1. (2 marks) In the MapReduce model, during the shuffle operation, we want to route key-value pairs to four machines A, B, C, and D. The key-value pairs are \{(1, 4), (1, 5), (2, 4), (2, 5)\}. If we know that (1, 4) is routed to machine A, which of the following statements is guaranteed to be true?
   A. (1, 5) is routed to A.
   B. (2, 4) is routed to A.
   C. (2, 5) is not routed to A.
   D. We can’t say anything for sure.

2. (2 marks) In the MapReduce model, suppose we are given machines with memory size \(O(N \log N)\) and a problem to solve whose input size is \(N\). What is the smallest upper bound on rounds required to solve the problem we can guarantee given just this much information?
   A. \(O(1)\) rounds.
   B. \(O(\log N)\) rounds.
   C. \(O(N)\) rounds.
   D. \(O(N \log N)\) rounds.
   E. We cannot say.

3. (2 marks) Suppose in the MapReduce model, you are given an input of size \(N\) and access to \(O(\sqrt{N})\) machines, where each machine has \(O(\log N)\) size of memory. Is it guaranteed that you will be able to solve a given problem \(P\), assuming there exists an algorithm to solve \(P\) in the centralized setting (when one computer has access to the entire input)?
   A. Yes.
   B. No.

4. (2 marks) In the \(k\)-machine model, in what way are the \(k\) machines connected to each other?
   A. Ring.
   B. Path.
   C. \((k - 1)\) clique.
   D. Complete graph.

5. (2 marks) In the \(k\)-machine model, suppose we want to solve a problem \(P\), whose input is of size \(n^3\), using \(O(n)\) machines where each machine has \(O(n^2)\) size of memory. Assuming there exists an algorithm to solve \(P\) in the centralized setting (when one computer has access to the entire input) using \(O(n \log n)\) size of memory, is it guaranteed that we can solve \(P\) in this model?
   A. Yes.
   B. No.
6. (2 marks) Suppose we have an input graph with $m$ edges, $n$ vertices, and max. degree 5 on which we want to perform some computation. We want to perform the computation in the 7-machine model. What will be the maximum value of the communication degree of the graph?

A. 5  
B. 6  
C. 7  
D. $m/6$

7. (2 marks) In the $k$-machine model, suppose we want to solve a problem on a graph with input size $n$. We have access to 4 machines, each with $O(n \log n)$ size of memory and the bandwidth of each link between machines is $O(n \log n)$ bits. Assuming that there exists a solution to the problem in the centralized setting (when one computer has access to the entire input) that takes $n^3$ running time and uses $O(n)$ size of memory, what can we say about the running time taken to solve the problem in the given 4-machine model?

A. It will take $\Omega(n^3)$ rounds to solve the problem in the given model.  
B. It will take $\Theta(n^2/\log n)$ rounds to solve the problem in the given model.  
C. It will take $O(1)$ rounds to solve the problem in the given model.  
D. There’s not enough information to talk about the running time.

8. (2 marks) Consider the broadcast algorithm simulated using $k$-machines in the video. Suppose a vertex $u$ of the original graph wants to locally broadcast a message to all its neighbors $v_1, \ldots, v_r$. For each set of neighbors that are present at the same machine, it is enough if $u$ sends a message to just one neighbor vertex present at that machine. How is it that the other neighbors of $u$ present at a given machine will also receive the message?

A. When $u$ sends its message to some $v_i$ located at a given machine, it also sends the list of its neighbors in that machine that $v_i$ has to share the message with.  
B. When $u$ sends its message to some $v_i$ located at a given machine, $v_i$ shares the message with all other vertices present in that machine.  
C. When $u$ sends its message to some $v_i$ located at a given machine, $v_i$ uses pre-computed knowledge of which neighbors of $u$ are present at the same vertices as it to determine which vertices to share the message with.