1 (15%)

(a) Indicate the lower three layers in the ISO OSI seven-layer model.

(b) Please determine the Internet checksum of the following two bit streams: 1000101001111110 and 0011101111001111

(c) Compare *datagram network* and *virtual-circuit network* in terms of their connection setup, addressing, effect of router failure (i.e., who will be affected?), QoS support flexibility, and operational complexity.

(d) Please list five key TCP features.

(e) Use simple words to describe routing and forwarding.

2 (10%)

Compare the delay in sending and *x*-bit message over a *k*-hop path in a circuit switched network and in a lightly packet switched network. The circuit setup time is *s* sec, the propagation delay is *d* sec per hop, the packet size is *p* bits, and the data rate of each link is *b* bps. Under what conditions does the packet switched network have a lower delay?

3 (20%)

Suppose a 100-Mbps link is being setup between Earth and a new lunar colony. The distance from the moon to Earth is approximately 385,000 km, and data travels over the link at the speed of light $3x10^8$ m/s.

(a) Calculate the minimum RTT for the link.

(b) Using the RTT as the delay, calculate the delay x bandwidth product for the link.

(c) What is the significance of the delay x bandwidth product computed in (b)?

(d) A camera on the lunar base takes pictures of Earth and saves them in digital format to disk. Suppose mission control on earth wants to download the most recent image, which is 25MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished?

4 (20%)

Compare Go-Back-N (GBN), Selective Repeat (SR), and TCP (no delayed ACK). Assume that the timeout values for all three protocols are sufficiently long such that 5 consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving host (Host B) and the sending host (Host A), respectively. Suppose Host A sends 5 data segments to Host B; and the 2^{nd} segment (sent from A) is lost. In the end, all 5 data segments have been correctly received by Host B.

How many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their segment numbers? Answer this question for all three

protocols.

If the timeout values for all three protocols are much longer than 5 RTT, then which protocol successfully delivers all five data segments in shortest time intervals?

5 (10%)

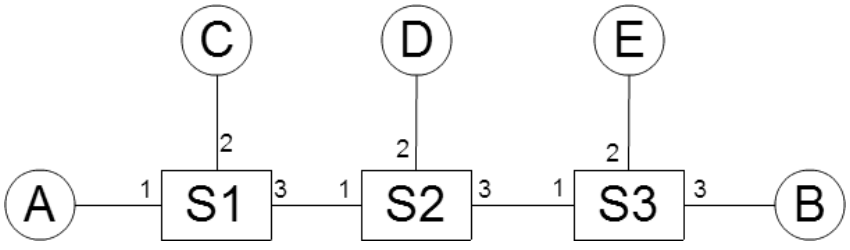
Suppose TCP operates over a 1-Gbps link. Assuming TCP could utilize the full bandwidth continuously, how long would it take the sequence numbers to wrap around completely?

6 (15%)

Suppose that between hosts A and B there is a router R. The A-R bandwidth is infinite (that is, packets are not delayed), but the R-B link introduces a delay of 1 packet per second (that is, 2 packets take 2 seconds, etc.). Acknowledgments from B to R, though, are sent instantaneously. R has a buffer size of three, in addition to the packet it is sending. Host A sends data to Host B over a TCP connection, using slow start but with an infinite receive window. Fast retransmit is done on the ***second*** duplicate ACK (i.e., the third ACK of the same packet). At each second, the sender first processes any arriving ACKs and then responds to any timeout. The timeout interval is fixed at 5 seconds, and slow start is used on a timeout. Ignore fast recovery. Give a table showing, for the first 15 seconds, what are sent and received by A, R, and B? Please also indicate A's congestion window size in each second. (Note: B sends ACK*x* to A for pkt*x*.)

7 (10%)

Consider the virtual circuit switches in Fig. 1. Table 1 lists, for each switch, what (Interface, VCI) pairs are connected to the others. Connections are bidirectional. List all end-to-end connections.



S1			
Incoming		Outgoing	
Port	VCI	Port	VCI
1	2	3	1
1	1	2	3
2	1	3	2

S2			
Incoming		Outgoing	
Port	VCI	Port	VCI
1	1	3	3
1	2	3	2

S3			
Incoming		Outgoing	
Port	VCI	Port	VCI
1	3	2	1
1	2	3	1

Table 1: VC Tables for S1