Hints: Reading chapters titled “Functional Dependencies and Normalization for Relational Databases”, “Relational Database Design and Further Dependencies”, “Introduction to Transaction Processing Concepts and Theory” and “Concurrency Control Techniques” should be sufficient to answer all questions in this homework.

1 Given a relation R = {P, R, S, T, U, V, W, X, Y, Z} with the following set of functional dependencies:

\[ \begin{align*}
  &XY \rightarrow Z \\
  &X \rightarrow UV \\
  &Y \rightarrow W \\
  &W \rightarrow ST \\
  &U \rightarrow PR
\end{align*} \]

For the following decomposition of R: State whether the relations in the decomposition are in 2NF, 3NF, BCNF (state explicitly for each of these normal forms whether each relation in the decomposition is in that normal form, given they are all in 1NF); Show your work and state reasons for all items.

Decomposition = \{R1, R2, R3\};
Where R1 = \{X, Y, Z, U, V\}, R2 = \{Y, W, S, T\}, R3 = \{U, P, R\}

2 Given a relation R = \{X, Y, Z, U, V\} with the following functional dependencies:

\[ \begin{align*}
  &XY \rightarrow Z \\
  &ZU \rightarrow V \\
  &UV \rightarrow Y
\end{align*} \]

Decompose R into 3NF relations. Show your work.
3 Consider the three transactions $T_1$, $T_2$ and $T_3$, and the schedules $S_1$ and $S_2$ below. Draw the serializability (precedence) graphs for $S_1$ and $S_2$ and state whether each schedule is serializable or not. If a schedule is serializable, write down the equivalent serial schedule(s). (Note: $r_x$ specifies a read in transaction $x$, and $w_x$ specifies a write in transaction $x$).

$T_1$: $r_1(A)$; $r_1(C)$; $w_1(A)$;
$T_2$: $r_2(C)$; $r_2(B)$; $w_2(C)$; $w_2(B)$;
$T_3$: $r_3(A)$; $r_3(B)$; $w_3(B)$;

$S_1$: $r_1(A)$; $r_2(C)$; $r_1(C)$; $r_3(A)$; $r_3(B)$; $w_1(A)$; $w_3(B)$; $r_2(B)$; $w_2(C)$; $w_2(B)$;
$S_2$: $r_1(A)$; $r_2(C)$; $r_3(A)$; $r_1(C)$; $r_2(B)$; $r_3(B)$; $w_1(A)$; $w_2(C)$; $w_3(B)$; $w_2(B)$;

4 What is two-phase locking? What are the performance measures for concurrency control? Explain them.

5 What is a serial, serializable and non-serializable history of concurrent transactions? Give an example for each history.

6 What are different approaches to recovery of a database system from a crash?