Advice

- Please check the completeness of your exam (14 numbered pages).
- Put your name and student id on the top of each page you hand in.
- Do not use pencil.
- Do not use a red pen.
- Stick to the notations and solutions used in the lecture.
- If you make any assumption for a solution, declare it clearly.
- Exercises with more than one solution will not be considered.
- Make sure to hand in all sheets at the end of your exam.
- You are allowed to use one A4 sheet with your personal notes and a pocket calculator.
- Time for the exam: 90 minutes.

Signature:

Correction slot

Please do not fill out the part below

<table>
<thead>
<tr>
<th>Exercise</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Points</td>
<td>16</td>
<td>24</td>
<td>20</td>
<td>15</td>
<td>75</td>
</tr>
<tr>
<td>Points Achieved</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exercise 1

1.1 Map the following ER diagram, including keys, to a corresponding relational database schema. Avoid NULL values and redundancy as much as possible (7 points).
1.2 Use SQL to create the relation schemas that map entity and relationship types $B$ and $X$. The definitions shall include primary and foreign keys. Assume that all attributes are Integer and all referenced relations have been defined accordingly. (2 points)
1.3 Assume the following ER diagram:

Tasks:
Modify the above ER diagram to satisfy the following new or changed requirements (7 points):

- A movie may have many genres.
- A spouse must be an artist.
- A movie may be shot in many countries.
- An artist must be an actor or a director or both of them in a movie.
- For each actor the character name (Character) that he/she plays in a movie (for example: the character Tony Stark by actor Robert Downey Jr. in the movie Iron Man) should be modeled.
- For each actor the set of awards (Awards) shall be stored.
- A director may direct movies.
A database stores the nutritive content of food. Here follows an extract.

**Nutrient**

<table>
<thead>
<tr>
<th>ID</th>
<th>NAME</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vit. C</td>
<td>Vitamine</td>
</tr>
<tr>
<td>2</td>
<td>Omega 3</td>
<td>Fat</td>
</tr>
</tbody>
</table>

**Food**

<table>
<thead>
<tr>
<th>ID</th>
<th>NAME</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tofu</td>
<td>Vegi-Cheese</td>
</tr>
<tr>
<td>2</td>
<td>Strawberry</td>
<td>Fruit</td>
</tr>
<tr>
<td>3</td>
<td>Focaccia</td>
<td>Bread</td>
</tr>
</tbody>
</table>

**Content**

<table>
<thead>
<tr>
<th>NID</th>
<th>FID</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>58.8</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Tasks:**

2.1 Write a **relational algebra expression** that returns, for each food type, the average content of the nutrient “Vit. A”. (8 points)
2.2 Write an **SQL query** that returns the name of the foods having no value of "Vit. A" or a value of "Vit. A" smaller than 0.01 (8 points).

2.3 Give a **domain relational calculus expression** that, for each food type, returns the name of the food with the highest "Vit. A" value (8 points).
Exercise 3  

Use the following notation for the following exercises:

<table>
<thead>
<tr>
<th>Operation example</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r_1(A) )</td>
<td>transaction ( T_1 ) reads data item ( A )</td>
</tr>
<tr>
<td>( w_2(B) )</td>
<td>transaction ( T_2 ) writes data item ( B )</td>
</tr>
<tr>
<td>( sl_1(A) )</td>
<td>transaction ( T_1 ) shared locks data item ( A )</td>
</tr>
<tr>
<td>( xl_2(B) )</td>
<td>transaction ( T_2 ) exclusive locks data item ( B )</td>
</tr>
<tr>
<td>( u_1(C) )</td>
<td>transaction ( T_1 ) unlocks data item ( C )</td>
</tr>
<tr>
<td>( c_1 )</td>
<td>transaction ( T_1 ) commits</td>
</tr>
<tr>
<td>( a_2 )</td>
<td>transaction ( T_2 ) aborts</td>
</tr>
</tbody>
</table>

3.1 Construct schedules for the following tasks:

a) A schedule for two transactions \( T_1 \) and \( T_2 \) that leads to a deadlock. Make sure to add the necessary lock operations. (3 points)

b) A schedule for two transactions \( T_1 \) and \( T_2 \) that is not recoverable. Make sure to add the necessary commit and abort operations. (3 points)
3.2 Consider the following schedule $S_1$:

$$S_1 = \langle r_4(A), r_1(A), r_2(A), r_3(A), w_1(A), w_2(B),$$
$$r_3(B), w_3(B), r_2(C), w_2(C), r_4(C), w_4(C) \rangle$$

**Tasks:**

a) Show the precedence graph (conflict graph) of schedule $S_1$. (2 points)

b) State if $S_1$ is conflict serializable. If yes give all serializability orders; If not give the first conflict. (2 points)
3.3 Consider the following schedule $S_2$:

$$S_2 = \langle r_1(A), r_1(B), r_2(A), r_3(A), w_3(A), r_1(C), w_1(C), c_1, w_2(B), c_2, r_3(E), c_3 \rangle$$

Tasks:

a) State if $S_2$ is a valid strict two-phase locking (S2PL) schedule. If yes add all required lock and unlock instruction ($sl$, $xl$ and $u$). If no explain why. (6 points)
b) Assume $r_2(A)$ is moved immediately after $w_3(A)$ in $S_2$. Is it a valid S2PL schedule? If yes add all required lock and unlock instruction ($sl$, $xl$ and $u$). If no explain why. (4 points)
4.1 Consider a relation R (A, B, C, D, E, F) for which the functional dependencies
\[ ACD \rightarrow A, \ C \rightarrow A, \ C \rightarrow E, \ CD \rightarrow F, \ F \rightarrow B \] hold.

4.1.1 Prove that DC is a candidate key of R. Write the necessary conditions
and elaborate them. (5 points)

4.1.2 Assume R is in 1NF. For each normal form that R does not satisfy, iden-
tify all functional dependencies that violate it. (3 points)
4.1.3 Compute the Boyce-Codd Normal Form (BCNF) decomposition of $R$. Indicate each step of the algorithm, by showing the schema and the violation of BCNF on which you focus during that step. Also, indicate clearly your final result: the relations and their attributes. (3 points)

**Note:** While applying the algorithm, use the violating functional dependencies in the order listed above.
4.2 In the following figure, you see an instance of relation R (B,C,D,E).

\[
\begin{array}{|c|c|c|c|c|}
\hline
   & B & C & D & E \\
\hline
r_1 & 1 & 4 & 1 & 2 \\
r_2 & 5 & 4 & 2 & 4 \\
r_3 & 3 & 8 & 1 & 2 \\
r_4 & 3 & 1 & 2 & \\
r_5 & 1 & 8 & 1 & 2 \\
r_6 & 5 & 6 & 2 & \\
r_7 & 8 & 4 & 2 & 4 \\
\hline
\end{array}
\]

4.2.1 Fill in the missing values for attributes C and E in the above instance of relation R so that the multivalued dependency DE \rightarrow C holds. (4 points)