Answer the questions in the spaces provided on the page. If you run out of room for an answer, continue on the back of the page.

- DO NOT START THE EXAM UNTIL TOLD TO DO SO
- You only need to answer 5 of the 6 questions.
- On one of the questions make a large slash through it, which indicates that it should not be graded.
- On every page (including the first and last page), write your first and last name, before answering the question. Unnamed pages may be lost.
- If you start to answer a question and then change your mind, please cross out the attempt and write DO NOT GRADE across it.

https://xkcd.com/844/
Question 1: Corrupted Database

Unfortunately, Pikachu got a bit upset too close to our database, and it erased some of the values. The data isn’t essential, but we would like to recover what we can. Here’s what we know:

- The relation has 6 attributes (A-F) as shown below.
- The relation has one multivalued dependency: \( AB \rightarrow F \)
- The relation has two functional dependencies: \( C \rightarrow D \)
- and \( AC \rightarrow E \)

Use the data given in the relation below to fill in the missing values. If the value is unknown, put a question mark (?) instead of a number.

\[
\begin{array}{cccccc}
A & B & C & D & E & F \\
5 & 4 & 9 & 2 & 2 & 1 \\
1 & 1 & 1 & 1 & ? & ? \\
5 & 4 & 2 & 5 & 3 & 7 \\
0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 \\
1 & 0 & 1 & 1 & ? & ? \\
5 & 4 & 2 & 5 & 3 & 1 \\
5 & 4 & 9 & 2 & 2 & 7 \\
\end{array}
\]

Points earned: __________ out of a possible 4 points
Question 2: Closures. 4 points

Here’s a relation (R), its attributes and its functional dependencies (F):

R(A, B, C, D, E, F, G)
A B → A
B C → D G
C D → F
F G → A

(a) (1 point) Which of the following are in the attribute set closure \{ACD\}^+?

- √ \{ACD\}
- ○ \{AB\}
- √ \{F\}
- ○ \{ADF\}
- ○ \{ADG\}
- √ \{CDF\}

(b) (1 point) Which of the following are in the functional dependency closure of F (F^+)?

- √ ABCDEFG → ABDEFG
- √ BCD → DFG
- ○ B → A
- √ CDG → A
- √ AE → E
- √ BC → D

(c) (1 point) Which of the following are superkeys?

- ○ \{A\}
- ○ \{AFG\}
- √ \{BCDEG\}
- √ \{ABCDEFG\}
- ○ \{BCE\}
- ○ \{ABDEFG\}

(d) (1 point) Which of the following are keys?

- ○ \{A\}
- ○ \{AFG\}
- ○ \{BCDEG\}
- ○ \{ABCDEFG\}
- √ \{BCE\}
- ○ \{ABDEFG\}

Points earned: __________ out of a possible 4 points
Question 3: Precedence ................................................................. 4 points

(a) (2 points) What are the conflicts and implied transaction precedence for the following schedule:

S: \( r_7(W); w_8(X); w_{10}(Y); r_9(Z); w_7(X); w_8(X); r_9(W); w_{10}(W); \)

Solution:

- \( r_7(W); w_{10}(W); \Rightarrow T_7 < T_{10} \)
- \( r_9(W); w_{10}(W); \Rightarrow T_9 < T_{10} \)
- \( w_8(X); w_7(X); \Rightarrow T_8 < T_7 \)
- \( w_7(X); w_8(X); \Rightarrow T_7 < T_8 \)

(b) (1 point) Draw the Precedence Graph for the schedule.

Solution:

(c) (1 point) Could a locking scheduler have generated the above schedule, why or why not?

Solution: No, a locking scheduler only generates conflict-serializable schedules, and the above schedule is not conflict-serializable because cycles are present in the precedence graph.

Points earned: __________ out of a possible 4 points
Question 4: Transaction Modes .................................................. 4 points
Below is a sequence of SQL commands.

After the statement is completed by the associated connection, write which connections are holding each type of lock in the table. If no connection holds a type of lock, leave it blank. No locks are held at the start of the following sequence of SQL commands. A connection can only hold one lock at a time.

If an error should be raised, write ERROR on all three columns for that statement and skip to the next statement (pretending that the error causing statement didn’t happen and has no effect on anything).

<table>
<thead>
<tr>
<th>ID</th>
<th>SQL statement</th>
<th>Shared</th>
<th>Reserved</th>
<th>Exclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>CREATE TABLE ...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>CREATE TABLE ...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>DROP TABLE ...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>INSERT INTO ...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>BEGIN IMMEDIATE TRANSACTION;</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>BEGIN TRANSACTION;</td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>SELECT ...</td>
<td>A</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>SELECT ...</td>
<td>A</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>COMMIT TRANSACTION;</td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>BEGIN TRANSACTION;</td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>SELECT ...</td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>COMMIT TRANSACTION;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
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<td>SELECT ...</td>
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</tr>
<tr>
<td>C</td>
<td>DELETE FROM ...</td>
<td>ERROR</td>
<td>ERROR</td>
<td>ERROR</td>
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<td>B</td>
<td>ROLLBACK TRANSACTION;</td>
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<tr>
<td>A</td>
<td>UPDATE ...</td>
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</tr>
<tr>
<td>B</td>
<td>BEGIN EXCLUSIVE TRANSACTION;</td>
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</table>

Points earned: __________ out of a possible 4 points
Question 5: Entity/Relationship Diagram .................................................. 4 points

We are creating a database to record which information about A Song of Ice and Fire.
You don’t need to distinguish between exactly one and one-or-zero for this question.
Below are some facts that need to be represented in the database:

- Every House has a unique name.
- Houses also have words (a.k.a. a motto) and a symbol.
- There are multiple Kingdoms and each House is part of one of the Kingdoms.
- Each Kingdom has a location and a unique name.
- Each Kingdom is ruled by one House. A House can only rule one Kingdom. Not
  every house rules an Kingdom, (you can call the Houses which do, Ruling Houses).
- Nobles are members of a House, and they have a first name and gender.
- However, a Noble’s first name isn’t unique (i.e. there are multiple Jon’s), but a
  first name and their House is unique.
- Each Noble can hate other Nobles, though this may not be reciprocated.

Draw an E/R diagram illustrating the structure of a database capturing the above information.

![E/R Diagram](image)

The "hater" link can be many or one.

Points earned: ___________ out of a possible 4 points
Question 6: Legal Optimistic Schedules................................. 4 points

Below is a time line of when three transactions \((T_1, T_2 \text{ and } T_3)\) performed actions on the database.

1. \(T_1\) begins transaction
2. \(T_2\) begins transaction
3. \(r_2(A)\)
4. \(w_1(B)\)
5. \(T_2\) commits transaction
6. \(T_3\) begins transaction
7. \(r_1(B)\)
8. \(w_3(A)\)
9. \(T_1\) commits transaction
10. \(T_3\) commits transaction

For proposed action, indicate if that action were added (in isolation from the other proposed actions) would the resulting schedule result in physically unrealizable behavior.

(a) \(r_2(B)\) between steps 2 and 3  ○ Legal  √ Physically Unrealizable
(b) \(r_1(A)\) between steps 2 and 3  √ Legal  ○ Physically Unrealizable
(c) \(r_2(B)\) between steps 4 and 5  √ Legal  ○ Physically Unrealizable
(d) \(w_1(A)\) between steps 4 and 5  ○ Legal  √ Physically Unrealizable
(e) \(w_1(A)\) between steps 7 and 8  √ Legal  ○ Physically Unrealizable
(f) \(r_1(B)\) between steps 8 and 9  √ Legal  ○ Physically Unrealizable
(g) \(w_3(B)\) between steps 8 and 9  √ Legal  ○ Physically Unrealizable
(h) \(r_1(A)\) between steps 8 and 9  ○ Legal  √ Physically Unrealizable

Points earned: __________ out of a possible 4 points
If you have finished early, feel free to bring your exam to an instructor.  
Or you can draw a picture of your favorite Pokémon.
Or you can write a haiku about your love of Boyce-Codd Normal Form.

<table>
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<th>Points</th>
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<td>Closures</td>
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<tr>
<td>Precedence</td>
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<td></td>
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<td>Transaction Modes</td>
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