Name

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# Homework Assignment 3

# April 4th, 2026
# Due on April 20th, 11:59pm (midnight)

# CS480 - Database Systems
# Results

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*Please leave this empty!*

3.1 3.2 3.3

Sum

# Instructions

- Try to answer all the questions using what you have learned in class
- Some questions are marked as bonus. You do not have to answer these questions to get full points for the assignment. However, you can get bonus points for these questions!

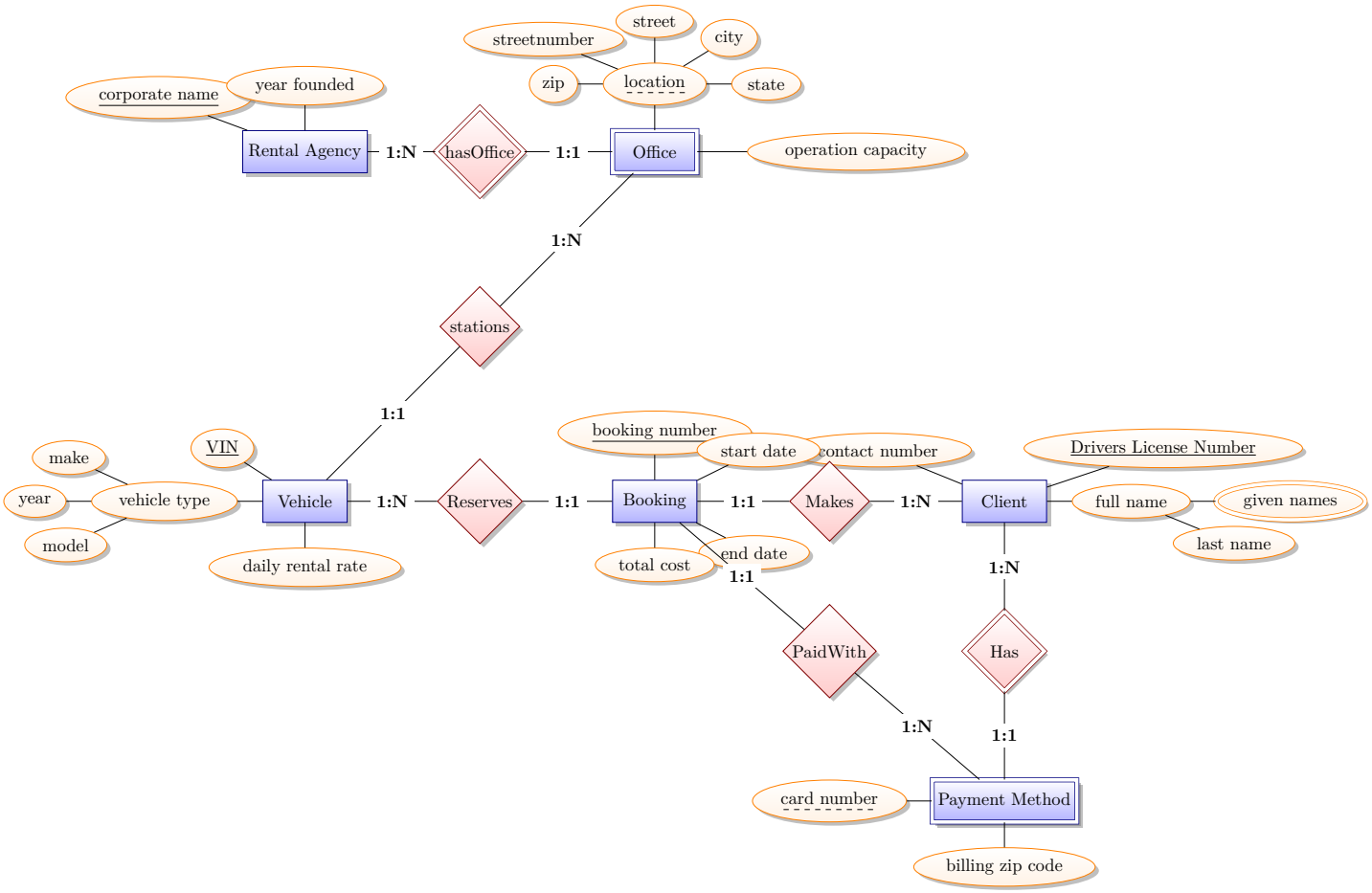
## Part 3.1 Modelling (Total: 60 Points)

### Question 3.1.1 (60 Points)

Build a conceptional model for a **online car rental system**. The solution should be presented as an **ER-diagram**. Your design should implement the following requirements.

- The database should record information about **Rental Agencies**, **Vehicles**, and **Clients**.
- A **Rental Agency** is identified by its unique *corporate name*. For each rental agency we also record the *year* it was founded. Furthermore, each rental agency can have one or more **Offices**. For each office we record the *location* (a composite attribute consisting of a *street*, *streetnumber*, *city*, *state*, and *zip*) and its *operation capacity* (total number of parking spots). Within a single agency, an office is uniquely identified by its *location*.
- Each **Vehicle** is stationed at exactly one office. Vehicles are described by their *VIN* (Vehicle Identification Number), *vehicle type* (which includes *make*, *model*, and *year*), and *daily rental rate*. A vehicle is uniquely identified by its *VIN*.
- **Clients** are uniquely identified by their *Drivers License Number*. We store the client's *full name* (which includes a *last name* and one or more *given names*) and a *contact number*. Furthermore, we record one or more **Payment Methods** for each client. A payment method is uniquely identified by its *card number* for a given client, and we also record its *billing zip code*.
- A **Booking** is uniquely identified by a *booking number*. Each booking is made by exactly one *client* for a specific *vehicle*. Furthermore, each booking is paid for using exactly one of the client's **Payment Methods** (a payment method can be used for multiple bookings). For each booking we also record the *start date*, *end date*, and the *total cost* of the reservation.

## Solution

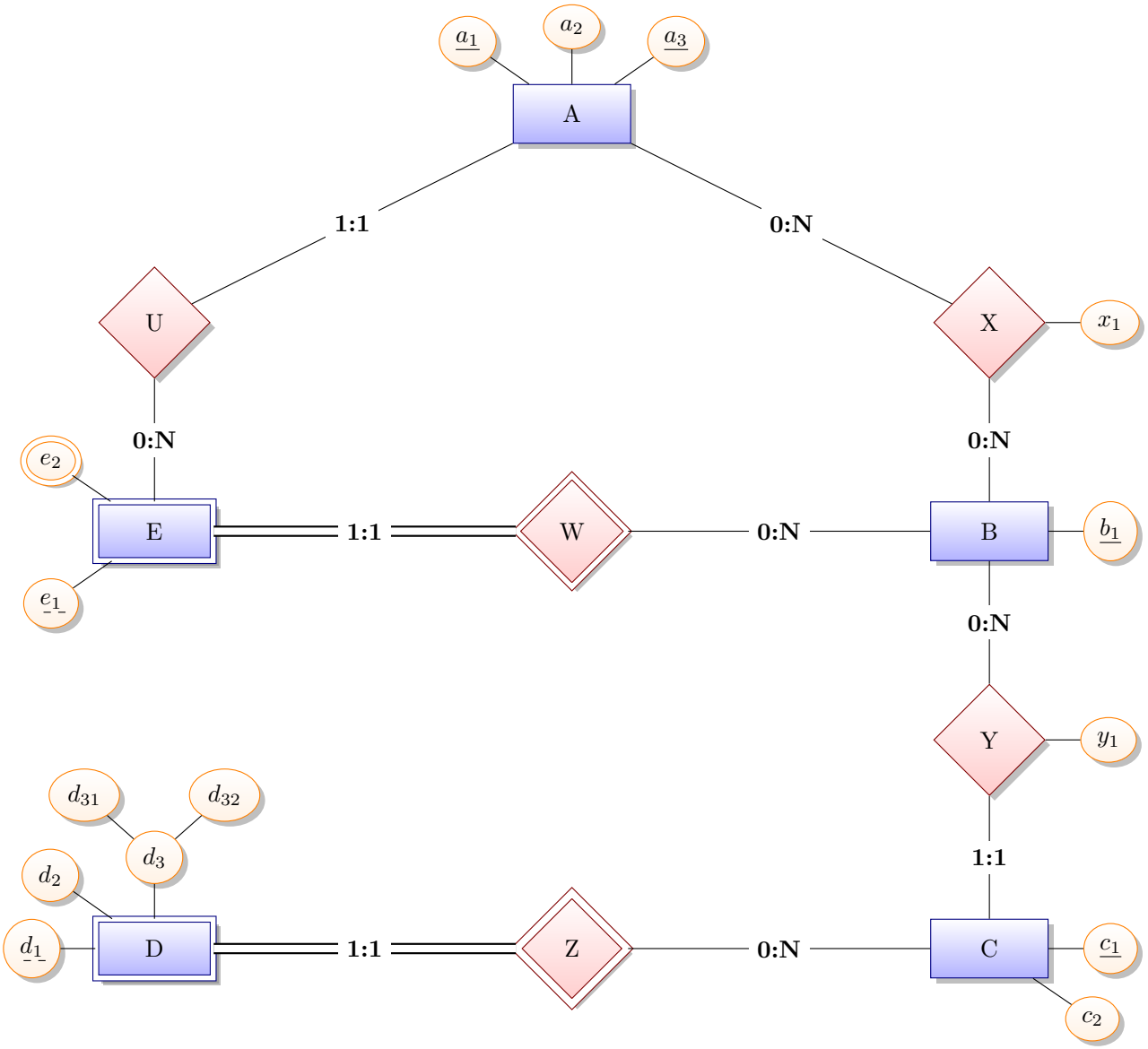

street
streetnumber
city
zip
location
state
corporate name
year founded
Rental Agency
1:N
hasOffice
1:1
Office
operation capacity
1:N
stations
1:1
booking number
start date
contact number
Drivers License Number
make
VIN
year
vehicle type
Vehicle
1:N
Reserves
1:1
Booking
1:1
Makes
1:N
Client
full name
given names
last name
model
daily rental rate
total cost
end date
1:1
1:N
PaidWith
Has
1:N
1:1
card number
Payment Method
billing zip code

## Part 3.2 Translation of ER into Relational Model (Total: 40 Points)

### Question 3.2.1 (40 Points)

Take the following ER-model and translate it into a relational schema using the rules presented in class. Present the relational schema as an SQL script (assume that all attributes are of data type `INT`). Present the results of the following intermediate steps in this order:

1. Translate strong entities + unnest composite attributes
2. Translate weak entities
3. Translated multi-valued attributes
4. Translate relationships



**Solution**

## 1st Step (strong entities)

```
CREATE TABLE A (
   a1 INT,
   a3 INT,
   a2 INT,
   PRIMARY KEY (a1, a3)
);

CREATE TABLE B (
   b1 INT PRIMARY KEY
);

CREATE TABLE C (
   c1 INT,
   c2 INT,
   PRIMARY KEY (c1)
);
```

## 2nd Step (weak entities)

```
CREATE TABLE E (
   e1 INT,
   b1 INT,
   PRIMARY KEY (e1, b1),
   FOREIGN KEY (b1) REFERENCES B
);

CREATE TABLE D (
   d1 INT,
   d2 INT,
   d31 INT,
   d32 INT,
   c1 INT,
   PRIMARY KEY (d1, c1),
   FOREIGN KEY (c1) REFERENCES C
);
```

## 3rd Step (multivalued attributes)

```
CREATE TABLE E2 (
    e1 INT,
    b1 INT,
    e2 INT,
    PRIMARY KEY (e1, b1, e2),
    FOREIGN KEY (e1, b1) REFERENCES E
);
```

## 4th Step (relationships)

```
CREATE TABLE X (
    a1 INT,
    a3 INT,
    b1 INT,
    x1 INT,
    PRIMARY KEY (a1, a3, b1),
    FOREIGN KEY (a1, a3) REFERENCES A,
    FOREIGN KEY (b1) REFERENCES B
);

CREATE TABLE C (
    c1 INT,
    c2 INT,
    b1 INT,
    y1 INT,
    PRIMARY KEY (c1),
    FOREIGN KEY (b1) REFERENCES B
);

CREATE TABLE A (
    a1 INT,
    a3 INT,
    a2 INT,
    e1 INT,
    eb1 INT,
    PRIMARY KEY (a1, a3),
    FOREIGN KEY (e1, eb1) REFERENCES E
);
```

## Part 3.3 Normalization (Total: 10 (BONUS) Points)

### Question 3.3.1 (10 (BONUS) Points)

Consider the following relations and for each determine in which normal form the relation is (note that a relation can be in multiple normal forms). Please consider the following normal forms: 1NF, 2NF, 3NF and BCNF.

1. $R(A, B, C, D, E, F)$ and the functional dependencies are $AB \to CF$, $B \to D$, $D \to E$, $B \to C$

2. $R(A, B, C, D, E, F)$ and the functional dependencies are $ABC \to D$, $D \to EF$, $D \to E$, $E \to F$

3. $R(A, B, C, D, E, F)$ and the functional dependencies are $AB \to CD$, $C \to DE$, $DE \to AB$, $D \to B$, $DEF \to C$

4. $R(A, B, C, D, E, F)$ and the functional dependencies are $A \to B$, $B \to C$, $C \to D$, $D \to E$, $E \to F$, $F \to A$, $AC \to B$

### Solution

**1. The relation is in 1NF.**

**Candidate keys**: $\{AB\}$

**Compute canonical cover**:
$AB \to C$ is redundant because $B \to C$. So $AB \to CF$ simplifies to $AB \to F$.

**Canonical cover**: $AB \to F$, $B \to D$, $D \to E$, $B \to C$

**not in 2NF** because nonprime attributes implied by partial key $B \to D$ for key $AB$.

**2. The relation is in 2NF.**

**Candidate keys**: $\{ABC\}$

**Compute canonical cover:**
E is redundant in LHS? No. $D \to E$ and $E \to F$ implies $D \to F$. So $D \to F$ is redundant in $D \to EF$.

**Canonical cover**: $ABC \to D$, $D \to E$, $E \to F$

**not in 3NF** because of transitive dependency $ABC \to D \to E$.

**3. The relation is in 3NF**
**Candidate keys**: $\{ABF\}$, $\{CF\}$, $\{DEF\}$, $\{ADF\}$

**Compute canonical cover:** $DEF \to C$ is redundant since $DE \to AB \to CD \to C$, meaning $F$ is extraneous and $DE \to C$ is also redundant via $DE \to A, D \to B \to AB \to C$. $AB \to D$ is redundant because $AB \to C$ and $C \to D$.

**Canonical cover**: $AB \to C$, $C \to DE$, $DE \to A$, $D \to B$

**not in BCNF** because of fd $D \to B$ where $D$ is not a superkey. It is in 3NF because $B$ is prime.

**4. The relation is in BCNF.**
**Candidate keys**: $\{A\}, \{B\}, \{C\}, \{D\}, \{E\}, \{F\}$
**Compute canonical cover**: $AC \to B$ is redundant because $A \to B$.

**Canonical cover**: $A \to B$, $B \to C$, $C \to D$, $D \to E$, $E \to F$, $F \to A$