**NOTE:** For all answers, show how you derived your answer, including diagrams and all formulas used. Just providing the end-result gets NO credit.

**Homework 1:** Network Performance

Assume propagation speed is 2 \* 108 m/sec for all problems.

1. Suppose we have a single link between sender and receiver. The transmission speed (R) is 10 Mbps and packets are 1500 bytes. Link distance is 50m.
   1. What is the transmission delay (dtrans) on the link? Show formula.
   2. What is the propagation delay (dprop) on the link? Show formula
   3. How many packets can the link transmit per second? Show formula
2. Suppose we extend the network above with three links and two routers: Sender ----> Router1----->Router2----> Receiver. The first and third links have the same properties as above. The middle link has a transmission speed of 50Mbps and a distance of 100km. Assume queuing and processing delays are negligible.
   1. What is the total end-to-end delay? Show formulas.
   2. What is the effective end-to-end throughput on this network? Why?

**Homework 2:** Web and HTTP

1. Assume a web browser caches web pages locally on a user machine. Explain in your own words how web caching impacts HTTP traffic sent to the web server. Be concise! Illustrate using a diagram. Cite any references you used to come up with your answer.
2. Explain how caching improves network performance. What potential negative impacts does caching have?

**Homework 3:** UDP Checksums

1. What is the 1’s complement of the sum of the following 8-bit bytes (show all calculations):
   1. 01010011
   2. 01100110
   3. 01110100
2. With 1’s complement, how does the receiver detect errors? Is it possible that a 1-bit error will go undetected? What about a 2-bit error?

**Homework 4**: TCP Congestion Control

Consider the figure below. Assume TCP Reno is the protocol experiencing the behavior, and answer the following questions. Justify your answer briefly.



1. Identify the intervals of time when slow start is operating
2. Identify the intervals of time when TCP congestion avoidance is operating
3. After the 16th transmission round, is segment loss detected by a triple duplicate ack or a timeout?
4. After the 22nd transmission round, is segment loss detected by a triple duplicate ack or a timeout?
5. What is the initial value of ssthresh at the first transmission round?
6. What is the value of ssthresh at the 18th transmission round?
7. What is the value of ssthresh at the 24th transmission round?
8. Suppose TCP Tahoe is used (instead of TCP Reno) and assume that triple duplicate acks are received at the 16th round. What are the ssthresh and the congestion window size at the 19th round?