1. Consider a frame consisting of two characters of four bits each. Assume the probability of a bit error in transmission is 10^{-3} and that it is independent for each bit.
   (a) **(4 Points)** What is the probability that the received frame contains at least one error?
   (b) **(3 Points)** Add a parity bit to each character. What is the probability that the received frame contains at least one error?

2. Consider an error-free 64 kbps GEO satellite channel sending 512-byte data frames in one direction, with very short acknowledgements coming back the other way. What is the maximum throughput for window sizes of 1, 7, and 70?
   (a) **(4 Points)** 1:
   (b) **(4 Points)** 7:
   (c) **(4 Points)** 70:

3. **(5 Points)** Data link protocols almost always put the checksum in a trailer, rather than in a header. Why?

5. A 12-bit Hamming code whose hexadecimal value is 0xE4F arrives at the receiver. Assume that one of the parity bits is in error.
   (a) **(5 Points)** What is the 8-bit data value that was transmitted?
   (b) **(10 Points)** What was the correct Hamming code (original) value in hexadecimal?

6. **(7 Points)** When bit stuffing is used, is it possible for the loss, insertion, or modification of a single bit to cause an error not detected by the checksum? If not, why not? If so, how? Does the checksum length play a role here?

8. Suppose that a selective-reject ARQ is used where N = 4. **(2 Points)** What is the recommended sequence number bit length (number of bits in the sequence number)? **(3 Points)** Explain your answer.

9. Two neighboring nodes (A and B) use a sliding window protocol with a 3-bit sequence number. The go-back-N ARQ mechanism is used with a window size of 4. Assume that A is transmitting and B is receiving. Show the window positions for each of the following sequence of events:

   (a) **(5 Points)** Before A sends frame 0.

A:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**
B:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**

   (b) **(5 Points)** After A sends frames 0, 1, 2 and B acknowledges 0, 1 and the ACKs are received by A.

A:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**
B:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**

   (c) **(5 Points)** After A sends frames 3, 4, 5 and B acknowledges 4 and the ACK is received by A.

A:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**
B:	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**0**	**1**	**2**	**3**	**4**