Dish, we want to store information about what date that customer makes the order, specifically the attribute "date".
- A Dish may be cooked by multiple Chefs, and a Chef may cook multiple Dishes.
- A Dish can only be offered by a single Restaurant, but a Restaurant may offer multiple Dishes.
- A Restaurant may employ multiple Chefs, but each Chef can only work in one Restaurant.
- A Restaurant is located at only one Building, but each Building may have multiple Restaurants.

Question 2. UML Diagram (15 pts)

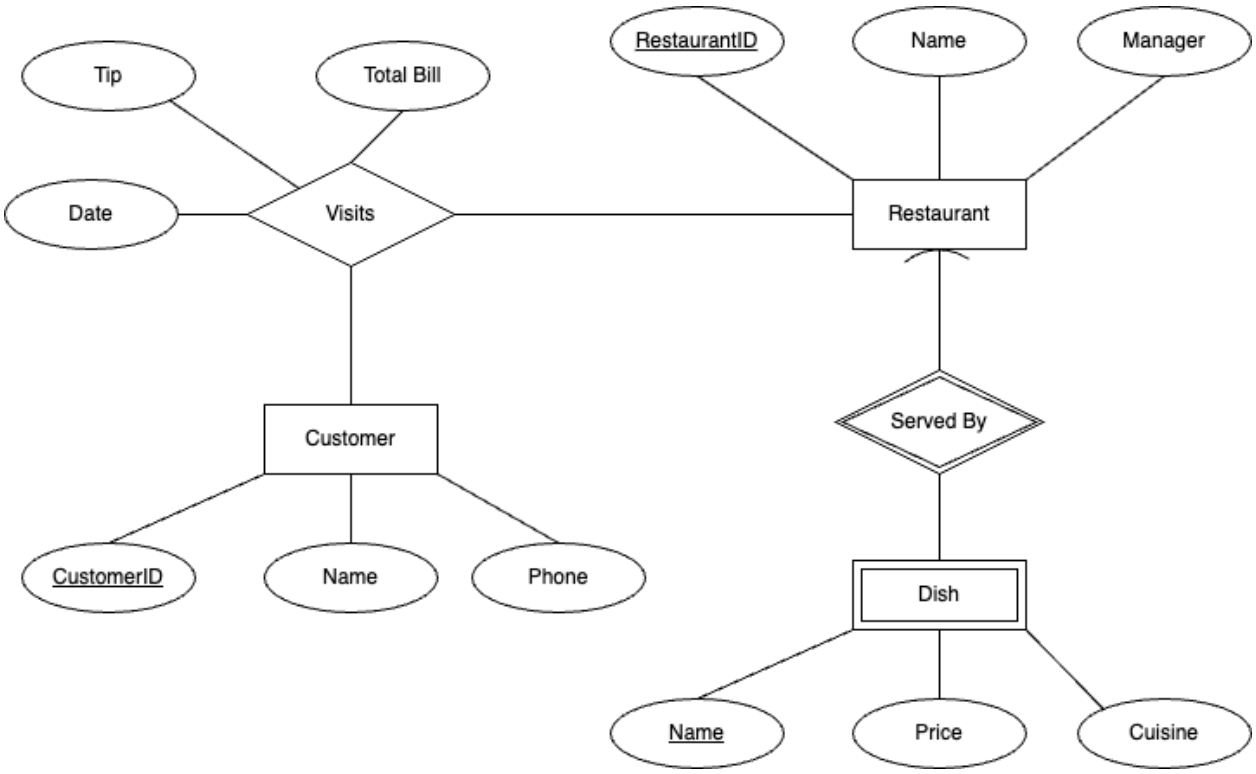
You are hired by UIUC to manage their library database. Your first task is to design tables to store information on Library and Users. Given the following information, draw the UML diagram:

- The database has Libraries. Each is uniquely identified by its address, and has the attributes name and establishment date.
- Each Book is uniquely identified by its book_ID and Library, and has attributes title, ISBN, rating, and publication date.
- Each Author is uniquely identified by its author_ID, and has attributes name and image url.
- Each Customer is uniquely identified by its customer_ID, and has attributes user name and birthday.
- Each Comment is uniquely identified by its comment_ID, and has attributes creation date and content.

- A Library may have multiple Books, but a Book is owned by exactly one Library.
- A Book can only be borrowed by at most one Customer, while a Customer can borrow multiple Books.
- Each Book must have at least one Author, and an Author can write one or more Books.
- Each Book may have multiple Comments, but a Comment is attached to exactly one Book.
- Each Customer may write multiple Comments, but a Comment is written by exactly one Customer.

Question 3. Conversion From ER Design to Relational Schema (10 points)

Convert the below ER diagram into a relational schema, and write the DDL SQL commands for implementing it as a database schema.



Section 2. Functional Dependencies and Normal Forms

Question 4. Attribute Closure and Functional Dependencies (20 pts)

a. Given the following relation:

R(A,B,C,D,E)

And functional dependencies:

A -> BCE

BC -> AE

C -> E

Find all candidate keys. **(5 points)**

b. Given the following relation

R (A,B,C,D,E)

And functional dependencies:

AC→E

D→B

BE→C

Find all candidate keys. **(5 points)**

c. Given the following relation:

R(A,B,C,D,E,F,G)

And functional dependencies:

AB -> CDEF

C -> ADE

D -> EBF

F -> DA

BE -> AF

i. Find all candidate keys. **(6 points)**

ii. Find at least four non-trivial functional dependencies that are different from the ones listed in the question. **(4 points)**

Question 5. Normal Forms (40 pts)

a. Consider the following relations R1, R2, R3. Which normal forms (BCNF,3NF) is each relation in? Explain why the relation is or is not in each of these normal forms. List all violating FDs if there's any. **(18 pts)**
   i. R1 = (A,B,C,D,E) with a set of functional dependencies FD = {AC→E, BE→AD, C→BD}. (6 pts)

   ii. R2=(A,B,C,D,E,F) with a set of functional dependencies FD={B→CF, AB→D, BF→E, BCE→A}. (6 pts)

   iii. R3=(A,B,C,D,E,F) with a set of functional dependencies FD={AE→CD, BD→E, B→E, ADE→BF}. (6 pts)

b. Given a relation R(A, B, C, D, E, F) and functional dependencies FD = {B → C; D → CE; DF→ B; C→ EF; BF → CE} **(12 pts)**
   i. Compute the minimal basis of FD. Show all steps to receive full credits. (7 pts)

   ii. Decompose the relation R into a set of relations that are in 3NF. (5 pts)

c. Decompose the relation R1, R2 into a set of relations that are in BCNF. List keys and violating FDs for the reasoning. **(10 pts)**

   i. R1 = (A,B,C,D) with a set of functional dependencies FD = {BC→A; A→D; B→C}. (5 pts)

   ii. R2 = (A,B,C,D) with a set of functional dependencies FD = {C→AB; D→AC; BD→C}. (5 pts)