Solutions to Assignment 4

Question 1

(a) If the taps in the PRBS generator are set to produce a ML sequence, the period of the sequence is given by $2^K - 1$ where K is the number of bits of state (number of flip-flops in the shift register). For $K = 6$ the period is $2^6 - 1 = 63$ bits.

(b) A ML PRBS generator will cycle through all possible states except for the all-zeros state. This includes the all-1's state. This state will result in an output of six consecutive ones[1].

Question 2

The generator polynomial is $G(x) = x^3 + 1 = 1x^3 + 0x^2 + 0x^1 + 1x^0$ or 1001. The CRC is computed as the remainder after appending 3 zeros:

```
      ---------
1001 |11011000
      1001
      ----
       1001
       1001
       ----
        0000
        ----
         0000
         ----
          0000
          ----
           000
```

The CRC is thus 000 and the message plus CRC is 11011000.

[1]The lecture notes are incorrect about the distribution of run lengths, there is one run of K ones and one run of $K-1$ zeros. There are also l runs of $K - l$ ones or zeros for $K > l > 1$.

Question 3

The first 6 bytes of of an Ethernet frame are the destination address and the next 6 are the source address. The next two bytes are the length-or-type field. The first three bytes of each address are the OUIs.

(a) the OUI of the source address is `00 24 1d`.

(b) the manufacturer of the destination interface can be looked up from the destination OUI `00 1d 7e`. It is "Cisco-Linksys, LLC".

(c) the protocol used by the payload is `08 00` which is IPv4 according to the IEEE and Wikipedia "Ethertype" tables.

Question 4

The following hex dump shows the contents of an IP packet:

```
45 00 00 3c
68 47 40 00
40 11 7b b2
0a 00 00 64
d0 50 7c 02
```

What are:

(a) the first byte of the packet is 0x45 which says this is an IPv4 packet with 5 32-bit words. The fifth word is the destination IP address: `d0 50 7c 02` which is 208.80.124.2 in "dotted-quad" notation?

(b) the protocol field is byte 10 (`0x11`) which is decimal 17 which is UDP (User Datagram Protocol).

(c) the total length of the IP packet is given by header bytes 3 and 4 (`0x003c`) which is 60 decimal.

(d) the maximum number of times this packet can be forwarded is given by the TTL field which is byte 9 (`0x40`) or 64 decimal.

(e) the correct value of the header checksum can be computed by: (1) adding all 16-bit words except for the checksum itself, (2) adding the MS 16 bits to the LS 16 bits, (3) complementing the bits of the result. The following spreadsheet shows the calculation:

	A	B	C
1	**hex**	**decimal**	**formula**
2	4500	17664	
3	003c	60	
4	6847	26695	
5	4000	16384	
6	4011	16401	
7	0000	0	
8	0a00	2560	
9	0064	100	
10	d050	53328	
11	7c02	31746	
12	step 1	164938	SUM(B2:B11)
13	step 2	33868	MOD(B12,65536)+BITRSHIFT(B12,16)
14	step 3	31667	BITXOR(B13,65535)
15	in hex	7BB3	DEC2HEX(B14,4)

And so the IP header checksum value is 0x7bb3.

By writing the header in hex to a file with an initial 0 (the offset):

```
0 45 00 ... 7c 02
```

they can be imported into Wireshark to show the values of the header fields:

```
Version: 4
Header length: 20 bytes
Differentiated Services Field: 0x00
Total Length: 60
Identification: 0x6847 (26695)
Flags: 0x02 (Don't Fragment)
Fragment offset: 0
Time to live: 64
Protocol: UDP (17)
Header checksum: 0x7bb3 [correct]
Source: 10.0.0.100
Destination: 208.80.124.2
```

Question 5

The netmask for a /11 network has the 11 MS bits set. In hex this is 0xffc00000. In decimal this is 255.224.0.0.

Question 6

A code contains the following four codewords:

```
0000000
1000011
0111100
1111111
```

(a) The minimum distance of this code can be coputed by finding all $\binom{4}{2} = 6$ distances:

	0000000	**1000011**	**0111100**	**1111111**
0000000		3	4	7
1000011			7	4
0111100				3
1111111				

from which we obtain the minimum Hamming distance of the code as $d = 3$. This code can correct $\lfloor \frac{d-1}{2} \rfloor = 1$ error and detect $d - 1 = 2$ errors.

(b) Since the codeword 1011100 does not match any of the valid codewords, there was an error. The distances to the valid codewords are: 4, 4, 2, 3 so there must be at least two errors. The receiver could guess that the codeword at the minimum distance (0111100, distance 2) was sent. This would minimize the bit error rate.

Although the receiver can do its best to minimize the number of errors, it can never be certain that all errors have been detected or corrected since the channel can convert any valid codeword into any other codeword, including other valid codewords.

(c) The codeword 1100011 does not match any of the valid codewords so there must have been an error. The minimum distance to the codeword 1000011 is 1 so the receiver should guess that this codeword was sent.

As always, the receiver cannot be certain how many errors were introduced by the channel. However, assuming only one error then the receiver can correct the error by choosing the codeword 1000011 which means the second bit was in error.

Question 7

(a) For a distance of 6000 km and a velocity of propagation of 200 m/μs, the one-way propagation delay is $\frac{d}{v} = \frac{6\times10^6}{2\times10^8} = 3\times10^{-2} = 30$ ms. The two-way delay is twice this, 60 ms.

The time to send a packet is $\frac{1250\times8}{1\times10^9} = 10\mu$s. However, there will be a gap of 60 ms between each packet due to the propagation delays for the packet and the ACK. Thus the throughput will be $\frac{1250\times8}{0.060+10\times10^{-6}} \approx 166$ kb/s.

(b) To ensure a throughput of 1 Gb/s, assuming no errors, the transmitter would have to buffer 60 ms worth of packets to ensure the ACK for the oldest buffered packet arrived before the transmitter had to stop to wait for an ACK. Since each packet takes 10 μs to send, this corresponds to $\frac{0.060}{10\times10^{-6}} = 6000$ packets. Since each packet is 1250 bytes long the buffer memory is $6000 \times 1250 = 7.5\times10^6$ bytes (about 7.1 MiB).