**Question 1:**

Consider the quorum replication protocol shown in class.

a) Suppose in the write protocol, we eliminate lines 1 and 2 and instead use as timestamp the output of an atomic clock (plus process id to break symmetry). Would the protocol work correctly? If your answer is yes, explain why. Otherwise, give a scenario in which some properties are violated.

b) Repeat (a) when the timestamp is the output of the network time protocol (NTP).

c) What properties would be violated if we skip Lines 3&4 of the read protocol? Give an example.

**Question 2:**

Suppose we have access to a consensus service. What is the difference between its usage in implementing a replicated state machine vs. its usage in implementing a hot-standby solution.

**Question 3:**

a) Explain how the properties of $\Omega$ failure detectors help the Paxos protocol solve the consensus problem?

b) Why is the optimization in which each node sends its accepted message to all other nodes allowed?

**Question 4:**

Provide a pseudo-code for a simple ZooKeeper based decentralized compare&swap (CAS) register service. Describe what assumptions you make and what are the membership properties provided by your service.

Note: A $\text{CAS}(\text{obj, old, new})$ operation accepts an object obj, an expected value old and atomically stores the value new in obj if its value just prior to invoking the CAS was old.

**Submission instructions:**

You should solve this exercise alone – submissions are individual. Solutions must be submitted through the course web site – either printed or a high-resolution scan of handwriting. Solutions must be written in Hebrew unless you get an authorization from Prof. Friedman to submit in English.

Notice, each question can be answered by a very short paragraph. If your answer is lengthy, it could be a sign that it is wrong.

The submission date is Thursday 11/12/2014 before midnight.

**Good luck!**