Problem 1. [4 points] Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 126. Suppose Host A then sends two segments to Host B back-to-back. The first and second segments contain 80 and 40 bytes of data, respectively. In the first segment, the sequence number is 127, the source port number is 302, and the destination port number is 80. Host B sends an acknowledgment whenever it receives a segment from Host A.

(a) In the second segment sent from Host A to B, what are the sequence number, source port number, and destination port number?

(b) If the first segment arrives before the second segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number, the source port number, and the destination port number?

(c) If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number?

(d) Suppose the two segments sent by A arrive in order at B. The first acknowledgment is lost and the second acknowledgment arrives after the first timeout interval. Draw a timing diagram, showing these segments and all other segments and acknowledgments sent. (Assume there is no additional packet loss.) For each segment in your figure, provide the sequence number and the number of bytes of data; for each acknowledgment that you add, provide the acknowledgment number.

Problem 2. [2 points] Compare GBN, SR, and TCP (no delayed ACK). Assume that the timeout values for all three protocols are sufficiently long such that 5 consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving host (Host B) and the sending host (Host A) respectively.

Suppose Host A sends 5 data segments to Host B, and the 2nd segment (sent from A) is lost. In the end, all 5 data segments have been correctly received by Host B.

(a) How many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their sequence numbers? Answer this question for all three protocols.

(b) If the timeout values for all three protocol are much longer than 5 RTT, then which protocol successfully delivers all five data segments in shortest time interval?

Problem 3. [4 points] Assuming TCP Reno is the protocol experiencing the behavior shown below, answer the following questions. In all cases, you should provide a brief justification for your answer.

![Congestion window size segments](image)
(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 ssthresh at the first transmission round?
(f) What is the value of ssthresh at the 24th transmission round?
(g) During what transmission round is the 70th segment sent?
(h) Assuming a packet loss is detected after the 26th round by the receipt of a triple duplicate ACK, what will be the values of the congestion window size and of ssthresh?

**Problem 4. [4 points]**

Consider the arrival of 12 packets to an output link at a router in the interval of time [0, 5], as indicated by the figure below. We’ll consider time to be “slotted”, with a slot beginning at \( t = 0, 1, 2, 3, \) etc. Packets can arrive at any time during a slot, and multiple packets can arrive during a slot. At the beginning of each time slot, the packet scheduler will choose one packet, among those queued (if any), for transmission according to the packet scheduling discipline (that you will select below). Each packet requires exactly one slot time to transmit, and so a packet selected for transmission at time \( t \), will complete its transmission at \( t+1 \), at which time another packet will be selected for transmission, among those queued.

For each of the scheduling algorithms below, indicate the departure time of each of these 12 packets. There are three classes of traffic (1, 2, 3), with lower class numbers having higher priority.

(a) Priority scheduling

(b) WFQ with queue quotas of 4, 2, and 1 for the priority classes 1, 2, and 3 respectively.

![Arrival and Departure Diagram](image)

**Problem 5. [3 points]** Consider the following network. With the indicated link costs, use Dijkstra’s shortest-path algorithm to compute the shortest path from \( x \) to all network nodes. Show how the algorithm works by computing a table similar to Table 4.3 in the text.
Problem 6. [2 points]

Consider a general topology (that is, not the specific network shown above) and a synchronous version of the distance-vector algorithm. Suppose that at each iteration, a node exchanges its distance vectors with its neighbors and receives their distance vectors. Assuming that the algorithm begins with each node knowing only the costs to its immediate neighbors, what is the maximum number of iterations required before the distributed algorithm converges? Justify your answer.

Problem 7. [3 points] Consider the network fragment shown below. x has only two attached neighbors, w and y. w has a minimum-cost path to destination u (not shown) of 5, and y has a minimum-cost path to u of 6. The complete paths from w and y to u (and between w and y) are not shown. All link costs in the network have strictly positive integer values.

(a) Give x’s distance vector for destinations w, y, and u.
(b) Give a link-cost change for either c(x,w) or c(x,y) such that x will inform its neighbors of a new minimum-cost path to u as a result of executing the distance-vector algorithm.
(c) Give a link-cost change for either c(x,w) or c(x,y) such that x will not inform its neighbors of a new minimum-cost path to u as a result of executing the distance-vector algorithm.

Problem 8. [3 points] Referring to the BGP problem we started in class, once router 1d learns about x it will put an entry (x, I) in its forwarding table.

(a) Will I be equal to I1 or I2 for this entry? Explain why in one sentence.
(b) Now suppose that there is a physical link between AS2 and AS4, shown by the dotted line. Suppose router 1d learns that x is accessible via AS2 as well as via AS3. Will I be set to I1 or I2? Explain why in one sentence.
(c) Now suppose there is another AS, called AS5, which lies on the path between AS2 and AS4 (not shown in diagram). Suppose router 1d learns that x is accessible via AS2 AS5 AS4 as well as via AS3 AS4. Will I be set to I1 or I2? Explain why in one sentence.