1. **Transaction Management** (10 points)  
   For each of the following schedules answer:  **(a)** what is the dependency graph for the schedule? , and   
   **(b)** is the schedule conflict-serializable? If so, what are ***all*** the conflict equivalent serial schedules?   
     
   (*R1(A)* indicates a read of object *A* by transaction *T1*.)

*1. R1(A); R2(A); R3(B); W1(A); R2(C); R2(B);W2(B);W1(C);  
2*. *R1(A); W1(B); R2(B); W2(C); R3(C); W3(A);   
3.W3(A); R1(A); W1(B); R2(B); W2(C); R3(C);  
4*. *R1(A); R2(A); R1(B); R2(B); R3(B); R4(B); W2(C); W1(D);  
5. R1(A); R2(A); R1(B); R2(B); R3(A); R4(B); W1(A); W2(B);*

1. **Transaction Management** *(12 points)*

Two transactions are *not interleaved* in a schedule if every operation of one transaction precedes every operation of the other. Give an example of a **conflict serializable** schedule *S* that has *all* of the following properties:

(a) transactions *T*1 and *T*2 are not interleaved in *S*,

(b) *T*1 precedes *T*2 in *S*, and

(c) in *every* serial schedule conflict equivalent to *S*, *T*2 precedes *T*1.

The schedule may include more than two transactions. Explain your answer.

1. **ARIES** (28 points)  
     
   Consider the following schedule log, where Update(Tx, Y, old\_value,new\_value) means that transaction Tx updates the value of object D from old\_val to new\_val.  
     
   100 Begin\_Checkpoint  
   110 Update(T2, A, 20,25)   
   120 Update(T1, D, 20,25)   
   125 T1 commits  
   130 End\_Checkpoint  
   135 T3 starts  
   140 Update(T3, C, 1,2)  
   145 T4 starts  
   150 T3 aborts  
   152 CLR: Undo T3 LSN 140  
   153 T3 ends  
   155 Update(T4, C, 2,3)  
   160 T5 starts  
   165 Update(T5, D, 25,30)  
   170 Update(T4,B,1,2)  
   175 T5 commits  
   SYSTEM CRASH  
   1. Augment the graph with the corresponding prevLSN and undonextLSN information (6 points)
   2. Which transactions are active at the time of system crash? (5 points)
   3. For each phase of the ARIES algorithm, what is the earliest possible log that it will consider? How does ARIES find this information (6 points)
   4. Show the actions taken to ensure recovery. What is the resulting log? (6 points)
   5. If the log operation with LSN 155 had happened at LSN 148, i.e., if the update of C by T4 had happened before T3 had aborted what would have been the consequences? (5 points)