Answer any FOUR questions out of SIX. All questions carry equal marks.

Time: TWO hours

Answer any Section A questions you attempt in Answer Book A
Answer any Section B questions you attempt in Answer Book B

The marks given in brackets are indicative of the weight given to each part of the question.

Calculators are NOT allowed in this examination.
A1.

a) Define each of the following relational database concepts using examples from the STUDENT relation given in Fig A1.1

i. Tuple. (1 mark)

ii. Cardinality. (1 mark)

iii. Degree. (1 mark)

iv. Attribute. (1 mark)

v. Schema. (2 marks)

vi. Domain. (2 marks)

vii. Composite key. (2 marks)

b) Explain the importance of the ANSI-SPARC database architecture in supporting data independence in a Database Management System (DBMS) and supporting database design. (5 marks)

c) Relational Algebra uses operators to manipulate a Relation. An operator can be either Unary or Binary. Consider the following Depositor and Borrower relations below:

i. Give examples of TWO Unary Relational Algebra (RA) operators that operate only on the Depositor or the Borrower relations. (4 marks)

ii. Give examples of THREE Binary Relational Algebra operators that operate on both the Depositor and Borrower Relations given above (Fig A1.2 and Fig A1.3). (6 marks)
B6.
a) Consider the following example of two concurrent transactions (Tx1 and Tx2) and answer the questions below.

<table>
<thead>
<tr>
<th>Tx1</th>
<th>Tx2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read (x)</td>
<td>Read (x)</td>
</tr>
<tr>
<td>x := x - 5</td>
<td>x := x + 5</td>
</tr>
<tr>
<td>Write (x)</td>
<td>Write (x)</td>
</tr>
<tr>
<td></td>
<td>ROLLBACK</td>
</tr>
<tr>
<td>COMMIT</td>
<td>COMMIT</td>
</tr>
</tbody>
</table>

i. What problem occurs in the example? 

ii. Explain the concept of 2 phase locking and show how 2 phase locking prevents the problem in part i. above.

b) Briefly explain the concept of a recovery strategy at business level and why a business would have one. Your answer should mention TWO options available for recovery strategies.

c) A database auditor detected both login changes and user permission changes to your database. Why should you be concerned?

d) Authorisation in SQL databases can be granted to users and roles. It controls how/whether they can access data in the database. Answer the following questions related to authorisation:

i. What is the effect of the following SQL statement?

GRANT DELETE on amy.Student TO Prof_Smith;

ii. What are the advantages in the use of roles?

iii. How can views help with database security in conjunction with granting permissions?

A2.
Normalisation to Third Normal Form (3NF) is one the most important objectives of database design.

Consider the following table in Fig A2, that holds data about players of a computer game. This table records the PlayerID and Playername and the types of weapons a player uses in the game. For example, Moeen uses a sword and an axe. A weapon may be assigned to a player and/or removed from a player at any time.

Each player has a rating and a skill level and is assigned a unique PlayerID. The Skill level of a player is on a numeric scale related to the player rating such as a Beginner has a skill level of either 1 or 2; Intermediate has skill level of either 3 or 4; Advanced level has either 5 or 6.

<table>
<thead>
<tr>
<th>PlayerID</th>
<th>PlayerName</th>
<th>Weapon</th>
<th>PlayerRating</th>
<th>Skill Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>JB</td>
<td>dagger, sword</td>
<td>Beginner</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>JonT</td>
<td>crossbow</td>
<td>Intermediate</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Moeen</td>
<td>sword, axe</td>
<td>Beginner</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Liam</td>
<td>dagger</td>
<td>Advanced</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig A2 Games Table

a) With reference to Fig A2 Games Table as a source of examples, describe the problems that can arise if a table is not fully normalised to 3NF.

b) Explain and justify the process of normalising the Fig A2 Games table to third normal form (3NF) by working through the following steps.

Step1: UNF->1NF:

Step2: 1NF->2NF:

Step3: 2NF->3NF:

(12 marks)

c) Suppose there is a new requirement:

A player can have the use of more than one weapon of the same type (for example another 2 axes). Therefore, it is required to record a count of the weapons used (for example Moeen uses 3 axes).

Explain how you would modify the 3NF table(s) in your answer in part b) to accommodate the above requirement. Illustrate your answer with sample data.

(4 marks)

d) Show all the functional dependencies that now exist, including the modification to your design in part c).

(4 marks)
Consider the following Tables (Fig A3.1 and A3.2) below and SQL script (Fig A3.3) on page 5.

**Fig A3.1 Table Borrower**

<table>
<thead>
<tr>
<th>BORROWERID</th>
<th>BORROWERFNAME</th>
<th>BORROWERNNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>874</td>
<td>Leon</td>
<td>Small</td>
</tr>
<tr>
<td>875</td>
<td>Gary</td>
<td>Lowe</td>
</tr>
<tr>
<td>876</td>
<td>Marik</td>
<td>Ahmed</td>
</tr>
<tr>
<td>877</td>
<td>Clywd</td>
<td>Morgan</td>
</tr>
</tbody>
</table>

**Fig A3.2 Table Loan**

<table>
<thead>
<tr>
<th>LOANID</th>
<th>BOOKID</th>
<th>BORROWERID</th>
<th>LOANDATE</th>
<th>DUEDATE</th>
<th>RETURNDATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>122</td>
<td>3932</td>
<td>874</td>
<td>15-NOV-2022</td>
<td>14-DEC-2022</td>
<td>24-JAN-2023</td>
</tr>
<tr>
<td>123</td>
<td>3944</td>
<td>874</td>
<td>23-DEC-2022</td>
<td>24-JAN-2023</td>
<td>24-JAN-2023</td>
</tr>
<tr>
<td>124</td>
<td>3906</td>
<td>874</td>
<td>23-DEC-2022</td>
<td>03-JAN-2023</td>
<td>30-DEC-2022</td>
</tr>
<tr>
<td>125</td>
<td>3944</td>
<td>876</td>
<td>29-JAN-2023</td>
<td>28-FEB-2023</td>
<td>-</td>
</tr>
<tr>
<td>126</td>
<td>3932</td>
<td>874</td>
<td>25-JAN-2023</td>
<td>21-FEB-2023</td>
<td>-</td>
</tr>
<tr>
<td>127</td>
<td>3945</td>
<td>876</td>
<td>25-JAN-2023</td>
<td>21-FEB-2023</td>
<td>-</td>
</tr>
</tbody>
</table>

c) Consider the following ERD model. Map the model into the relevant physical design. Add keys as required. You do not need to provide sample data.

![ERD Diagram]

(8 marks)

d) Consider the **NOT NULL** constraint in SQL. Explain what it means and provide a simple SQL DDL statement in which you use it.

(4 marks)
B5. 

a) Consider the following notations used in entity Relationship Diagrams (where they differ, both Chen’s notation and the Crow’s foot version are provided) and explain their meaning.

i. 

ii. 

iii. 

iv. 

b) Consider the following SQL Data Definition Language extract. Identify suitable key constraints (both foreign and primary) and add the respective SQL statements to implement the keys.

CREATE TABLE Student 
(Name VARCHAR(50), 
DoB DATE, 
Studid INT NOT NULL 
);
CREATE TABLE Course 
(Name VARCHAR(50), 
Courseid INT NOT NULL 
);
CREATE TABLE Enrolment 
(StudID INT NOT NULL, 
CourseID INT NOT NULL 
);
The below questions refer back to (Fig A3.1 and A3.2) on page 4 and SQL script (Fig A3.3) on page 5.

a) Refer to the SQL script. Both the Borrower and Loan tables are not constrained by entity integrity.
   i. Define entity integrity and briefly explain how entity integrity may be compromised when more data is inserted into these tables. (4 marks)
   ii. Write the SQL statement necessary to enforce entity integrity in the Borrower table. (Approximate SQL syntax/pseudocode is acceptable) (2 marks)

b) Refer to the SQL script. The relationship between Borrower and Loan is not constrained by referential integrity.
   i. Define referential integrity and briefly explain how data integrity might be compromised when a row of data is deleted from either the Loan or Borrower tables. (4 marks)
   ii. Write the SQL statement that would enforce referential integrity between Borrower and Loan. (Approximate SQL syntax/pseudocode is acceptable). (2 marks)

c) There is at least one further type of constraint that should be added to the table Loan in the script. Identify a constraint that needs enforcing and show how you would alter the SQL statement that creates the Loan table to enforce this constraint. (3 marks)

d) Refer to the Borrower and Loan tables. Write a SQL statement and show the output it generates when returning the BorrowerID, BorrowerLname and BorrowerFname of those borrowers that have not borrowed a book. (5 marks)

e) There are many ways in which a user can interact with a database. For example, the script shown in Fig A3.3 was developed using a Command Line interface.

   Describe the key differences between the following types of user interface, contrasting the different needs of users and the way users interact with an underlying database.
   - Command Line (Text based)
   - Forms based (GUI) (5 marks)

Section B

Answer any Section B questions you attempt in Answer Book B

B4.

You are employed as a consultant by a bus transport company. They want you to advise on the next database system for their operations in the context of new government regulation requiring publication of timetables, bus locations and fares. Specifically, their CEO is very keen to employ some new technology in the form of a graph database as they have heard that they are very flexible. Read the following description of their system needs and answer the questions below.

The database will be queried by route planning software and a web application for users that allows them to identify departure times at specific stops and for specific destinations. It will also identify any delays to the bus service. The information to be stored in the database are:
   - Bus timetables: a bus timetable is a list of stops together with arrival and departure times at each stop; each bus route has two timetables (weekday and weekend), and the operator runs in the order of 10 bus routes.
   - Bus locations: each bus sends updated information to the database when it arrives at or leaves a stop.

Note that both arrival and departure times for stops are recorded to allow for scheduled breaks as well as tracking where buses consistently arrive earlier than anticipated.

a) Briefly describe the concept of a Graph Database. (4 marks)

b) Up to now, timetables have been kept in a flat file. Discuss whether this is a reasonable approach and consider any limitations. (4 marks)

c) Consider whether a Graph Database or a Relational Database is better for the new database implementation. Your answer should include a discussion of the pros and cons for each. (10 marks)

d) Without referring to the scenario above, explain the concepts of logical data independence and physical data independence in a DBMS. You might wish to use the following diagram to aid your description:

   ![Diagram of database levels]

   (7 marks)