1. **Query Processing (30 pts):** A file of 4096 blocks is to be sorted with an available buffer space of 5 blocks. Assume that reading a block has 1 unit cost and writing a block has 1 unit cost. What is the minimal cost of the sort-merge algorithm in units?

2. **Transaction Processing (40 pts):** Consider the three transactions $T_1$, $T_2$ and $T_3$ and the schedules $S_1$ and $S_2$ given below. Subscript denotes the transaction id performing the operation and $c_i$ means transaction $T_i$ commits. Draw the serializability (precedence) graph for $S_1$ and $S_2$ and state whether each schedule is serializable, strict, cascadeless and recoverable.

   - $T_1 : r_1(X); r_1(Z); w_1(X); c_1$
   - $T_2 : r_2(Z); r_2(Y); w_2(Z); w_2(Y); c_2$
   - $T_3 : r_3(X); r_3(Y); w_3(Y); c_3$
   - $S_1 : r_1(X); r_1(Z); r_3(X); r_3(Y); w_1(X); c_1; w_3(Y); c_3; r_2(Y); w_2(Z); w_2(Y); c_2$
   - $S_2 : r_1(X); r_2(Z); r_3(X); r_1(Z); r_2(Y); r_3(Y); w_1(X); c_1; w_2(Z); w_3(Y); c_3; w_2(Y); c_2$

3. **Concurrency Control (30 pts):** Consider the three transactions $T_1$, $T_2$ and $T_3$

   - $T_1 : r_1(X); r_1(Z); w_1(X)$
   - $T_2 : r_2(Z); r_2(Y); w_2(Z); w_2(Y)$
   - $T_3 : r_3(X); r_3(Y); w_3(Y)$

Answer the following questions

   (a) Give an execution of these transactions where two-phase locking is used for concurrency control.

   (b) Can deadlock happen when $T_1$, $T_2$ and $T_3$ are executed. If so, show how it can happen. If not, explain why it can not happen.