**Problem 1: Concurrency Control**

Consider following schedule S with five transactions T1,T2,T3,T4 and T5:

***S: r1(A ) w2(A) r2 (B) w3(A) w3(B) w4(C) w4(B) w5(C) w3(C)***

where: ***ri(X)*** means transaction ***Ti*** read data ***X***.

***wi(X)*** means transaction ***Ti*** write data ***X***.

1. Draw the precedence graph of S.
2. Explain whether S is serializable.
3. Explain whether S be generated by the two–phase locking protocol.
4. If S is serializable, give out all serial schedules to which S is equivalent. If S is not serializable, figure out an operation in S such that if this operation was removed from S，S would become serializable.

**Problem 2: Aries Recovery Method**

A DBMS uses **Aries** algorithm for system recovery. Following figure(next page) is a log file just after system crashes. The log file consists of 16 log records with LSN from 1001 to 1016. The figure does not show PrevLSN and UndoNextLSN in log records. Assuming that last completed checkpoint is the log record with LSN 1012.

Please answer following questions：

1. Which log record is the start point of Redo Pass?
2. Which log record is the end point of Undo Pass?
3. After Analysis Pass，what content is the dirty page table?
4. After recovery, what is the value of data items identified by “8002.1” and “8002.2” respectively?
5. After recovery, what additional log records appended to log fie?

1010

1006

T3

1011： <T2, 8002.2, 88, 99>

PageLSN

PageID

1006

1011

8002

1010

1010

8001

T4

1011

T2

LastLSN

Txn

RecLSN

1012： checkpoint

1010： <T4, 8001.1, 22, 77 >

1009： <T4 begin>

1008： <T1 commit>

1004： <T2 , 8001.2, 33, 44>

1006： <T3, 8002.1, 55, 66 >

1001： <T1 begin>

1005： <T3 begin>

1003： <T2 begin>

1002： <T1 , 8001.1, 11, 22>

1013： <T2 commit>

1014： <T3, 8002.1, 66, 77>

1015： <T4, 8003.1, 11, 22>

1016： <T4 commit>