1) Indicate the positions where a zero-bit needs to be stuffed if the following frame is to be sent

\[ 1 0 1 1 0 1 1 1 1 1 0 0 0 0 0 0 1 1 1 1 1 0 0 0 1 \]

Stuff a bit after a sequence of five ones:

\[ 1 0 1 1 0 1 1 1 1 1 0 1 0 0 0 0 1 1 1 1 1 0 0 0 1 \]

2) A DL channel employs a CRC with generator \( G(x) = 1101 \). The following sequence of bits have to be sent over the channel

\[ M(x) = 1 1 0 1 1 1 0 0 0 0 1 1 1 0 1 \]

How many redundant bits will be added? What are their values?

\( G(x) \) is of order 3. Three CRC bits will be added. First add three zeros to \( M(x) \)

\[ 1 1 0 1 1 1 0 0 0 0 1 1 1 0 1 0 0 0 \]

Now divide by \( G(x) \)

\[
\begin{array}{r|cccccccc|c}
1 1 0 1 & 1 1 0 1 1 1 0 0 0 0 1 1 1 0 1 & 0 0 0 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
1 1 0 1 & 1 1 0 0 0 & 1 1 0 1 & 1 0 1 & 1 1 0 1 & 1 1 0 1 & 1 0 0 0 0 1 1 1 0 1 0 0 0 1 \\
\end{array}
\]

\[ T(x) = 1 1 0 1 1 1 0 0 0 0 1 1 1 0 1 1 1 0 \]

3) A DL channel employs a Hamming Error correction code with \( m=11 \) and \( n=15 \). The sequence of 15 bits received by the receiver is \( 1 0 1 1 0 1 1 1 0 0 1 1 0 0 \). (assume even parity and that bit positions are counted right to left – LSB in position 1 and MSB in position 15). What was the sequence of 11 bits sent?

\[ 1 0 1 1 1 0 1 1 1 0 0 1 1 0 0 \]

Gr1
\[ 1 1 1 1 1 0 1 1 0 1 0 0 \] (correct parity) \( x \ x \ x \ 0 \)

Gr2
\[ 1 0 1 0 1 0 1 1 0 1 0 0 \] (correct parity) \( x \ 0 \ 0 \)

Gr3
\[ 1 0 1 1 1 0 0 1 \] (wrong parity) \( x \ 1 \ 0 \ 0 \)

Gr4
\[ 1 0 1 1 1 0 1 1 1 1 0 1 \] (correct parity) \( 0 \ 1 \ 0 \ 0 \)

Syndrome is \( 0 1 0 0 \) - bit number 4 was flipped

Corrected 15 bits
\[ 1 0 1 1 1 0 1 1 1 0 0 0 1 1 0 0 \]

The 11 message bits are \( 1 0 1 1 1 0 1 1 0 0 1 \)
4) The DL layer which employs SRP with a window size of 6 receives a sequence of 15 packets from the network layer (packets P1, P2, ..., P15), which needs to be sent to the next hop.
   a) Indicate the DL number that will be assigned to each packet
   b) The receiver has received a sequence of packets numbered 0, 1, 2, 3, 4, 5, 6, X.
      i. What are the possible values for X? (can X be 0? 1? 2? .... 12? etc)
      ii. Explain a scenario which makes each value of X possible
      iii. When a packet with a number X is received indicate what the receiver should do with the packet (discard or store)

   P1  P2  P3  P4  P5  P6  P7  P8  P9  P10 P11 P12 P13 P14 P15  (packets)
   0   1   2   3   4   5   6   7   8   9   10  11  0  1  2  (packet numbers 0 to 11)

X can be any value between 0 and 11

X=0 → P13  (packets P8 to P12 were lost); store packet and send ACK
X=1 → P2   (ACK for P2 lost; so P2 was retransmitted); discard packet and send ACK
X=2 → P3   (ACK for P3 lost; so P3 was retransmitted)); discard packet and send ACK
X=3 → P4   (ACK for P4 lost; so P4 was retransmitted)); discard packet and send ACK
X=4 → P5   (ACK for P5 lost; so P5 was retransmitted)); discard packet and send ACK
X=5 → P6   (ACK for P6 lost; so P6 was retransmitted)); discard packet and send ACK
X=6 → P7   (ACK for P7 lost; so P7 was retransmitted)); discard packet and send ACK
X=7 → P8   (this is what you would expect); store packet (or provide to higher layer) and send ACK
X=8 → P9   (P8 lost); store packet and send ACK
X=9 → P10  (P8 and P9 lost); store packet and send ACK
X=10 → P11 (packets P8, P9 and P10 lost); store packet and send ACK
X=11 → P12 (packets P8, P9, P10 and P11 lost); store packet and send ACK

5) What are the functions of LCP and NCP in PPP?

PPP frames can carry different payloads. Usually they carry network layer (IP) packets. However, before they can carry IP packets, the two ends will need to negotiate some parameters.

LCP (link control protocol) packets are carried by PPP frames to negotiate physical layer parameters (for example, the physical layer protocol like V32 or V90, V92 etc. to be used, depending on the quality of the line).

Once this step is done, the client modem will need to be provided an IP address before it can start sending IP packets. This is performed using NCP (network control protocol) packets. NCP packets sent from the modem (which connects the client to the Internet) will contain an IP address. It can also contain other parameters like DNS addresses, net-mask, duration for which the IP address is leased etc.