Problem Set 1
10 points for each graded problem: Total of 70 points.
Turn in before class on January 30, 2025

1. This problem explores various types of delays in networks.
   (a) What is the propagation delay for sending a signal a distance of 3000 kilometers, assuming the speed of the signal is 2.5×10^8 meters per second. Assuming the same speed of the signal, find the propagation delay across a cable of length 300 meters.
   (b) A music CD of 700 Mbytes is sent 3000 kilometers over a 2 Gigabit link. Assuming there is a 100 millisecond processing delay at the destination, what is the total time (including propagation delay and processing delays) to get the CD at the destination? Assume the signal speed is an in part (a). What is the total time required if two intermediate routers (at distances of 1000 and 2000 kilometers) acting as message switches first gets the entire CD as a message and then send it out immediately with no intermediate processing delays? Assume the links are each 2 Gbits/sec. What is the total time if the CD is sent as 1500 byte packets with the intermediate routers acting as packet switches to send out a packet immediately after it receives it?

2. *This problem will not be graded. It will be useful for you to try to solve it. However, it will be covered in the solution set.*
   Different computers store a multibyte word in different orders.
   (a) Explain the difference between little endian and big endian storage by considering Intel 80x86, SPARC, and PowerPC architectures.
   (b) Explain the difference between network byte order and host byte order. Does the storage order of the bits in the byte matter? Does the transmission order of bits in a byte matter? Explain.

3. A periodic signal is represented as the following sum of sinusoids:
   $$g(t) = \sum_{\substack{k=1 \\ k\ odd}}^{\infty} \frac{1}{k} \sin(2k\pi t)$$
   (a) Graph the first two terms of *g(t)* separately. Note that the first term is when k =1 and the second term has k = 3. Graph the two terms for the interval $0 \le t \le 2$.
   (b) Graph the approximation of *g(t)* as the sum of the first two terms.
   (c)) What kind of function do you think you would get if $k \to \infty$?

4. Consider a Hamming (8, 4) code.
   (a) How many legitimate code words are there? How many potential received words are there?
   (b) For linear block codes, as defined in the text, prove that the 0 vector is always a legitimate code word.
   (c) Prove that the minimum weight of a linear block code is the Hamming distance of the code.

5. S/N is the signal to noise ratio or SNR. When measured in decibels (DB), $SNR_{DB} = 10 \log_{10} SNR$. What is the maximum reliable bit rate possible over a channel with the following parameters:
   (a) W = 6 kHz and SNR = 40 dB.
   (b) W = 6 kHz and SNR = 80 dB.
   (c) Assume that you are setting up a communications channel that operates in the frequency

range of 200 kHz to 8.0 MHz. You need to support several PCM voice channels, an upstream digital channel of 800K bits /second, and a downstream broadband channel of 2.0 Mps for data. What is the maximum number of voice channels you could support? Assume you can only achieve a SNR of 40 dB on the line.

6. Suppose a header consists of four 16-bit words:

    11111111 00001100
    11111111 11110000
    11110000 11110000
    11000010 11100011

    (a) Find the internet IP checksum for this header.
    (b) Suppose a burst error changed the first 8 bits (reading left to right) of the first word to 00000110. Would the error be detected? Explain your answer.
    (c) Is the checksum header algorithm used in IPv4 the same in IPv6? Explain.

7. You are implementing a CRC polynomial check code using the generator polynomial $x^4 + x^2 + x + 1$. Suppose the following message is to be sent: 10110011.
    (a) What is actually transmitted?
    (b) If the message is received without error, show how you would have verified this.
    (c) Suppose the first and last bits of your transmitted message were changed by errors on the line. Would you detect the error? Show your work.
    (d) Is the generator polynomial above better or worse than the generator polynomial $x^4 + x^3 + 1$? Explain your answer.

8. *This problem will not be graded. It is worth trying it to get a better idea of how things work. It will be covered in the solutions.*
    Suppose you are provided with a transmission channel that operates at 4Mbps and has a bit error rate of 10^{-4}. Assume bits are not "lost" but only possibly changed. Assume also that bit errors occur at random and independent of each other. Suppose that the following code is used. To transmit a 1, the codeword 111 is sent; and to transmit a 0, the codeword 000 is sent. The receiver takes the three received bits and decides which bit was sent by taking the majority vote of the three bits. Find the probability that the receiver makes a decoding error. What is the expected throughput of the channel? Explain.

9. Consider the (7,4) Hamming code we discussed in class. Describe how you would represent the (7,4) Hamming code using matrix multiplications. Explain what is meant by the generator matrix $G_{(4,7)}$ and parity check matrix $H_{(3,7)}$ and describe each of these matrices. Show how the code word set is generated by $G_{(4,7)}$. The (7,4) Hamming code has minimum distance 3. Using this fact, prove that no two columns in the parity check matrix $H_{(3,7)}$ are the same.