Note: Choose either problem 7 or problem 8. Problems 1-4 are scored as 10 points each, 5-6 as 15 points each, and 7 or 8 is 30 points, for a total of 100 possible.)

1. If you are calculating the data rate for a (assume wired) link, how does its length factor into the calculation of the data rate:
   a. Using Nyquist's theorem? Explain
   b. Based on Shannon's formula? Explain

2. Find the minimum Hamming distance between these three code words.

   0101110
   0011010
   0110110

3. (a) Why isn't CSMA/CD (as in Ethernet) used in wireless LANs?
   
   (b) What is added to CSMA for its use in wireless LANs?

4. For a data link, the technique known as "piggybacking" delays the outgoing acknowledgment frame until there is an outgoing data frame, and incorporates the acknowledgment into this frame. What is gained by this?
5. (a) If you desire a data rate on a link of 1Mbps, and you have QPSK modems with the constellation diagram as shown, what is the minimum bandwidth you need to achieve this data rate?

(b) What factors might keep you from achieving this rate?

6. (a) If a (simplified) data link has frames that use a CRC code of $X^3 + X^2 + X + 1$ and the received frame is the sequence 11010101100, what is the data in the frame? (Assume for simplicity that it this is only the data with the FCS appended – headers, flags and control bytes have already been removed.)

(b) What can you determine from this received frame about errors in this frame?
7. For a tourist Moon-shot, the customer is to be given a luxurious trip around the Moon. ("Be among the first to see the back side of the Moon – for only a $1M"). The spacecraft will have a 10Mbps Ethernet (for passenger use), and a data link back to the Earth. If the data link is to bridge the spacecraft Ethernet to one on the Earth at 10 Mbps, what is the requirement – as a function of distance – for the buffers for a sliding window protocol on this link? (Assume that the maximum distance is \( \frac{450 \times 10^3}{3 \times 10^8} \) km, and the speed of transmission is \( 3 \times 10^8 \) m/sec.)

(b) Discuss the re-transmission timer, the duration of the wait for acknowledgments before the transmitter resends buffered frames. How would you determine the value for this time delay? How would it need to change as the spacecraft travels from Earth to the Moon – assuming we want to keep the delay in the message traffic from the spacecraft to Earth (caused by the need to resend damaged frames) as small as we can? What is the value of the “NACK” in this situation, from the perspective of an email sender or receiver?

8. A small office has a growing number of workers with computers on an Ethernet (10Mbps on Cat-3 wiring) implemented in a star topology, with a hub at the center. Also connected to the hub are the office database server and the T-1 line router that provides the office Internet connection. As the business has grown, the staff has become increasingly frustrated with the slow response they get, especially from the database server. They find that the response is good when only a few users are active, but at peak times it slows noticeably. The database server was very recently upgraded to a much faster machine, but this seemed not to make any significant difference in response from the user’s perspective. The boss (a lawyer) played golf recently with an engineer from a network hardware company, and came back with the idea of putting each user’s workstation on its own “private LAN”, and upgrading the link to the database server, and believes that should fix the problem as it is “caused by collisions”. He’s asked you to develop a proposal for this new architecture and to get a significant speedup at – of course – minimum cost. He does not own the building and does not want to spend money on significant rewiring as there is a planned move to another facility in about a year. What is your proposal? State your assumptions, constraints and trade-offs, and justify your recommendations.