Instructions - Try to do your homework on your own. Some of the questions will require additional thought. It is more important to have your own opinion on the problems and argue along, than copying from other persons’ answer sheet. You will get extra credit for good argument.

1. (5pt) Is it possible for an application to enjoy reliable data transfer even when the application runs over UDP? If so, how?

2. (14pt - 2pt each) True or false? In all cases, provide a short discussion justifying your answer.
   (a) Host A is sending Host B a large file over a TCP connection. Assume Host B has no data to send Host A. Host B will not send acknowledgement to Host A because Host B cannot piggyback the acknowledgements on data.
   (b) The size of the TCP RcvWindow never changes throughout the duration of the connection.
   (c) Suppose Host A is sending Host B a large file over a TCP connection. The number of unacknowledged bytes that A sends cannot exceed the size of the receive buffer.
   (d) Suppose Host A is sending Host B a large file over a TCP connection. If the sequence number for a segment of this connection is \(m\), then the sequence number for the subsequent segment will necessarily be \(m + 1\).
   (e) The TCP segment has a field in its header for RcvWindow.
   (f) Suppose that the last SampleRTT in a TCP connection is equal to 1 sec. Then the current value of TimeoutInterval for the connection will necessarily be \(\geq 1\) sec.
   (g) Suppose Host A sends over a TCP connection to Host B one segment with sequence number 38 and 4 bytes of data. In this same segment the acknowledgement is necessarily 42.

3. (5pt) Consider the Go-Back-N and Selective-Repeat protocols. Suppose the sequence number space is of size \(k\). What is the largest allowable sender window that will avoid the occurrence of problems such as that in Figure 3.27 in the textbook (page.226) for each of these protocols? Explain why.

4. (10pt) Review the Figure 3.53 in your textbook (page.273), which illustrates the convergence of TCP’s AIMD algorithm. Suppose that instead of an additive increase, TCP increased the window size by doubling its rate. Would the resulting MIMD converge to an equal share algorithm? Justify your answer using a diagram similar to Figure 3.53.
5. (18pt - 2pt each) Consider the figure in the page 291 of your textbook, which plots the TCP window size as a function of time. Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions. In all cases, you should provide a short discussion justifying your answer.

(a) Identify the intervals of time when TCP slow start is operating.
(b) Identify the intervals of time when TCP congestion avoidance is operating.
(c) After the 16th transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?
(d) After the 22nd transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?
(e) What is the initial value of \( \text{Threshold} \) at the first transmission round?
(f) What is the value of \( \text{Threshold} \) at the 18th transmission round?
(g) What is the value of \( \text{Threshold} \) at the 24th transmission round?
(h) During what transmission round is the 70th segment sent?
(i) Assuming a packet loss is detected after the 26th round by the receipt of triple duplicate ACK, what will be the values of the congestion-window size and of \( \text{Threshold} \)?

6. (8pt - 2pt each) True or false? In all cases, provide a short discussion justifying your answer.

(a) If a Web page consists of exactly one object, then nonpersistent and persistent connections have exactly the same response-time performance.
(b) Consider sending object of size \( O \) from server to browser over TCP. If \( O > S \), where \( S \) is the maximum segment size, then the server will stall at least once.
(c) Suppose a Web page consists of 10 objects, each of size \( O \) bits. For persistent HTTP, the \( RTT \) portion of the response time is 20 \( RTT \).
(d) Suppose a Web page consists of 10 objects, each of size \( O \) bits. For nonpersistent HTTP with five parallel connections, the \( RTT \) portion of the response time is 12 \( RTT \).

7. (5pt) Suppose two programs use TCP to establish a connection, communicate, terminate the connection, and then open a new connection. Further suppose a \( FIN \) message sent to shutdown the first connection is duplicated and delayed until the second connection has been established. If a copy of the old \( FIN \) is delivered, will TCP terminate the new connection?
8. (20pt - 10pt each) Recall the idealized model for the steady-state dynamics of TCP. Int the period of time from when the connection’s window size varies from \( W/(2 \cdot RTT) \) to \( W/RTT \), only one packets is lost (at the very end of the period).

(a) Show that the loss rate is equal to

\[
L = \text{loss rate} = \frac{1}{\frac{3}{8}W^2 + \frac{3}{4}W}
\]

(b) Use the result above to show that if a connections has loss rate \( L \), then its average bandwidth is approximately given by

\[
\approx \frac{1.22 \cdot MSS}{RTT\sqrt{L}}
\]

9. (8pt) Consider the case \( RTT = 1 \text{ sec} \) and \( O = 100\text{abytes} \). Prepare a chart (similar to the charts in Section 3.8.2) that compares the minimum latency \((O/R + 2RTT)\) with the latency with slow start for \( R = 28\text{kbps}, 100\text{kbps}, 1\text{Mbps}, \) and \( 10\text{Mbps} \).

10. (7pt) Read all the interviews at the end of each chapter, and identify research interests of at least three of them. (Note. three of them had visited KAIST and gave talk last year.)