1. Two-Dimensional Parity
   Given below is a series of 7 7-bit items of data, with an additional bit each and an extra byte to account for parity.

   | 1 1 1 0 1 1 0 |
   | 1 1 0 1 0 1 0 |
   | 0 1 1 1 1 1 0 |
   | 0 1 1 0 1 0 0 |
   | 1 1 0 0 0 1 0 |
   | 0 0 1 0 1 0 1 |
   | 1 1 0 0 0 0 0 |

   a. Fill in the parity bit for each blank, assuming even parity is followed.
   b. Will two-dimensional parity catch all 2-bit errors?
c. Will two-dimensional parity catch all 3-bit errors?

d. Will this parity check catch all 4-bit errors?

For parts b, c, and d, if your answer is yes, explain, and if your answer is no, give an example.

2. Maximum Throughput

Consider a 10Mbps link with a 20-ms round-trip time (RTT). Assume that the sender can send only one frame per RTT, and that the sender has a frame size of 5 KB. Calculate:

a. The Bandwidth-Delay Product of the channel
b. The maximum throughput the sender can achieve
c. The fraction (or percentage) of the capacity of the link that is being used by the sender.

3. The HDLC Protocol

Given our understanding of the HDLC protocol, assume that the following bit stream arrives at the receiver at a particular instant of time:

```
0111 1111 1001 1101 1011 0110 0111 1110 1111 0111 1111 0111 1111 0111 0110 1101 1011 1111 0100 0111 1000 0001 1110 1111 1101 1111 1110 0010 1111 0010 1101 0011 1111 1101 1101 1111 0110 0101 0011 1101 1111 1001
```

Calculate the total number of:

a. Correctly received end of frames
b. Stuffed 0's
c. Received errors
4. **Error-checking using CRC**

Assume we have the following bit stream as the sender’s message - 1011 0011 0101 0110 - and we want it to encode it with the help of the CRC-8 polynomial.

a. What does the CRC-8 polynomial look like? Write it down using the standard polynomial notation. (Look up Table 2.3 on Page 102 of the textbook for your reference)

b. What is the sequence for the CRC-8 polynomial in binary form?

c. What does the transmitted bit-sequence look like? Highlight your steps in the calculation.

d. Assume the 7th bit in the transmitted sequence is flipped. What is the calculated remainder at the receiver?

5. **Hamming codes**

Assume fixed-length bit-strings of length 9 where only some bit-string sequences are allowable in the encoding scheme. Assume that the bit-strings in blue are the allowed codewords and those in gray are the ones that aren’t. The following diagram elucidates the assumption.

![Hamming code diagram](image)

Now, calculate the following:-

a. What is the hamming distance of this encoding scheme?

b. Is the encoding scheme efficient? Why or why not?

c. How many bit flips can be detected?

d. How many bit flips can be corrected?
6. The Automatic Repeat Request (ARQ) Protocol

Assume that two computers are communicating using the stop-and-wait ARQ protocol. Assume that the RTT for the communication channel is 2ms, and that the timeout is twice the RTT. Also assume that both parties use sequence numbers on data and ACK frames. If the sender has to send 8 frames to the receiver, draw the sequence of steps involved if the first 3 frames are sent without incident (as shown in the figure) and the following takes place:

   a. The 4th frame is lost during the first and second transmission, but is acknowledged without incident after the third transmission.
   b. The 5th frame is lost during the first transmission, but acknowledged without incident after the second transmission.
   c. The 6th frame is sent and acknowledged without incident.
   d. The 7th frame is sent without incident but the acknowledgment is lost the first time; sent without incident during the second transmission.
   e. The 8th frame is sent and acknowledged without incident.

Also, how much time (in ms) did it take for the above 8 frames to be transferred and acknowledged successfully?

To get you started, the diagram for the transmission of the first 3 frames is shown below. Draw separate diagrams for each part.