

# ACS Theory Assignment 2

This assignment is due via Absalon on December 21, 23:59. While individual hand-ins will be accepted in exceptional cases, we strongly recommend that this assignment be solved in groups of maximum three students. A well-formed solution to this assignment should include a PDF file with answers to all theory questions.

All homework assignments have to be submitted via Absalon in electronic format. It is your responsibility to make sure in time that the upload of your files succeeds. While it is allowed to submit scanned PDF files of your homework assignments, we strongly suggest composing the assignment using a text editor or LaTeX and creating a PDF file for submission. Email or paper submissions will not be accepted.

## Learning Goals

This assignment targets the following learning goals:

- Analyze the relationship of serializability definitions and concurrency control protocols to the schedules they possibly generate.
- Discuss basic concepts in recovery for durability of a two-level memory under a restricted set of fail-stop failures.
- Explain in detail the functioning of the ARIES algorithm in recovery scenarios.

## Question 1: Concurrency Control Concepts

For each of the following items, you are asked to exhibit a schedule fulfilling the requirements stated, as well as to justify why the schedule fulfills the requirements:

1. Show a schedule that is conflict-serializable, but could not have been generated by a strict two-phase locking (S2PL) scheduler. Explain. (1-2 sentences)
2. Show a schedule that could be generated by a S2PL scheduler, but not by a conservative two-phase locking (C2PL) scheduler. Explain. (1-2 sentences)
3. Show a schedule that is serializable, but not conflict-serializable. Is your schedule view-serializable? Explain. (1-2 sentences)
4. Show a schedule of two transactions that is **not** view-serializable and consists of the minimal possible number of read/write actions to have this property. Explain, in particular also why any schedule with fewer actions is view-serializable. (1-2 sentences)

## Question 2: More Concurrency Control

Consider the following two transaction schedules with time increasing from left to right. C indicates commit. Transactions are denoted Ta, Tb, and Tc so as to avoid implying any pre-determined relative order.

### Schedule 1

Ta:	R(Y)	W(Y)	C							
Tb:	R(X)				W(X)		R(Y)	W(Y)	C	
Tc:			R(X)	W(Y)		W(X)	C			

### Schedule 2

Ta:			R(X)		W(X)	C				
Tb:	R(Y)	W(Y)	C							
Tc:	R(X)			R(Y)	W(X)		W(Y)	C		

Now answer the following questions:

1. Could Schedule 1 have been generated by a strict two-phase locking (S2PL) scheduler? Explain why or why not. (yes/no + 2 sentences)
2. Could Schedule 1 have been generated by a two-phase locking (2PL) scheduler? Explain why or why not. (yes/no + 2 sentences)
3. Could Schedule 2 have been generated by a conservative two-phase locking (C2PL) scheduler? Explain why or why not. (yes/no + 2 sentences)
4. Could Schedule 2 have been generated by a two-phase locking (2PL) scheduler? Explain why or why not. (yes/no + 2 sentences)

## Question 3: Recovery Concepts

Regarding recovery techniques, answer the following questions:

1. In a system implementing force and steal, is it necessary to implement a scheme for undo? What about a scheme for redo? Explain why. (2-3 sentences)
2. What is the difference between volatile and stable storage? What types of failures are survived by each type of storage? (2 sentences)
3. In a system that implements Write-Ahead Logging, which are the two situations in which the log tail must be forced to stable storage? Explain why log forces are necessary in these situations and argue why they are sufficient for durability. (3-4 sentences)

## Question 4: ARIES

Consider the recovery scenario described in the following, in which we use the ARIES recovery algorithm. At the beginning of time, there are no transactions active in the system and no dirty pages. A checkpoint is taken. After that, three transactions, T1, T2, and T3, enter the system and perform various operations. The detailed log follows:

LOG

LSN	PREV_LSN	XACT_ID	TYPE	PAGE_ID
---	-----	-----	-----	-----
1	-	-	begin CKPT	-
2	-	-	end CKPT	-
3	NULL	T1	update	P2
4	3	T1	update	P1
5	NULL	T2	update	P1
6	NULL	T3	update	P2
7	6	T3	commit	-
8	5	T2	commit	-
9	4	T1	update	P2
10	8	T2	end	-
-----	XXXXXXX	-----	CRASH!	-----

After LSN 10, the system crashes. Apply the ARIES recovery algorithm to the scenario above. Show:

1. the state of the transaction and dirty page tables after the analysis phase of recovery;
2. the sets of winner and loser transactions;
3. the values for the LSNs where the redo phase starts and where the undo phase ends;
4. the set of log records that may cause pages to be rewritten during the redo phase;
5. the set of log records undone during the undo phase;
6. the contents of the log after the recovery procedure completes.

For each of the items above, justify your answer. (2-3 sentences for each item)

## Question 5: More ARIES

In the recovery scenario described in the following, we ask you to explain the functioning and justification behind the ARIES recovery algorithm. At the beginning of time, there are no transactions active in the system and no dirty pages. A checkpoint is taken. After that, three transactions, T1, T2, T3, enter the system and perform various operations. The detailed log follows:

# LOG

LSN	PREV_LSN	XACT_ID	TYPE	PAGE_ID	UNDONEXTLSN
---	-----	-----	----	-----	-----
1	-	-	begin CKPT	-	-
2	-	-	end CKPT	-	-
3	NULL	T1	update	P3	-
4	3	T1	update	P1	-
5	NULL	T2	update	P3	-
6	NULL	T3	update	P2	-
7	5	T2	update	P2	-
8	4	T1	update	P4	-
9	6	T3	commit	-	-
10	8	T1	abort	-	-
11	7	T2	abort	-	-
12	11	T2	CLR	P2	A
13	9	T3	end	-	-
14	10	T1	CLR	P4	B
15	12	T2	CLR	P3	C
16	14	T1	CLR	P1	D
-----	XXXXXXX	-----	CRASH!	-----	XXXXXXX

A crash occurs at the end of the log as shown. Considering again that the system employs the ARIES recovery algorithm, answer the following questions, and justify your answers.

1. In the log, A-D are placeholders for the undonextLSN values of the CLRs. For each letter, state the specific value and explain why it has the given value. (1 paragraph)
2. What are the states of the transaction table and of the dirty page table after the analysis phase of recovery? Explain why. (1 paragraph)
3. Show the additional log contents after the recovery procedure completes. Provide a brief explanation for why any new log records shown need to be added. (1 paragraph)
4. Let us assume that the database is memory-resident, i.e., upon start-up all contents of non-volatile storage are loaded into volatile storage (which is large enough). Thus, no page replacements are ever necessary during normal operation. Furthermore, assume plenty of log buffer space is available and no background page writes are performed. Under these conditions, answer the following (1 paragraph each):
  - (a) Which log records could trigger writes to stable storage during normal operation in the scenario above? Why?
  - (b) Following the ARIES log record structure introduced in the course for update records, is there any information that would not need to be written to stable storage in such a scenario? If so, explain which information and why. Otherwise, justify why all information in these records needs to reach stable storage.