Problem 1 (20 pts)
Design an Entity-Relationship schema for a database of tourist information. The database should contain the information about:

- cities: name, state, population;
- services: name, city, street address;
- tourist guides: title, featured services with the associated ratings.

Each city is only in a single state. City names are unique within each state. Each service has a unique name. A service is a hotel or a restaurant. For each restaurant the information about its cuisine (American, Chinese, Italian,...) is kept. The ratings are captured as numbers of stars (between 1 and 5). Different guides may rate the same service differently. You can make any other additional assumptions that make sense in the real world.

Solution.
Entity types:

- City with attributes Name, State and Population, and key (Name, State);
- Service with attributes Name, Address, and key Name;
- Hotel with attribute Name which is a key;
- Restaurant with attributes Name (key) and Cuisine;
- Guide with attribute Title.

Relationship types:

- Location(Service, City), N:1;
- Listing(Guide, Service), N:M, with attribute Stars.

isa relationships:

- Hotel isa Service;
- Restaurant isa Service.

Problem 2 (20 pts)
Produce a relational schema in BCNF from the E-R schema obtained in Problem 1. Identify keys and foreign keys. Eliminate redundancies.

Solution. Keys are underlined.
Relations:

- CITY(CNAME, STATE, POPULATION);
The relations SERVICE and LOCATION can be merged to yield a single relation

\[
\text{SERVICE}(\text{SNAME}, \text{ADDRESS}, \text{CNAME}, \text{STATE})
\]

with foreign keys: \text{SNAME} referencing SERVICE(\text{SNAME}) and \text{(CNAME,STATE)} referencing CITY(\text{CNAME}, \text{STATE}).

**Problem 3 (20 pts)**

Let \( R(ABC) \) be a relation schema together with the set of dependencies \( F = \{ A \rightarrow B, B \rightarrow C, C \rightarrow B \} \).

1. Find the keys of \( R \) and check whether \( R \) is in BCNF or 3NF. Explain the answers, using the appropriate definitions.

2. If \( R \) is not in BCNF, provide a lossless join decomposition of \( R \) into BCNF and check which dependencies in \( F^+ \) it preserves.

**Solution.**

Answers:

- One key: \( A \),

- Check that \( BC \) is not a key using a counterexample \( r = \{(3, 1, 2), (4, 1, 2)\} \) which satisfies \( F \) but not \( BC \rightarrow A \).

- \( R \) is not in BCNF because there is a nontrivial, nonkey FD \( B \rightarrow C \) in \( F \). (\( C \rightarrow B \) also violates BCNF.) It is not in 3NF because \( C \) does not belong to any key.

- A lossless-join decomposition into BCNF, \( (AB, BC) \), preserves all FDs. (Note that another lossless-join decomposition, \( (AC, BC) \), also preserves all FDs, while \( (AC, AB) \) is also lossless-join but loses \( B \rightarrow C \) and \( C \rightarrow B \).)