Duration: 2h. **Grades:** I (4 points), II (6 points), III (10 points).
Course materials are authorized. You can answer in English or French.

Exercise I: Functional Dependences and Normalization

The following questions are independent.

1. Consider the sets of attributes A, B, C, and D.
   Do the following statements hold? If yes, prove your answer using Armstrong's axioms. Otherwise, give a relevant counter-example to support your answer, *e.g.*, using a set of tuples from the instance of a relation.
   a. If $AB \to C$ and $B \to D$, then $AD \to C$.
   b. If $A \to B$, $A \to C$, and $BC \to D$, then $A \to D$.

2. Consider a relation R with five sets of attributes A, B, C, D, and E, and consider the following functional dependencies: $A \to B$, $BC \to E$, and $ED \to A$.
   a. List all keys for R.
   b. Is R in 3NF?
   c. Is R in BCNF?

Exercise II: Design of a Relational Database

The Council of Paris has offered to give you a free lifetime access to all of its museums and events, if you design a part of its database related to cultural expositions. Being yourself an art enthusiast (and a database enthusiast, ever since SD202), you accept the offer, and are given the following information:

- An exposition is a temporary event organized in a specific museum and is centered around a single art movement, such as surrealism or impressionism, *i.e.*, it only showcases a number of works of art from one art movement. Each exposition is also defined by a unique code and a title. In order to make it easier for the visitors to attend expositions, several occurrences of an exposition (gathering the same works of art) can be held in different museums, but never twice in the same one.
- For each museum, its name and location, *i.e.*, latitude and longitude, should be recorded.
- For each artist, the name and birth date should be recorded.
- Each work of art is produced by one artist and has a specific name and a unique number identifying it.
- Visitors visit an exposition on a specific day. One visitor can buy several tickets to an exposition, *e.g.*, for him/her and for the group accompanying him/her, and tickets can be of different categories, *e.g.*, minor, student, or adult. For each buyer, the name and email should be recorded. Regarding the ticket price, and for simplicity reasons, only the total amount paid by the buyer for one purchase should be recorded.

1. In this context, write the set of corresponding relations in BCNF, specifying their keys and the set of functional dependencies. Note that it is strongly recommended to clearly indicate if any additional assumption is made in the process of designing the database.

2. How would your design change in each of the following cases:
   a. Each exposition gathers works of art from multiple art movements.
   b. Each person can only buy tickets of a single specific category for all expositions.
   c. Each exposition has only one occurrence: It is held in a single museum over a single interval of time.

Exercise III: SQL

When you are neither in class nor visiting museums and expositions, you spend part of your time in a local aero club, *i.e.*, organization providing its members with access to airplanes, and help its managers retrieve specific information regarding flights and members. In this context, you have access to a database with the following schema (the primary keys of the relations are underlined):

> **Flights** (*Flight_ID*, Departure_airport, Arrival_airport, Distance, Departure_time, Arrival_time)
> **Airplanes** (*Airplane_ID*, Airplane_model, Manufacturer, Range)
> **Certifications** (*Member_ID, Airplane_ID*)
> **Members** (*Member_ID*, Member_name, Date_of_birth, Nationality, Seniority)

Notes:
- *Range* indicates the maximum distance that can be covered by an airplane in a single flight.
- *Certifications* highlights the airplanes that can be piloted by members.
- *Seniority* indicates the number of years since the member first joined the club.

You are asked to provide the following information. Write the corresponding queries in SQL:

1. List the distances of flights traveled by American members on airplanes manufactured by *Boeing* and going from *Paris* to *Bora Bora*.

2. List the names of all members who are certified to pilot every single airplane in the club.

3. List the IDs of the airplanes that have the highest range.

4. List the airplane models that are only operated by members who have more than four years seniority in the club.

5. For each member certified to pilot more than three airplanes, list their member ID and the highest range of all the airplanes they are certified to pilot.

6. List the names of the members who can operate airplanes with a range greater than 4000 miles but who are not certified to pilot any airplane manufactured by *GE Aviation*.

7. List the names of the members who are not certified to pilot any airplane and who have a seniority greater than the average seniority of all members.

8. Privileged guests are allowed to accompany other members during their trip. One of them wants to travel from *Vancouver* to *Reykjavik* with no more than two stops. List all the departure options from *Vancouver* available to this guest, if they want to arrive to *Reykjavik* before 25/10/2019 at 8 p.m.