1. (30 points)
   There are four necessary conditions for a system to be capable of deadlock: Mutual Exclusion, Hold and Wait, No Preemption, and Circular Wait. Deadlock prevention schemes aim to eliminate the possibility of one of these four conditions from occurring.

   The Dining Philosophers problem presents one scenario in which deadlocks are possible. The textbook outlines three solutions for the deadlock problem are mentioned. One of them is the following

   Use an asymmetric solution; that is, an odd philosopher picks up first her left chopstick and then her right chopstick, whereas an even philosopher picks up her right chopstick and then her left chopstick.

   (a) Which necessary condition does this solution prevent? Briefly explain why.

   Another scheme is the following.

   Allow a philosopher to pick up her chopsticks only if both chopsticks are available.

   (b) Which necessary condition does this solution prevent? Briefly explain why?

2. (20 points)
   Several divisions of the Byzantine army, each commanded by its own general, surround an enemy camp. The Byzantine generals must reach agreement on whether or not to attack the enemy at dawn. The various divisions are geographically dispersed and the generals can communicate with one another only via messengers who run from camp to camp. We will assume that messengers cannot be caught (i.e. communication is reliable) and that some generals may be traitors who can say or do anything they wish to confuse the others.

   (a) If we have a total of three generals and one of the three is a traitor, do you think it is possible for those two good generals to reach an agreement? Briefly explain why.

   (b) Now assume that we have a total of four generals, one of whom is a traitor. Under this situation, can you give a protocol/algorithm by which the good generals can reach agreement?

3. (25 points)
   Consider a hash table implementation of the symbol table for a block-structured language such as Pascal. Discuss (briefly) the operations required on the symbol table when a new scope is entered, when a name is looked up, and when a scope is exited. In particular, comment on the efficiency (i.e., worst-case complexity) of these operations.

4. (25 points)
   Assume you were required to add to the Pascal language with the following statements:

   ```pascal
   catch statement
   throw
   ```

   The semantics of `catch` states that control passes to statement `S`, which may be a procedure call. Furthermore, control flows to the statement after `catch` `S` whenever

   - statement `S` finishes normally, or
   - a `throw` statement is evaluated during the evaluation of `S` (which could be a procedure call).

   Discuss (briefly) how these statements affect the run-time implementation model for Pascal.