1. What are two reasons for using layered protocols? (10 points)

2. List two ways in which the OSI reference model and the TCP/IP reference model are the same. Now list two ways in which they differ. (10 points)

3. What is the principal difference between connectionless communication and connection-oriented communication? (10 points)

4. Calculate the latency (from first bit sent to last bit received) for the following:
   a) 10-Mbps Ethernet with a single store-and-forward switch in the path, and a packet size of 5000 bits. Assume that each link introduces a propagation delay of 10 microseconds, and that the switch begins transmitting immediately after it has finished receiving the packet. (10 points)
   b) Same as part ‘a’ but with three switches (10 points)
   c) Same as ‘a’ but assume the switch implements “cut-through” switching: It is able to begin retransmitting the packet after the first 200 bits have been received. (10 points)

5. Calculate the bandwidth * delay product for the following links. Use one-way delay, measured from first bit sent to first bit received.
   a) 10-Mbps Ethernet with delay of 10 microseconds. (5 points)
   b) 1.5-Mbps T1 link, with a transcontinental one-way delay of 50 milliseconds. (5 points)
   c) 1.5-Mbps T1 link through a satellite in geosynchronous orbit, 35,900 km high. The only delay is speed-of-light propagation delay. (5 points)
6. A 64,000-byte message is to be transmitted over two hops in a network. Assume

- Fiber optic cable are used
- Each hop is 1000 km long
- Links are error free
- Sender and receiver windows are arbitrarily large
- The network limits packets to maximum size of 2 kilobytes
- Each packet has a 32-byte header
- DS-3 transmission speeds are available (44.736 Mbps)
- Store and forward operation

How long does it take to get the entire message from source to destination? You must show all work. (25 points)