# McMaster University
## SFWRENG 3DB3 Fall 2021
## Assignment 3
## Due: December 3, 2021 at 10:00pm

November 11, 2021

## I. Database Design (65 marks)

### Question 1 (40 marks) Functional Dependencies

The Department has a database containing information about all lectures during a term. The `Schedule` relation has the following schema:

> `Schedule` $(C, D, T, R, P, A)$

where $C$ represents a course, $D$ for day (weekday), $T$ for time, $R$ for room, $P$ for professor, and $A$ for head TA. The set of functional dependencies $F$ defined over `Schedule` are:
$F = \{RDT \rightarrow P, RDT \rightarrow C, C \rightarrow A, PDT \rightarrow R, PDT \rightarrow C, CDT \rightarrow P, CDT \rightarrow R\}$

Answer the following questions:

(a) (4 marks) What do these functional dependencies mean? Describe them in words.

(b) (4 marks) Is the FD $RDT \rightarrow AP$ entailed by $F$? Explain and show your work with references to Armstrong's axioms.

(c) (6 marks) Find all the key(s) of relation `Schedule`. Show your work (i.e., how each key is derived) with references to Armstrong's axioms.

(d) (6 marks) Is `Schedule` in BCNF? If not, decompose it into smaller relations that are each in BCNF. Again, show your work.

(e) (6 marks) We can create a new relation `ProfsSchedule`$(D, T, P)$ by projecting some attributes of `Schedule`. Are there new functional dependencies that hold over `ProfsSchedule`? If so, state these FDs. If not, state why not. In both cases, show your work to justify your answer.

(f) (14 marks) Find a minimal cover $F_{min}$ for $F$. Show all the steps in your derivation of $F_{min}$.

## Question 2 (15 marks) Decomposition, 3NF, BCNF

Consider the relation R(A,B,C,D,E,F), and the decomposition of R into R1(ABCD) and R2(DEF).

(a) (4 marks) Give a set of functional dependencies (FDs) such that the decomposition into R1 and R2 is lossless join and dependency preserving. Justify why your FDs satisfy the criteria.

(b) (4 marks) Give a set of functional dependencies such that the decomposition into R1 and R2 is not lossless join, but dependency preserving. Justify why your FDs satisfy the criteria.

(c) (7 marks) Consider a relation S(A,B,C,D,E,F), and functional dependency $F_1 : A \rightarrow BCDEF$, that holds over S. Define two other functional dependencies $F_2$ and $F_3$, which satisfy the following three properties:

    i. Neither $F_2$ nor $F_3$ can be inferred from $F_1$ using Armstrong's axioms.

    ii. Relation S with functional dependencies $F_1$ and $F_2$ is in BCNF.

    iii. Relation S with functional dependencies $F_1$, $F_2$, and $F_3$ is in 3NF but not in BCNF.

State your two FDs $F_2$ and $F_3$, and justify how your FDs satisfy the above properties.

## Question 3 (10 marks) Armstrong's Axioms

Prove the following using Armstrong's axioms (using only the axioms presented in class). Show the steps of your proof, and indicate which of Armstrong's axioms is applied in each step.

a) (5 marks) Given the relational schema R(A,B,C,D,E,F) and the FDs $F_1$: $\{AB \rightarrow C, A \rightarrow D, CD \rightarrow EF\}$. Show that $AB \rightarrow F$.

b) (5 marks) Consider the schema R(A,B,C,D,E,F), and the following functional dependencies: $A \rightarrow BCD, BC \rightarrow DE, B \rightarrow D, D \rightarrow A$.

Show that $AF$ is a superkey.

# II. Transactions and Concurrency (35 marks)

## Question 4 (6 marks) Serializability

Which of the following schedules is (conflict) serializable? For each serializable schedule, find the equivalent serial schedules.

(a) (3 marks) r1(X); r3(X); w1(X); r2(X); w3(X)

(b) (3 marks) r3(X); r2(X); w3(X); r1(X); w1(X)

## Question 5 (9 marks) Schedules

Consider schedules $S_1$, $S_2$, $S_3$ below. State which of the following properties hold (or not) for each schedule: strict, avoids cascading aborts, recoverability. Provide a brief justification for each answer.

(a) (3 marks)
   $S_1$: r1(X); r2(Z); r1(Z); r3(X); r3(Y); w1(X); c1; w3(Y); c3; r2(Y); w2(Z); w2(Y); c2

(b) (3 marks)
   $S_2$: r1(X); r2(Z); r1(Z); r3(X); r3(Y); w1(X); w3(Y); r2(Y); w2(Z); w2(Y); c1; c2; c3;

(c) (3 marks)
   $S_3$: r1(X); r2(Z); r3(X); r1(Z); r2(Y); r3(Y); w1(X); w2(Z); w3(Y); w2(Y); c3; c1; c2;

## Question 6 (6 marks) Locking

Consider the following locking protocol: Before a transaction T writes a data object A, T has to obtain an exclusive lock on A. For a transaction T, we hold these exclusive locks until the end of the transaction. If a transaction T reads a data object A, no lock on A is obtained. State which of the following properties are ensured by this locking protocol: serializability, conflict-serializability, recoverability, avoids cascading aborts, avoids deadlock. Explain and justify your answer for each property.

## Question 7 (14 marks)

In this question, you will execute a few concurrent transactions against a banking table. The `accounts` table is shown in Table 1. Create the `accounts` table in DB2. You may assume `username` is of type char(10), `name` is char(20), and `balance` is of type decimal(10,2). Write the appropriate INSERT INTO statements to load the four records shown into your `accounts` table.

Table 1: `accounts`

| username | name | balance |
|----------|--------|---------|
| ana | Anakin | 1150.00 |
| vader | Vader | 7000.00 |
| leia | Leia | 100.00 |
| obi | Obiwan | 2275.00 |

**Setup**

You will simulate concurrent database queries, using two different database connections, against the `accounts` table. You will open two terminal sessions, and execute the following commands to prepare your environments. We will call the two sessions, A and B.

**In Session A**

1. Invoke db2 using `db2 +c`. This command turns off the AUTO COMMIT feature in DB2. You will now be at the DB2 command line.

2. Verify AUTO COMMIT is turned OFF by running the command
   `list command options`. (You should see "Auto-Commit OFF" in the second entry of the table.)

3. Change the transaction isolation level to 'Read Stability' by running the command
   `change isolation to rs`. Transaction isolation levels define the degree of access and interaction among a set of concurrent transactions which operate against the same data. Please see the DB2 reference for more information on isolation levels in DB2.

4. Connect to your database.

### In Session B

1. Invoke DB2 by typing `db2` (do not turn AUTO COMMIT off).

2. Run `change isolation to rs`

3. Connect to your database.

## Transactions

Run the following commands (in the given order) and provide your answers to the stated questions.

1. In Session A, insert the record `('yoda', 'Yoda', 8000.00)`, followed by a `select * from accounts`.

2. In Session B, run `select * from accounts`. Is the output you get the same or different than in (1)? Why did this occur? What is a possible solution?

3. Return to Session A, and implement your solution from the previous step.

4. In Session B, do the SELECT * query again (to list all records). Provide your output.

5. We will update accounts from two different transactions. In Session A, change the isolation level to cursor stability (CS). In Session B, change the isolation level to uncommitted read (UR). (You will have to disconnect and reconnect to the database.)

6. In Session A, transfer $800 from Anakin's account into Vader's account.

7. Then, in Session B, list all accounts and their balances. Then issue a $50 transfer from Leia's account to Vader's account. What happens and why?

8. Commit the transaction in Session A. What is Vader's balance now?

9. Change the transaction isolation level in Session A to 'Uncommitted Read'.

10. Now, in Session A, transfer 80% of Vader's account balance to Obiwan's account. Commit the transaction.

11. In Session A, transfer 50% of Yoda's funds to Obiwan's account. In session B, list all data records. What is Obiwan's balance? Does it reflect the latest transfer from Yoda? Based on your transaction in step (7) and this step, what can you say about the allowed actions in CS and UR isolation levels? How do these compare with the RS isolation level?

4

12. Abort the Yoda to Obiwan transfer transaction in Session A, by executing the command `rollback`.

13. In session A and B, list all data records. What are the final balances for each user?

# Grading

This assignment is worth 14% towards your final grade.

# Submission

All files are to be submitted via Avenue. Please ensure your answers are typed and clearly readable. Non-typed solutions will not be marked and receive a mark of zero. Include your name and student ID number in the file. Submit your solutions to all questions in a file called **asg3.pdf**.