CS582 Distributed Systems
Quiz 2 A Key

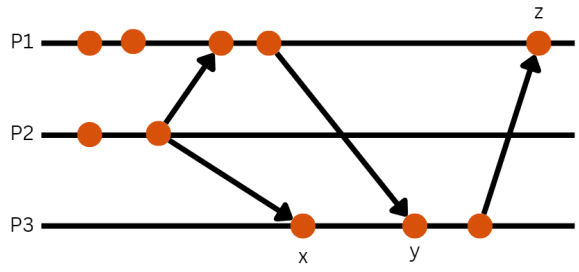
Student Name:		**Student ID:**
Time Allowed: 20 mins.	**Total Marks:** 13	**Marks Obtained:**

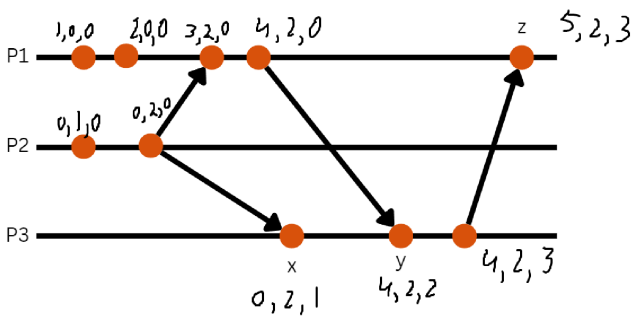
1. (3 marks) Your TAs Danish and Ayain are discussing the ordering of events in a distributed system. Danish makes the following claim: "For any pair of events x and y in the system, if according to an accurate physical clock x occurs before y, then we can always say that x 'happens-before' y in the system, regardless of whether x and y occur on the same node or different nodes." Do you agree or disagree? Justify your answer with a brief proof or an example.
Answer:
Disagree. Even with synchronized and accurate physical clocks, we cannot always conclude that if event x occurs before event y (in physical time), then $x \rightarrow y$ (happens-before). For the happens-before relationship to hold for events across different nodes, there must be a causal link, such as message passing between the events.

   Suppose event x occurs on node A at 11:57 AM, and event y occurs on node B at 11:59 AM. If there is no communication (message exchange) between nodes A and B, then x and y are concurrent, i.e., $x||y$. Therefore, even though x occurred before y in physical time, we cannot say that $x \rightarrow y$.

2. (2 marks) Select **all** the correct statements from the statements below. You will lose marks for selecting any wrong options, but your total score for this question cannot go below zero.
   A. If a and b are concurrent operations then $V(a) = V(b)$.
   B. Suppose we use Lamport clock timestamps and process ids to create a total ordering of events. In this case, if $C(a) < C(b)$, it implies that $a \rightarrow b$, where C(a) and C(b) are the Lamport timestamps of event a and b, respectively.
   C. In Lamport clocks, a process sets its counter to max(local_counter, received_counter) + 1 on every message it receives.
   D. If a majority of the elements in a vector timestamp $V(a)$ are greater than the corresponding $V(b)$, we can say that a happens before b.

3. (3 marks) Consider 3 processes P1, P2 and P3 below. The circles represent events.
   Write down the vector timestamps at x, y and z.





4. (3 marks) You are trying to figure out a way to have your latest distributed application having 10 replica nodes run smoothly. Initially, you set up your favourite replica as the leader/coordinator for all replicas. However, you quickly notice that your system struggles to continue operations whenever something happens to this replica.

   On a fine Monday afternoon, after attending a Distributed Systems lecture, you wonder if Raft's leader election algorithm is the solution to all your distributed problems. You implement it and simulate the splitting of your network into two partitions during term 1. Assume that nodes on one side of a partition can communicate with each other but not with nodes on the other side of the partition.

   Your favourite replica, which was serving as the leader previously, is in Partition 1, while the other 9 replicas are in Partition 2. After a very small time period, you see that there's now a new leader in Partition 2 and your distributed application is operational.

   Assume that timeouts are unique and set such that election timeout did not elapse i.e., elections were successful on the first replica's initiation. What are the terms for partition 1 and partition 2 at this stage? Explain briefly.

   Answer:

   - Partition 1: term 1 (the old leader is partitioned and keeps sending heartbeats in the same term)
   - Partition 2: term 2 (successful candidacy for elections in term 2, so a new leader starts serving in term 2)

   0.5 for correct term, 1 mark for correct reasoning/explanation for each

5. (2 marks)Your TA Hamna suggests that even with Raft's election algorithm, a single partition (network split into two parts) could lead you to a total network failure where you have no leader on either side of the partition. This would not be resolved until you repair communication for some nodes across the partition. Do you agree or disagree? Justify your answer.

   Answer:
   I disagree. Even if we have a 5-5 split where neither side has a majority, the leader will be in one of the two partitions and will continue to send heartbeats to the replicas within that partition. So even then, a leader will exist in one of the partitions.