In this assignment you will explore the various steps required to convert and refine a conceptual model into a practical relational schema design that is ready for actual implementation.

**Problem 1: CIOM to Relational Schema Conversion (50 points)**

Fig. 1 shows a CIOM conceptual schema for tracking the resources and managing the operations of a police department.

![Diagram of CIOM conceptual schema for Problem 1](image.png)

**Fig. 1: CIOM conceptual schema for Problem 1**

Design a conceptual schema in the basic relational model that corresponds to the CIOM schema given in Fig. 1. In your design, underline the primary keys for each of your relations, specify domains for each of your (relational) attributes, and indicate all reasonable referential integrity constraints in italics, making a separate note of what they refer to. See Fig. 2 for example formatting; here, the first referential constraint is “from EMPS.Dept to DEPTS.DeptName”.

Justify your design decisions when choosing between different mapping options. Explicitly state any assumptions you make. In addition, briefly describe what semantic information, if any, you lost in the mapping process.

In particular, with respect to the Senior Officer class and the Precinct Commander attribute present in the CIOM model, briefly discuss the tradeoffs involved in your design choices when deciding between alternative ways to handle them when creating your relational model – what advantages do you gained by using your selected approach, and what disadvantages arise from your choice? This part of the discussion should not exceed a paragraph of a few sentences.
Problem 2: Relational Algebra (30 points)

a) Refer to the following relational schema:

```plaintext
PERSON( SSN, FirstName, LastName, Address)
    [N] [S] [S] [S]

CUSTOMER( SSN, Phone)
    [N] [N]
    • from CUSTOMER.SSN to PERSON.SSN

MECHANIC( SSN, Specialty, HourlyRate)
    [N] [S] [N]
    • from MECHANIC.SSN to PERSON.SSN

CAR( VIN, Make, Model, LicensePlate, Owner)
    [S] [S] [S] [S] [N]
    • from CAR.Owner to CUSTOMER.SSN

SERVICE_TYPE( ServiceID, Name, PartsCost, HoursRequired)
    [N] [S] [N] [N]

WORK_ORDER( OrderNo, Date, Car)
    [N] [D] [S]
    • from WORK_ORDER.Car to CAR.VIN

WORK_ORDER_ITEM( OrderNo, Service, Mechanic, Notes)
    [N] [N] [N] [S]
    • from WORK_ORDER_ITEM.OrderNo to WORK_ORDER.OrderNo
    • from WORK_ORDER_ITEM.Service to SERVICE_TYPE.ServiceID
    • from WORK_ORDER_ITEM.Mechanic to MECHANIC.SSN
```

Specify the following queries in relational algebra:

i. List the full details for all service types that take more than two days to complete.

ii. Give the first and last names and the hourly rate of all electricians who worked on a Toyota Camry between 2013-08-01 and 2013-08-31.

iii. Find all mechanic-owned cars that were fixed by their own owner in the shop. Give the make and model of each car, along with the address and phone number of the owner.

iv. List the order numbers and dates of all work orders involving a Nissan Versa in which all of the requested services cost less than $100 in parts.
b) Consider the two relations $T_1$ and $T_2$ shown in Fig. 3.

![Database state for relations $T_1$ and $T_2$](image)

Show the results of the following operations:

i. $\sigma_{T_2.M > 4} T_2$

ii. $\pi_C T_1 - \pi_M T_2$

iii. $T_1 \cup T_2$

iv. $T_1 \bowtie_{T_1.C < 6 \land T_1.A < T_2.K} T_2$

**Typesetting notes:** Follow the notation presented in the textbook. You will need a Unicode font with the necessary relational algebra symbols to typeset your answers. We recommend the open source Free UCS Outline Fonts, available in both OpenType and TrueType formats from http://savannah.gnu.org/projects/freefont/. Use only the basic operators given in Fig. 4 (typeset in FreeSerif for your copy-and-paste convenience).

![Relational algebra symbols](image)

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1 Note that for natural join, we use the asterisk operator $\ast$ (U+2217) rather than the asterisk $\ast$ (U+002A), which is too high.
Problem 3: Functional Dependencies and Normalization (20 points)

Suppose that we have the following requirements for a room scheduling database at a local community college that is used to keep track of room reservations and reservation requests:

i. Each room at the college has a building name, a room number, a room type (“classroom”, “conference room”, “activity room”, “study room”) and capacity (i.e. number of seats in the room). Rooms may be equipped with amenities such as: “wifi access”, “desktop computer”, “projector”, etc. A room is only accessible between the opening and closing times of the building in which it is located.

ii. A room request can be made by any member of the community college. The person requesting a room needs to provide their name and email. They need to specify the time at which they wish to reserve a room, how many hours the room is needed for and the required capacity.

iii. Requests are processed as such: a staff member reviews all requests for room availability before approving or denying the request. In order to approve a request the staff member must find a room that fulfills the scheduling and space requirements of the request. If such a room can be found, it is allocated to the request and the request is marked as approved; otherwise the request is denied.

Design a relational conceptual schema for this database, such that all relations are in BCNF. For each relation, provide a name, list the attributes and underlying domains, specify a primary key, and state all referential constraints. Note any unspecified requirements, and make appropriate assumptions to render the specification complete. You may start with relations that are not initially normalized, and refine them gradually in steps; if you do this, you must indicate clearly which relations are part of your final solution.

Please adhere to the example formatting from Fig. 2 when presenting your solution.
Submission Instructions:

- Your submission must be prepared electronically. This means that all answers are to be typed in a word processor. Use font size 12 and single line spacing (double spacing for relational algebra).
- This assignment is due before the class at the specified due date and time.
- On-campus students: Only hard-copy submissions are accepted for this assignment. Submissions will be collected at the beginning of class on the specified date.
- DEN students: Please follow DEN procedures for homework submission.
- Late submissions: procedures are outlined on the course website. Do not submit by email. There is a 20% deduction per day or part thereof, starting from the submission deadline.
- Note that you must complete all the assignments and take both exams in order to pass the course.

Discussion Board and Student Collaboration Policy

- You should work on this assignment individually and within the realm of the USC Academic Integrity Guidelines.
- We encourage you to discuss general issues related to this assignment with other students without revealing and/or hinting at any answers.
- A discussion board for this assignment is available on DEN's Blackboard system.
- Use the discussion board as your main resource to post questions related to the assignment.
- The TAs will participate in the discussions and answer questions on the board.
- Do not ask TAs homework-specific questions by email.
- The discussion boards are moderated, so your posts will not show up until after they have been approved. Please do not re-post the same message.
- Start your homework early. Although the discussion board will remain open until the assignment deadline, the TAs cannot guarantee that they will be able to answer any/all last minute questions posted less than 24 hours before the deadline.