1. Consider the following set of simplified requirements for a System-info database that is used to keep track of the usages of (software) systems in a company.

(i) Each department has a unique name and a unique number. A department may use several systems. The database keeps track of the number of hours per week that a department uses each system.

(ii) Each system has a unique name, a unique number, and a particular administrator who manages the system. A system may be used by a number of departments.

(iii) The database stores each administrator’s name, unique identifier and e-mail address. Each administrator must manage at least one system.

(a) (8 points) Draw an ER (Entity-Relationship) schema diagram for this application. You need to clearly indicate the cardinality ratio (1:1, 1:N, or M:N) and participation constraints (total or partial) of each relationship. (State clearly any additional assumptions you make.)

(b) (8 points) Map the ER schema into the corresponding relational database schema diagram. Specify all primary keys and foreign keys.

Suppose that it is also necessary to keep track of different types of systems (Internet systems and Intranet systems), in which an Internet system may serve several customers (cooperative companies). Each customer has a unique name, a unique identifier, and an address. A customer may be served by several Internet systems. Notably, a system may be a member of Internet systems, Intranet systems or both. Every system in the company is a member of Internet or Intranet systems.

(c) (8 points) Modify the ER schema in (a) according to the above requirements, using ER and Enhanced ER concepts of specialization and generalization. You need to clearly indicate the disjointness and completeness constraints. (State clearly any additional assumptions you make.)

2. (3 points) Explain the differences between a relationship instance and a relationship type in the Entity-Relationship Model.

3. (6 points) Explain the database approach of a general purpose DBMS software to achieve the self-describing nature of a database system. What are the benefits of using such approach?

4. (9 points) Given the following relational instances, show the result relations by doing

(a). r(R1) natural-join r(R2); (b). r(R1) divide by r(R3); (c) r(R1) minus r(R4)

<table>
<thead>
<tr>
<th>r(R1)</th>
<th>r(R2)</th>
<th>r(R3)</th>
<th>r(R4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a1, b1, c1)</td>
<td>(a2, d1)</td>
<td>(a1, c1)</td>
<td>(a1, b1, c2)</td>
</tr>
<tr>
<td>(a2, b1, c2)</td>
<td>(a2, d2)</td>
<td>(a2, c2)</td>
<td>(a2, b2, c3)</td>
</tr>
<tr>
<td>(a2, b2, c2)</td>
<td>(a3, d1)</td>
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<tr>
<td>(a2, b2, c3)</td>
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5. (12 points) Use examples to describe the properties of relational databases.
   (a) the referential integrity constraint
   (b) the entity integrity constraint.
   (c) Each value in a tuple is an atomic value.

6. (12 points) Explain the meaning for the following statement in SQL on the following
   Company database tables
   EMPLOYEE (SSN, ENAME, SALARY, SUPERVISOR-SSN, DNO>  
   DEPARTMENT (DNO, DNAME, MANAGER-SSN)  
   PROJECT (PNO, PNAME, DNO)
   WORK-ON (SSN, PNO)
   DEPENDENT (SSN, DEP-NAME):
   (a) SELECT ENAME
       FROM EMPLOYEE E
       WHERE EXISTS (SELECT *
                       FROM DEPENDENT D
                       WHERE E.SSN=D.SSN)
       AND
       EXISTS (SELECT *
               FROM DEPARTMENT
               WHERE SSN=MANAGER-SSN);
   (b) SELECT COUNT (*)
       FROM EMPLOYEE E, DEPARTMENT D
       WHERE E.DNO=D.DNO AND DNAME='Research';
   (c) SELECT A.ENAME, B.ENAME
       FROM EMPLOYEE AS A, B
       WHERE A.SUPERVISOR-SSN=B.SSN;

7. (12 points) In a normalization process, one goal is to reduce the redundant information.
   Without this process, it may produce so-called update anomalies, insertion anomalies, and
   modification anomalies. Give clear relational database examples for explaining what are
   those three anomalies.

8. (7 points) Specify a relational schema in third normal form using its functional
   dependencies. Then decompose it into schemas in Boyce-Codd normal form. What are the
   major differences between both forms.

9. (15 points) For the concurrency control in transaction processing, give examples to explain
   what are (a) lost update problem, (b) dirty read problem, and (c) incorrect summary
   problem.