Answer all problems. **Some problems are deliberately underspecified** (you need to make assumptions); in such cases clearly state any assumptions you need to make.

**Problem 1:** (20 pts – 15 minutes) Give brief discussions/answers for the following possibly wrong statements

1. Statistical Multiplexing is always better than Frequency Division Multiplexing
2. 4b/5b encoding is better than NRZI
3. Process-per-message protocols avoid context switches completely
4. With Forward Error Correction, ARQ is not needed
5. Using packet length as well as sentinels for framing is worse than using either alone
6. Receiver window size is not essential for correct sliding window operation (can just choose it to be infinite)
7. The three-way handshake protocol (CSMA/CA) used in IEEE 802.11 is better than pure CSMA for wireless networks
8. A reservation protocol would perform best for an ethernet like environment
9. Connection-oriented networks is another name for reliable networks
10. AAL 5’s CRC scheme is stronger and more efficient than AAL 3/4s one

**Problem 2:** (15 pts – 15 minutes) **Briefly** answer the following questions:

1. Give three reasons that affected the ATM cell size choice
2. Show the Manchester encoding for 10000110111
3. Give three examples of how a bridge is different from a repeater
4. Discuss an extension to the connection-oriented model to allow broadcast and/or multicast
5. Discuss any difficulties in building an extended Token ring Network (using bridges to logically extend a token ring over multiple identical rings)
Problem 3: (10 points – 5 minutes) A new learning bridge protocol has been suggested: A bridge forwards all frames that are not in its “route cache” on all outputs. However, it marks a frame the first time it sees it and discards it if it sees it again. Compare this to the solution in 802.1 (the spanning tree algorithm) and identify any problems with it.

Problem 4: (15 points – 15 minutes) Consider a network with 3 hosts (A, B and C). A is connected to B using a link with a 10Mbps bandwidth and 10msec delay. B is connected to C using a 5Mbps link with 20msec delay.

(i) How long does it take to send a 2000 bit packet from A to C?

(ii) Suppose that A starts transmitting 2000 bit packets to C at the maximum rate possible on the link from A to B. How much buffering does B need to provide such that the first packet will not be dropped until 1 second has passed?

(iii) Assume that C immediately signals A to stop sending packets after it receives the first packet. Assume that this “signal” packet experiences the minimum possible delay. A stops sending packets immediately after receiving the “signal” packet. How many packets has A sent?

Problem 5: (10 points – 10 minutes) A pair of hosts is directly connected via an M bps link with a latency of $l$ and is using ARQ. Packet sizes are fixed at $s$ bytes, and the probability of an error is $p$ per packet. The retransmit timer(s) are set at $1.5l$.

(i) What is the throughput if stop-and-wait is used? Suggest a window size for a sliding window implementation.

(ii) Quantitatively (using equations) discuss the effect of corrupted packets on throughput. Does it matter if they occur in bursts or are spaced out?

Problem 6: (10 points – 8 minutes) An engineer in your company suggests an extension to 2-D parity called 3-D parity constructed in the following way. Starting with $n$ by $n$ squares where usual 2-D parity is applied, every $n^{th}$ square is followed by a parity square where each bit is the bitwise parity of the $n$ squares that precede it. Compare 2-D and 3-D parity using relevant metrics for equal size payloads.