SWE3003 Introduction to Database Systems - Final Spring 2024

Student ID	Name

For Instructor/TA only,

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total

Academic Honor Pledge

I affirm that I will not at any time be involved with cheating or plagiarism while enrolled as a student at Sungkyunkwan University.
I understand that violation of this code will result in penalties as severe as indefinite suspension from the university.

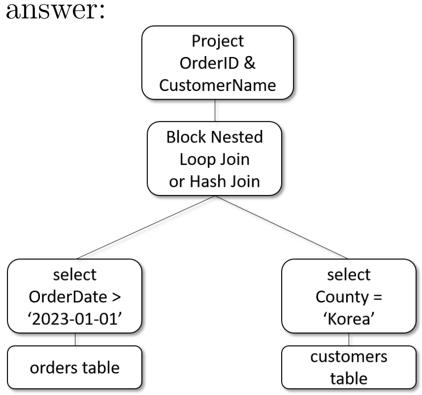
Your signature: ____________________

1. [Query Optimization (15 pts)] Suppose you are have `orders` (with 1,000,000 rows) and `customers` tables (with 100,000 rows). Each disk page holds maximum 1,000 orders records or 1,000 customers records. Consider the following query.

```
SELECT orders.OrderID, customers.CustomerName
FROM orders JOIN customers ON orders.CustomerID = customers.CustomerID
WHERE orders.OrderDate > '2023-01-01' AND customers.Country = 'Korea';
```

Suppose the orders are sorted by date in the table and 10% of the orders were made since 2023-01-01. Additionally, 20% of the customers live in Korea.

(a) Draw an expression tree for a query execution plan that you think the most efficient. Describe how a cost-based optimizer would evaluate and choose between different query execution plans: If necessary, you may make specific assumptions on the database.
answer:



(b) What is the expected number of block transfers if we employ Block Nested-Loop Join?
answer:

(c) What is the expected number of block transfers if we employ Hash Join? Recursive partitioning is not required, but the build input does not fit in memory.
answer:

2. [Serializability (10pts)] Consider the following schedules where time increases from top to bottom.

time	T1	T2	T3	T4
1	R(A)			
2		R(A)		
3				R(C)
4			R(C)	
5			R(B)	
6				W(C)
7	W(A)			
8	R(C)			
9		R(C)		
10			W(B)	

Table 1: Schedule 1

(a) Draw a precedence graph:

(b) Which of the following serial schedules are conflict equivalent to the schedule above?

[1] T4, T2, T1, T3

[2] T3, T2, T4, T1

[3] T3, T4, T2, T1

[4] T1, T2, T4, T3

[5] T1, T4, T2, T3

[6] None of the above

answer:

3. [2PL (10 pts)] Suppose T1 is older than T2, and T2 is older than T3. The oldest transaction has the highest priority. No locks are released in the time frame shown. Note that not all requests may be granted immediately; in some cases, the transaction remains blocked, waiting for a preceding request to be completed.

time	T1	T2	T3
1	X(D)		
2		X(A)	
3	S(A)		
4		S(B)	
5			S(B)
6	S(C)		
7			X(B)
8		S(D)	
9			S(C)

The above schedule could not successfully occur whether one uses deadlock avoidance or not. Suppose we are not using any deadlock avoidance algorithms by default.

(a) Which lock requests are denied and blocked?

answer:

(b) In which time step, deadlock will occur?

answer:

(c) Which transactions will deadlock?

answer:

(d) If we were using the wound-wait deadlock avoidance algorithm, what would happen at time step 3?

[1] The transaction requesting the lock would wait
[2] The transaction requesting the lock would abort
[3] The transaction that holds the lock would abort

answer:

4. [Timestamp-ordering (10pts)] Consider the following schedule under timestamp-ordering protocol. Initially, the write and read timestamps of data `A`, `B`, and `C` are all 0, and the timestamps of `T1`, `T2`, and `T3` are 1, 2, and 3, respectively.

time	T1	T2
1	R(A)	
2		R(A)
3	W(B)	
4		W(B)
5	R(B)	
6		W(A)

Table 2: Schedule 3

time	T1	T2	T3
1	R(A)		
2		R(A)	
3			R(A)
4		R(B)	
5	R(C)		
6	W(A)		
7		R(A)	

Table 3: Schedule 4

(a) Does Schedule 3 abort any transaction under timestamp-ordering protocol? Justify your answer.

answer:

time	T1	T2	R-ts(A)	W-ts(A)	R-ts(B)	W-ts(B)
1						
2						
3						
4						
5						

(b) Does Schedule 4 abort any transaction under timestamp-ordering protocol? Justify your answer.

answer:

	T1	T2	T3	R-ts(A)	W-ts(A)	R-ts(B)	W-ts(B)	R-ts(C)	W-ts(C)
1									
2									
3									
4									
5									
6									

5. [Multi-version Timestamp Ordering (10 pts)] Consider the following schedule under multi-version timestamp-ordering (MVTSO) protocol. Initially, the write and read timestamps of data `A`, `B`, and `C` are all 0, and the timestamps of `T1`, `T2`, and `T3` are 1, 2, and 3, respectively.

time	T1	T2
1	R(A)	
2		R(A)
3	W(B)	
4		W(B)
5	R(B)	
6		W(A)

Table 4: Schedule 5

time	T1	T2	T3
1	R(A)		
2		R(A)	
3			R(A)
4		R(B)	
5	R(C)		
6	W(A)		
7		R(A)	

Table 5: Schedule 6

(a) Does Schedule 5 abort any transaction under MVTSO protocol? Justify your answer.

answer:

time	T1	T2	R-ts(A)	W-ts(A)	R-ts(B)	W-ts(B)
1						
2						
3						
4						
5						

(b) Does Schedule 6 abort any transaction under MVTSO protocol? Justify your answer.

answer:

	T1	T2	T3	R-ts(A)	W-ts(A)	R-ts(B)	W-ts(B)	R-ts(C)	W-ts(C)
1									
2									
3									
4									
5									
6									

6. [Recovery (10pts)] The following table shows a log file after a crash occurred. The DBMS employs the *immediate database modification*, which allows updates of an uncommitted transaction to be made to the buffer, or the disk itself, before the transaction commits

LSN	LOGS
1	<START T1>
2	<T1, X, 0, 5>
3	<START T2>
4	<T1, Y, 0, 7>
5	<T2, X, 5, 9>
6	<START T3>
7	<T3, Z, 0, 11>
8	<COMMIT T1>
9	<CHECKPOINT (T2,T3)>
10	<T2, X, 9, 13>
11	<T3, Y, 7, 15>
*C*R*A*S*H*	

Figure 1: Schedule 3

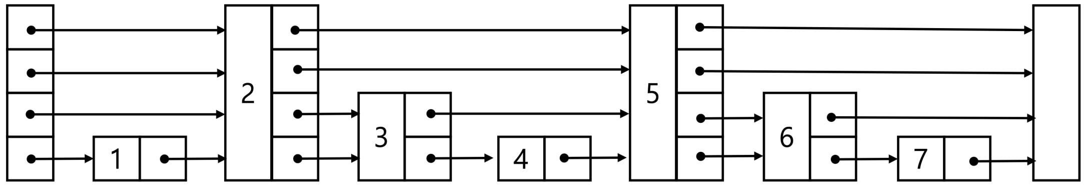
(a) Show below the log records appended by the recovery manager during recovery.

answer:

(b) What is the value of X at the end of the recovery?

answer:

7. [Skip Lists (10 pts)] Consider the following Skip Lists.



(a) How many key comparisons are required to search 4?

answer:

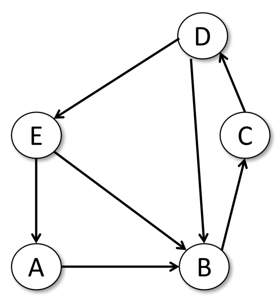
(b) How many pointers need to be updated to delete 2?

answer:

8. [NoSQL (10 pts)] For each of the following statements, indicate whether it is TRUE or FALSE. You will get 2 points for each correct answer, -2 points for each incorrect answer, and 0 point for each answer left blank or both answers marked.

	T	F
(a) One of the goals of the MapReduce framework is to avoid using low-level programming techniques in developing large-scale distributed and parallel applications.	☐	☐
(b) In SkipLists, write operations are generally faster than read operations.	☐	☐
(c) The primary goal of compaction in LSM-trees is to improve search performance.	☐	☐
(d) The stall issue in an LSM tree arises from the accumulation of read queries. F	☐	☐
(e) MongoDB supports all the functionalities of a relational DBMS except for DDL (Data Definition Language).	☐	☐

9. [Graph Processing (10 pts)] Consider the following graph. Determine the nodes with the highest and lowest rank after running the PageRank algorithm on the network. Using the chromatic engine, how many steps are needed per iteration to maximize parallelism in this graph? Briefly justify your answer for each question.

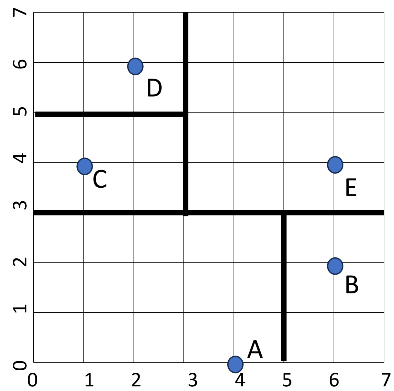


highest rank:

lowest rank:

The number of steps required per iteration:

10. [Spatial Indexing (10 pts)] Consider the following spatial data and K-d-tree.



(a) Fill in the labels (i.e., A, B, C, D, E) for the leaf nodes within the circles in the following tree structure.

(b) How many nodes need to be visited to process the range query $1 < X < 4$ and $2 < Y < 6$? If the same node is visited multiple times, count it only once.

answer: