1. (10 points) Consider A newly established TCP connection that sends a message of 100,000 bytes

   (a) (5 points) Will there ever be any outstanding segments with the same sequence number? Yes

   Explain: The number of TCP sequence numbers $2^{32} \gg 100,000$

   (b) (5 points) Will the sequence number ever roll over? Yes, possibly.

   Explain: TCP sequence numbers do not necessarily start at 1, depending on the syn cookie, they can be any value.

2. (10 points) UDP and TCP use 1s compliment for their checksums. Suppose you have the following three 8-bit bytes: 01010101, 01100100, 01011101.

   (a) (5 points) What is the 1s compliment of the sum of these 3 8-bit bytes?

   11101000

   (b) (5 points) With the 1s compliment scheme, how does the receiver detect errors?

   The receiver adds the numbers and then adds the result to the checksum. If the result is not all 1's, there is an error.

3. Suppose two stations A and B are connected with a 10Mbps link. Suppose the round trip propagation delay on the link is 40ms. Packet lengths are 10,000 bits. There are no channel errors.

   (a) (5 points) What is the channel utilization for stop-and-wait ARQ if the block size is 1?

   $U = 1/41$

   (b) (5 points) What must the block size be for the channel utilization for stop-and-wait to be greater than 60%?

   $\frac{x}{40+x} \geq 0.6$

   $x = 60$

4. (10 points) Suppose A and B are connected with a 10Mbps link. Suppose the round trip propagation delay on the link is 100ms. Segment lengths are 10,000 bits. Consider the maximum number of in-flight segments possible on this link.

   (a) (5 points) How many bits are needed in the sequence number field for GBN?

   RTT + L/R $= 0.101 \approx 0.1$
   Delay bandwidth product $\approx 0.101 * 10 \cdot 10^6 = 1.01 \cdot 10^6$
   For a 10,000 bit segment or frame, that is about 101 frames. For GBN you will need about 102 sequence numbers, which requires 7 bits.

   (b) (5 points) How many bits are needed in the sequence number field for SR?

   For SR you will need about 202 sequence numbers, which require 8 bits.