Section A

This section contains one question, worth 20 marks. You MUST answer it using a SEPARATE answer book.

1. a) Consider the following University database schema represented as a graph where nodes denote relations (relation names in the shaded area, column names listed below, primary key components underlined) and a directed edge from attribute \( f \) of relation \( S \) to an attribute \( p \) of relation \( R \) denotes that \( f \) is a foreign key in \( S \) referencing \( p \) in \( R \):

   1. i) Code a solution to the following problem as a relational-algebraic expression against the University database schema: \textit{Retrieve the names of instructors that do not advise any student.} \hspace{1cm} (2 marks)

   1. ii) Code a solution to the following problem as an SQL statement against the University database schema: \textit{Retrieve the names of instructors, the name of the department the instructors work for, and the number of courses they teach in descending order of the latter.} \hspace{1cm} (3 marks)

   1. iii) Translate the following assignment sequence into one single SQL statement:

      \[
      \begin{align*}
      I_1 & \leftarrow \text{section} \bowtie_{\text{course_id}} \text{takes} \\
      I_2 & \leftarrow I_1 \bowtie_{\text{ID}} \text{student} \\
      I_3 & \leftarrow \sigma_{\text{dept_name}=\text{"Comp.Sci."}}(I_2) \\
      I_4 & \leftarrow \pi_{\text{room_number}}(I_3)
      \end{align*}
      \] \hspace{1cm} (3 marks)

   b) Briefly explain the purpose of a data requirements specification and of a logical model in terms of their role in the database design methodology as you have practiced it in this course unit. \hspace{1cm} (2 marks)
c) Map the ER diagram in the figure below into a relational schema, indicating the primary and foreign key (or keys) for each relation and stating, for each foreign key, which attribute of which relation the foreign key depends on. (8 marks)

![ER Diagram]

\[ 
\begin{align*}
\text{S} & \rightarrow \text{n1} \quad \text{il} \\
\text{H} & \rightarrow \text{M} \quad \text{a} \\
\text{A} & \rightarrow \text{n2} \quad \text{t} \\
\end{align*} \]

\[ \text{G} \rightarrow \text{N} \]

\[ \text{W} \rightarrow \text{l} \]

\[ \text{M} \rightarrow \text{N} \]

\[ \text{i2} \rightarrow \text{n2} \]

\[ \text{p} \rightarrow \text{t} \]

\[ \text{c} \rightarrow \text{a} \]

\[ \text{d} \rightarrow \text{n1} \]

\[ \text{l} \rightarrow \text{il} \]

\[ \text{l} \rightarrow \text{il} \]

\[ \text{N} \rightarrow \text{n2} \]

\[ \text{M} \rightarrow \text{n2} \]

\[ \text{N} \rightarrow \text{n2} \]

\[ \text{N} \rightarrow \text{n2} \]

\[ \text{N} \rightarrow \text{n2} \]

d) Explain how you would modify the logical schema in your answer to Q(1c) above if the relationship type \( W \) were many-to-many. (2 marks)
Section B

This section contains one question, worth 20 marks.
You MUST answer it using a SEPARATE answer book.

2. a) Given the relation \( R(A, B, C, D, E, F, G, H) \), let the following functional dependencies hold among its attributes:

\[
A \rightarrow B \\
CH \rightarrow A \\
B \rightarrow E \\
BD \rightarrow C \\
EG \rightarrow H \\
DE \rightarrow F
\]

Given the information above, explain (using the notions taught in this course unit) whether or not each of the following postulated functional dependencies holds over \( R \), and, if it does, use Armstrong’s axioms to write down a step-by-step derivation that proves the claim.

i) \( BED \rightarrow CF \)

ii) \( CGH \rightarrow BF \)

(4 marks)

b) Consider the following Loan table, which stores information about loans, their borrowers and their loaners:

\[
\text{Loan}
\begin{align*}
\text{borrower_id} & , \\
\text{borrower_name} & , \\
\text{borrower_address} & , \\
\text{loaner_id} & , \\
\text{loaner_name} & , \\
\text{loaner_address} & , \\
\text{total_amount_borrowed} & , \\
\text{date_loan_requested} & , \\
\text{date_final_payment} & , \\
\text{interest} & , \\
\text{amount_left_to_be_paid} & , \\
\text{amount_paid_instalment} & , \\
\text{date_paid_instalment}
\end{align*}
\]: \( \text{PK:}\{\text{borrower_id}, \text{loaner_id}, \text{date_loanRequested}\} \)

Note that the date when a loan is requested is required to identify a loan, i.e., it is part of the primary key. Also note that loans can be paid in instalments (i.e., partial payments distributed over a period of time), with interest being charged.

i) Using notions of normalization theory, briefly explain why the design that
led to this table is flawed, and give an example of an update (or insertion, or deletion) anomaly that may result from it. (3 marks)

ii) If the above schema is in 3NF or BCNF, then argue why this is so from the respective definitions. If it is neither in 3NF nor BCNF, then normalize it step-by-step to 3NF (or to BCNF, if possible). (4 marks)

c) Consider the following relational database schema describing departments and academics in a university:

```sql
CREATE TABLE Departments
    (dept_name VARCHAR (10),
     budget DECIMAL(3,2),
    PRIMARY KEY (dept_name));

CREATE TABLE Academics
    (acad_ID VARCHAR(2),
     acad_name VARCHAR (10),
     acad_position VARCHAR (2),
     dept_name VARCHAR(10)
    REFERENCES Departments (dept_name)
    ON DELETE CASCADE,
    PRIMARY KEY (acad_ID));
```

i) Write a PL/SQL function that, given the name of a department, returns the count of the number of academics in that department. (3 marks)

ii) Write a SQL query that, using the function you have defined in Q2(c)i above, returns the names and budgets of all departments with more than 12 academics. (3 marks)

d) Consider the following T1, T2, T3 and T4 and schedule S, which concurrently involves them:

T1: r1(x); w1(y); c1.
T2: r2(q); c2.
T3: r3(x); r3(y); w3(p); w3(x); c3.
T4: w4(q); r4(y); w4(y); c4.

S: r3(x); r3(y); w3(p); w4(q); r2(q); w3(x);
c3; r1(x); w1(y); c1; r4(y); w4(y); c4; c2.

In the notation used, r1(x), e.g., denotes T1 reading object x from disk into memory; w3(z), e.g., denotes T3 updating object z and writing it back to disk from memory, and c2, e.g., represents a commit from T2.

State whether the schedule S above is conflict-serializable and briefly explain why or why not. (3 marks)