Homework must be done individually. Due at 11:59pm on Feb 12, 2019. Please submit your solutions via Sakai.

1. (10 pts) **[PD] Page 63: Problem 14**

   Suppose a 128-Kbps point-to-point link is set up between Earth and a rover on Mars. The distance from Earth to Mars (when they are closest together) is approximately 55 Gm, and data travels over the link at the speed of light 3×10^8 m/sec.

   (a) Calculate the minimum RTT for the link.

   (b) Calculate the delay $\times$ bandwidth product for the link.

   (c) A camera on the rover takes pictures of its surroundings and sends these to Earth. How quickly after a picture is taken can it reach Mission Control on Earth? Assume that each image is 5 MB in size.

2. (10 pts) **[PD] Page 64: Problem 17**

   Calculate the latency (from first bit sent to last bit received) for:

   (a) A 1-Gbps Ethernet with a single store-and-forward switch in the path, and a packet size of 5,000 bits. Assume that each link introduces a propagation delay of 10 μs and that the switch begins retransmitting immediately after it has finished receiving the packet.

   (b) Same as (a) but with three switches.

   (c) Same as (b) but assume the switch implements cut-through switching: it is able to begin retransmitting the packet after the first 128 bits have been received.

3. (5 pts) **[PD] Page 153: Problem 3**

   Show the 4B/5B encoding, and the resulting NRZI signal, for the following bit sequence:

   ```
   1101 1110 1010 1101 1011 1110 1110 1111
   ```

4. (5 pts) **[PD] Page 154: Problem 7**

   Suppose the following sequence of bits arrive over a link:

   ```
   011010111110101001111111011001111110
   ```

   Show the resulting frame after any stuffed bits have been removed. Indicate any errors that might have been introduced into the frame.

5. (10 pts) **[PD] Page 155: Problem 11**

   Show that two-dimensional parity allows detection of all 3-bit errors.

6. (10 pts) **[PD] Page 153: Problem 16**

   Suppose that one byte in a buffer covered by the Internet checksum algorithm needs to be decremented (e.g., a header hop count field). Give an algorithm to compute the revised checksum without rescanning the entire buffer. Your algorithm should consider whether the byte in question is low order or high order.

7. (10 pts) **[PD] Page 158: Problem 25**

   Suppose you are designing a sliding window protocol for a 1-Mbps point-to-point link to the stationary satellite evolving around the Earth at an altitude of 3×10^4 km. Assuming that each frame carries 1 KB of data, what is the minimum number of bits you need for the sequence number in the following cases?
   Assume the speed of light is $3 \times 10^8 m/s$

   (a) RWS=1

   (b) RWS=SWS

8. (10 pts) **[PD] Page 159: Problem 32**

   Draw a timeline diagram for the sliding window algorithm with SWS=RWS=4 frames in the following two situations. Assume the receiver sends a duplicate acknowledgment if it does not receive the expected frame. For example, it sends DUPACK[2] when it expects to see Frame[2] but receives Frame[3] instead. Also, the receiver sends a cumulative acknowledgment after it receives all the outstanding frames. For example, it sends ACK[5] when it receives the lost frame Frame[2] after it already received Frame[3], Frame[4], and Frame[5]. Use a timeout interval of about $2\times$ RTT.

   (a) Frame 2 is lost. Retransmission takes place upon timeout (as usual).

   (b) Frame 2 is lost. Retransmission takes place either upon receipt of the first DUPACK or upon timeout. Does this scheme reduce the transaction time? (Note that some end-to-end protocols, such as variants of TCP, use similar schemes for fast retransmission.)