1. Consider the following sequence of log records representing the actions of one transaction T:

\[ \langle \text{START } T \rangle; \langle T, A, 10 \rangle; \langle T, B, 20 \rangle; \langle T, C, 30 \rangle; \langle \text{COMMIT } T \rangle; \]

tell all the sequences of events that are legal according to the rules of UNDO logging, where the events of interest are the writing to disk of the blocks containing database elements, and the blocks of the log containing the update and commit records. You may assume that log records are written to disk in the order shown, i.e., it is not possible to write one log record to disk while a previous record is not written to disk.

2. Repeat Question 1 for REDO logging.

3. The following is a sequence of undo-log records written by two transactions T and U:

\[ \langle \text{START } T \rangle; \langle T, A, 10 \rangle; \langle \text{START } U \rangle; \langle U, B, 20 \rangle; \langle T, C, 30 \rangle; \langle U, D, 40 \rangle; \langle \text{COMMIT } U \rangle; \langle T, E, 50 \rangle; \langle \text{COMMIT } T \rangle. \]

Describe the action of the recovery manager, including changes to both disk and the log, if there is a crash and the last log record on disk is:

- \langle \text{START } U \rangle
- \langle \text{COMMIT } U \rangle
- \langle T, E, 50 \rangle
- \langle \text{COMMIT } T \rangle

For each of the above situations, what values written by T and U must appear on disk (you need only to specify the variable)? Which values might appear on disk?

4. Repeat Question 3 for REDO logging.

5. Consider the following transaction log from the start of the run of a database system that is capable of running undo/redo logging with checkpointing:

\[ \langle \text{START T1} \rangle; \langle T1, A, 49, 20 \rangle; \langle \text{START T2} \rangle; \langle T1, B, 250, 20 \rangle; \langle T1, A, 75, 49 \rangle; \langle T2, C, 35, 20 \rangle; \langle T2, D, 45, 20 \rangle; \langle \text{COMMIT T1} \rangle; \langle \text{START T3} \rangle; \langle T3, E, 55, 20 \rangle; \langle T2, D, 46, 45 \rangle; \langle \text{START CKPT(T2, T3)} \rangle; \langle T2, C, 65, 35 \rangle; \langle \text{COMMIT T2} \rangle; \langle \text{START T4} \rangle; \langle T4, F, 100, 20 \rangle; \langle T4, G, 111, 20 \rangle; \langle \text{COMMIT T3} \rangle; \langle \text{END CKPT} \rangle; \langle T4, F, 150, 100 \rangle; \langle \text{COMMIT T4} \rangle. \]

Assume the log entries are in the format \langle Tid, Variable, Newvalue, Oldvalue \rangle. What is the value of the data items A, B, C, D, E, F, and G on disk after recovery:

- if the system crashes just before \langle T2, D, 46, 45 \rangle is written to disk?
- if the system crashes just before \langle \text{COMMIT T2} \rangle is written to disk?
- if the system crashes just before \langle \text{START T4} \rangle is written to disk?
- if the system crashes just before \langle \text{COMMIT T4} \rangle is written to disk?
- if the system crashes just after \langle \text{COMMIT T4} \rangle is written to disk?

6. (2009 Exam Question) When the recovery manager runs after a crash, it can execute the following types of actions:

a) write(Z, v): This action stores the value v into database object Z.

b) abort(Tj): This action writes an abort Tj record into the log. (The record is not written to the log until all Tj writes generated during recovery have been flushed to disk.)
A tanklDB1 system uses UNDO logging only. Given the contents of the log below, list the actions performed by the recovery manager (using the two action types given above). In the log shown here, the format of each record is <Tid, ObjectID, OldValue>. The oldest record is shown in the left most position. The second log record written is the second one. The last record written before the crash is the last one.

<T1, start>; <T1, X, 10>; <2, start>; <T2, Z, 12>; <T2, Y, 20>; <T2, commit>

The tanklDB2 system uses REDO logging only. The contents of the log at recovery time are given below. List the actions performed by the recovery manager. The format of each log record is <Tid, ObjectID, NewValue>.

<T1, start>; <T1, X, 10>; <T1, commit>; <T2, start>; <T2, Z, 12>; <T2, Y, 20>; <T2, commit>

The tanklDB3 system uses UNDO/REDO logging with non-quiesce checkpointing. Given the contents of the log below, list the actions performed by the recovery manager. The format of each log record is <Tid, ObjectID, OldValue, NewValue>.

<T1, start>; <T1, X, 10, 11>; <T1, commit>; <Start Checkpoint>; <T2, start>; <T2, Y, 20, 21>; <T3, start>; <T3, Z, 30, 31>; <End Checkpoint>; <T4, start>; <T3, commit>; <T4, W, 40, 41>, <T2, Z, 80, 30>