Instructions: You have 1 hour, 20 minutes to complete this test. The test is closed book and closed notes. No calculators, phones, or other electronic devices are allowed. Make sure to show your work on all problems. No credit will be given for answers without sufficient work.
Multiple Choice: 10 points  (choose only one answer to each question)

1) Which of the following is not guaranteed by serial consistency?
   a) two reads that are concurrent with each other but are not concurrent with any write will return the same value
   b) if \( w_2 \) begins after \( w_1 \) ends, where \( w_1 \) and \( w_2 \) are write operations, any reads that come after \( w_2 \) ends and before any other writes begin will return the value written by \( w_2 \)
   c) two reads that begin after two writes that were concurrent with each other have ended will return the same value (assuming no other writes occur after the concurrent ones)
   d) two reads that are concurrent with the same write operation will return the same value
   e) all of the above are guaranteed by serial consistency

2) With high probability in a Chord system with \( n \) nodes, the size of the finger table used for routing and the number of routing hops necessary are:
   a) finger table: \( O(\log n) \), routing hops: \( O(\log n) \)
   b) finger table: \( O(\log n) \), routing hops: \( O(n) \)
   c) finger table: \( O(n) \), routing hops: \( O(\log n) \)
   d) finger table: \( O(n) \), routing hops: \( O(n) \)
   e) none of the above

3) Which of the following statements about Byzantine quorum systems is true? Note that \( f_{\text{max}} \) is the maximum number of servers that are Byzantine faulty at one time.
   a) for a given \( f_{\text{max}} \), dissemination quorum systems require fewer total servers than masking quorum systems
   b) for a constant \( f_{\text{max}} \), the load of a masking grid quorum system approaches 0 as \( n \to \infty \)
   c) for a masking quorum system, the size of the intersection between any read quorum and any write quorum must be at least \( 2f_{\text{max}} + 1 \)
   d) none of the above
   e) all of the above, except d)

4) Which of the following statements about MegaStore is true?
   a) it provides ACID properties across entity groups
   b) reads and writes are consistently ordered at all servers of an entity group using Paxos
   c) the version of Paxos used is optimized so that most writes experience a latency of about one round-trip time in a wide-area network
   d) it uses a master-slave approach to wide-area replication
   e) none of the above

5) Which of the following is not a feature employed in the BitTorrent protocol:
   a) rarest-first piece selection
   b) optimistic unchoking
   c) deterministic peer selection
   d) tit-for-tat: a peer uploads pieces to peers that it successfully downloads pieces from
   e) all of the above are features of BitTorrent
6) 30 points

Consider using the GridSharing approach with \( l = 2, b = 1, \) and \( c = 4 \). Show two different GridSharing designs that will maintain confidentiality and availability with these parameters. It is OK for one of the designs to be the “direct approach” discussed in the paper.
Consider a Pastry system with 12-bit node IDs represented in base-4 format ($b=2$). Assume the following nodes are present in the system at a given time:

<table>
<thead>
<tr>
<th>Node ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>001120</td>
</tr>
<tr>
<td>020001</td>
</tr>
<tr>
<td>100203</td>
</tr>
<tr>
<td>202020</td>
</tr>
<tr>
<td>301033</td>
</tr>
</tbody>
</table>

Also, assume that when multiple nodes are suitable for an entry in a node’s routing table that the entry will contain the node whose ID is closest numerically to the ID of the node whose routing table it is. For example, the first row in the routing table of node 123000 would be:

<table>
<thead>
<tr>
<th>Entry 1</th>
<th>Entry 2</th>
<th>Entry 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>032330</td>
<td>blank</td>
<td>202020</td>
</tr>
</tbody>
</table>

Finally, assume that the leaf set of each node is of size 2.

Suppose node 222131 issues a query for an object whose key hashes to 011013. List the nodes in the routing path for this query, in order from 222131 to the destination that stores the object with key 011013.
Assume that servers S1, S2, S3, S4, and S5 in a Dynamo system are the preference list for a specific data object, e.g. the shopping cart of a user. Show the sequence of vector clocks that are maintained at each of the servers resulting from the sequence of read and write operations given below. Assume N=5, R=5, and W=1. Assume that any conflicts are resolved by application logic whenever a read occurs and a single consistent version with updated vector clock is written to all 5 servers before the read completes. Assume that conflicts are neither detected nor resolved at any other point.

Write D1 to S3, Write D2 to S3, Write D3 to S3, Write D4 to S1, Write D5 to S4, Read from S2,
Write D6 to S5, Write D7 to S1, Write D8 to S5, Write D9 to S1, Read from S3