The assignment is to be turned in before Midnight (by 11:59pm) on February 5th, 2016. You should turn in the solutions to this assignment as a pdf file through the TEACH website. The solutions should be produced using editing software programs, such as LaTeX or Word, otherwise they will not be graded.

1: Concurrency control (2 points)

Consider the schedule shown at Table 1.

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>start</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>read X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>read Y</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>write X</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>start</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>read X</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>write X</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>Commit</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>read X</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>write Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>write X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Commit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>read Y</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>write Y</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Commit</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Transaction schedule

(a) What is the equivalent serialization order for this schedule? If no order is possible, you may state so and justify your claim.

(b) Let us remove transaction T1, i.e., all operations of T1, from the schedule in Table 1. Is the resulting schedule in 2PL? Assume that in a 2PL schedule, each transaction requests proper locking mode for each read or write operation, i.e., S lock for read and X lock for write, immediately before executing the operation.

(c) Let us remove transaction T2, i.e., all operations of T2, from the schedule in Table 1. Is the resulting schedule in 2PL? Assume that in a 2PL schedule, each transaction requests proper locking mode for each read or write operation, i.e., S lock for read and X lock for write, immediately before executing the operation.

(d) Let us remove transaction T1, i.e., all operations of T1, from the schedule in Table 1. What are the maximum degrees of consistency for T2 and T3 in the resulting schedule?

2: Concurrency control (1 point)

Consider a database DB. DB has two relations R1 and R2. The relation R1 contains tuples t1 and
t2 and R2 contains tuples t3, t4, and t5. Assume that the database DB, relations, and tuples form a hierarchy of lockable database elements. Tell the sequence of lock requests and the response of the locking scheduler to the following sequence of request. You may assume all requests occur just before they are needed, and all unlocks occur at the end of the transaction, i.e., EOT.

r1(t1); w2(t2); r2(t3); w1(t4)
[w2(t2) represents the update on t2 by transaction T2.]

### 3: Recovery (2 points)

In this problem, you need to simulate the actions taken by ARIES. Consider the following log records and buffer actions:

<table>
<thead>
<tr>
<th>time</th>
<th>LSN</th>
<th>Log</th>
<th>Buffer actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>00</td>
<td>update: T1 updates P7</td>
<td>P7 brought in to the buffer</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>update: T0 updates P9</td>
<td>P9 brought into the buffer; P9 flushed to disk</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>update: T1 updates P8</td>
<td>P8 brought into the buffer; P8 flushed to disk</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>begin_checkpoint</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>end_checkpoint</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>update: T1 updates P9</td>
<td>P9 brought into the buffer</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>update: T2 updates P6</td>
<td>P6 brought into the buffer</td>
</tr>
<tr>
<td>7</td>
<td>70</td>
<td>update: T1 updates P5</td>
<td>P5 brought into the buffer</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
<td>update: T1 updates P7</td>
<td>P6 flushed to disk</td>
</tr>
<tr>
<td>9</td>
<td>CRASH - RESTART</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) For the actions listed above, show Transaction Table (XT) and Dirty Page Table (DPT) after each action. Assume that DPT holds pageID and recLSN, and XT contains transID and lastLSN.

(b) Simulate Analysis phase to reconstruct XT and DPT after crash. Identify the point where the Analysis phase starts scanning log records and show XT and DPT after each action.

(c) Simulate Redo phase: first identify where the Redo phase starts scanning the log records. Then, for each action identify whether it needs to be redone or not.

(d) Simulate Undo phase: identify all actions that need to be undone. In what order will they be undone?