Name: ______________________ Student ID: ______________________

Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page.

For the following questions, please show your work. Without seeing how you calculated something, I cannot give you partial credit for it.

1. [5 points] Suppose two hosts, A and B, are separated by 10,000km and are connected by a link with a transmission rate of$R = 1Mbps$. The propagation delay is $2.5 * 10^8$m/s. *Remember: 1KB = 1024 bytes, 1MB = 1024 KB, 1Mbps =* $1 \times 10^6 bits/second$.

   (a) [1 point] Calculate the time to send a 10MB file (assuming it is sent as one large message):

   (b) [2 points] While sending the 10MB file, how many bits will be on the link at any given time?

   (c) [1 point] What is the length of a bit in meters?

   (d) [1 point] Assume we can change the rate R. At what value of R is the length of the bit equal to the length of the link?

2. [5 points] Suppose an institution is connected to the Internet with a link with bandwidth $R = 10Mbps$ and that on average, its users retrieve objects from the Web that are 256KB in size with an average request rate of 4/s.

   (a) [1 point] What is the traffic intensity on the link?

   (b) [2 points] If the average amount of time that it takes for an HTTP request to be received, responded to and returned is 1.5 seconds, what is the average response time? Recall that the average response time is modeled as the sum of the average access delay and the average Internet delay. The average access delay is: $\Delta/(1 - \Delta\beta)$, where Δ is the average time to send an object over the Internet and β is the arrival rate of objects on the link.

   (c) [2 points] Suppose the institution installs a cache which achieves a hit rate of 40%. Find the new average response time.

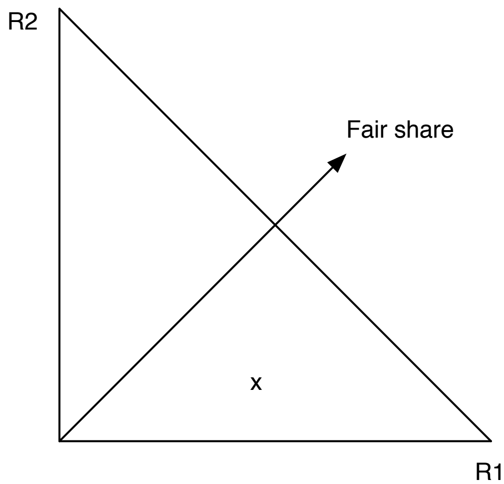
3. [5 points] Suppose two hosts, A and B, are connected through the Internet with a 7Mbps link with an RTT of 40ms. Assume we are sending a 200MB file and that our transfer is one way so that acknowledgements are negligible in size. In addition, assume that the MSS is 1500 bytes and that we experience no packet loss.

   (a) [2.5 points] If the WS is 28, calculate how long will it take to transfer the file? Are we limited by the WS or by the bandwidth of the link?

   (b) [2.5 points] If the window size (WS) advertised by the receiver is 20, calculate how long it will take to transfer the file. Are we limited by the WS or by the bandwidth of the link?

4. [5 points] We know that TCP uses AIMD to determine the congestion window. We can show that two or more connections 'play fair' by graphing their window sizes and calculating the results of packet loss with two or more dimensions. Assume two hosts, A and B, are competing for the bandwidth. Host A increases its window by α_1 and decreases by α_2. Host B increases its window by β_1 and decreases its window by β_2.

   (a) [2.5 points] In the given figure, assume that AIMD is used with $\alpha_1 = 1$, $\alpha_2 = 1/2$, $\beta_1 = 1$ and $\beta_2 = 3/4$. Determine if a fair share is achieved by graphing the results on the diagram starting at x.



   (b) [2.5 points] In the given figure, assume MIMD is used with $\alpha_1 = 3/2$, $\alpha_2 = 1/2$, $\beta_1 = 3/2$, $\beta_2 = 1/2$. Graph the results in the diagram starting at x.