Question 1 (Knowledge Questions) [20 points]

1. What is a “functional dependency”? Provide its formal definition. [4 points]

2. Describe in your own words what the closure F^+ of a set F of functional dependencies is. What are the drawbacks of calculating F^+? [4 points]

3. What are the advantages of integrity constraints? What are static integrity constraints? What are dynamic integrity constraints? [4 points]

4. List the terms for the two main requirements of normalization. [4 points]

5. How is the third normal form (3NF) formally defined? What are the differences, advantages, and disadvantages of 3NF and BCNF? [4 points]

Question 2 (Functional Dependencies and Normal Forms) [32 points]

Consider the relation schema $R(A, B, C, D, E)$ with the functional dependencies $F = \{A \rightarrow BC, CD \rightarrow E, B \rightarrow D, E \rightarrow A\}$. Answer the following questions.

1. What is the attribute closure of CE? Please apply the Armstrong axioms (do *not* use the attribute closure algorithm) and indicate the rules that you have used in each step. What can we say about the result of CE^+? [6 points]

2. List the candidate keys of *R*, and precisely describe your determination method and argumentation. [6 points]

3. Suppose that we decompose the above schema R into $R1(A, B, C)$ and $R2(A, D, E)$. Is this decomposition a lossless join decomposition? Please give the reason for your answer. [5 points]

In the following, let $R(A, B, C, D)$ be a relation schema with the FDs $F = \{B \rightarrow C, B \rightarrow D\}$.

4. Identify the candidate keys for R. [3 points]

5. Is the relation schema R in 3NF? If yes, justify your answer. If not, point out the violations, decompose R into 3NF, and show the detailed steps. [8 points]

6. Is the above FDs in BCNF? If yes, justify your answer. If not, point out the violations. [4 points]

Question 3 (Functional Dependencies and Normal Forms) [28 points]

1. Which of the following attribute sets is a candidate key for $R(A, B, C, D, E, F, G)$ with functional dependencies $\{AB \rightarrow C, CD \rightarrow E, EF \rightarrow G, FG \rightarrow E, DE \rightarrow C, BC \rightarrow A\}$? Please circle your answers and provide an argumentation for your choices. [3 points]

BDF *ACDF* *ABDFG* *BDFG*

2. Let us decompose $R(A, B, C, D, E)$ into relations with the following three sets of attributes: $\{A, B, C\}$, $\{B, C, D\}$, and $\{A, C, E\}$. For the set $F = \{A \rightarrow D, D \rightarrow E, B \rightarrow CD\}$ of FDs, use the chase test to tell whether the decomposition of R is lossless. If it is not lossless, give an example of an instance of R that returns more tuples than R has when projected onto the decomposed relations and rejoined. [10 points]

3. Compute a canonical cover F_c for a relation schema $R(A, B, C, D, E)$ with FDs $F = \{C \rightarrow B, CB \rightarrow AC, CAE \rightarrow FB, D \rightarrow E, CA \rightarrow B\}$. [10 points]

4. Are the FDs of F of the previous question equivalent to $F2 = \{C \rightarrow ABC, CB \rightarrow A, A \rightarrow B, CE \rightarrow F, D \rightarrow DE\}$? Please give reasons for your answer. [5 points]

Question 4 (Data Integrity) [20 Points]

Consider the following database schema of student application (primary keys are underlined):

Student(sID: integer, name: varchar(20), address: varchar(100), GPA: float, sizeHS: integer)
Campus(cID: integer, location: varchar(200), enrollment: integer, rank: integer)
Apply(sID: integer, cID: integer, date: varchar(20), major: varchar(20), decision: char)

1. Write SQL statements to create tables for these schemas and clearly specify primary key and foreign key using referential integrity. For any deletion in Table Student and Campus, table Apply will delete also. State clearly how the foreign key constraints will perform on the deletion operation of table Apply. [5 points]

2. Write assertions for each of the following conditions: Students with GPA < 3.0 can only apply to campuses with rank > 4. [5 points]

3. Suppose that “decision” in Table Apply can only have the three values ‘Y’, ‘N’, and ‘U’. Add integrity constraints to Apply to check about that. [5 points]

4. Write triggers for the following situation: If an application tuple is inserted for a student with GPA > 3.9 and sizeHS > 1500 to a campus whose ID is 5566, set decision to "Y". [5 points]