Solutions to Midterm Exam

Question 1

(a) $\log_2(4) = 2$ bits can represent four symbols. Since the duration of each symbol is 1 μs, the bit rate is $\frac{2}{10^{-6}} = 2$ MHz.

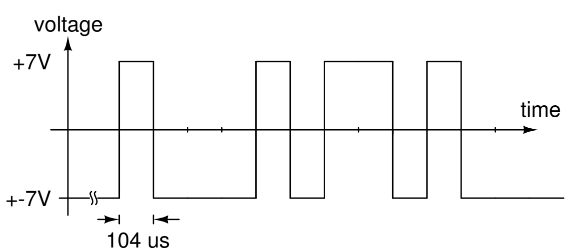
(b) The symbol rate is one symbol every microsecond or 1 MHz.

(c) The information rate can be computed as the product of entropy (bits per symbol) times the symbol rate (symbols per second). The entropy can be computed as $H = \sum_i(-\log_2(P_i) \times P_i) = -0.1\log_2(0.1) - 02.\log_2(0.2) - 0.3\log_2(0.3) - 0.4\log_2(0.4) \approx 1.846$ bits/symbol. At a symbol rate of 1 MHz this is about 1.85 Mbits/s.

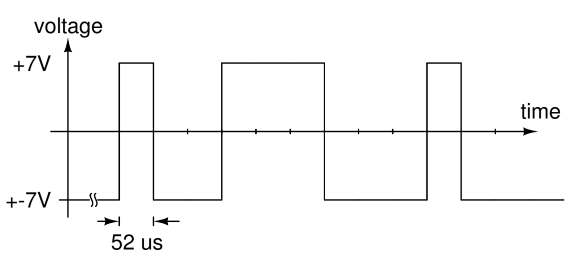
(d) The baud rate is defined by the minimum time between signal level transitions. In this case it is 0.5μs so the baud rate is 2 MHz.

Question 2

There were two RS-232 waveforms:



and



(a) The bit values from MS to LS can be read from right to left from the diagram: 1001 0111=0x97 and 1110 0011=0xE3.

(b) The bit rate is the inverse of the bit durations which are approximately 9600 bps and 19,200 bps.

(c) The bit following the start bit and the 8 data bits is high (0) so it cannot be a stop bit and must be a parity bit. In both cases the number of 1's is odd (5, including the parity bit) so odd parity was used.

Question 3

We can solve the Friis path loss equation:

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

for the distance as a function of the other variables:

$$d = \frac{\lambda}{4\pi}\left(\frac{P_R}{P_T G_T G_R}\right)^{-\frac{1}{2}}$$

which are all given: $\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = \frac{1}{3}$ m, $P_R = 1$ μW, $P_T = 1$ W or 10 W, $G_T = G_R = 10^{10/10} = 10$, $P_R = 1 \times 10^{-6}$. The two answers are: 265 m (for 1 W) and 839 m (for 10 W).

This question was marked out of 4 as noted on the question although the summary at the front shows it being worth 3 marks. Thus the total number of marks on the exam was 34, not 33.

Question 4

The generator polynomial is $x^3 + x + 1$ (1011) which is of order 3 so the CRC has 3 bits. The messages, including the CRC were 011001 or 011101. Dividing the messages by the generator polynomial we get remainders:

```
      ------
1011|011001
      ----
       1100
       1011
```

```
   ----
    1111
    1011
    ----
     100
```

In this case the remainder is not zero so there must have been an error, and:

```
      ------
1011|011101
      ----
       1110
       1011
       ----
        1011
        1011
        ----
           0
```

and in this case there is no remainder so there is not likely to have been an error.

Question 5

An FEC code uses the following four codewords:

```
000110
011011
101100
110001
```

(a) $k = \log_2(4) = 2$ is the number of data bits, $n = 6$ is the number of bits per codeword and $k/n = 2/6 = 1/3$ is the code rate.

(b) The bit differences between the different codewords are shown below:

	000110	011011	101100	110001
000110	000000	011101	101010	110111
011011	011101	000000	110111	101010
101100	101010	110111	000000	011101
110001	110111	101010	011101	000000

and the corresponding Hamming distances are:

	000110	011011	101100	110001
000110	0	4	3	5
011011	4	0	5	3
101100	3	5	0	4
110001	5	3	4	0

so the minimum distance of the code is $d_{min} = 3$.

(c) Since $d_{min} = 3$ this code is guaranteed to detect $d_{min} - 1 = 3 - 1 = 2$ errors.

(d) Since $d_{min} = 3$ this code is guaranteed to correct $\lfloor \frac{d_{min}-1}{2} \rfloor = \lfloor \frac{3-1}{2} \rfloor = 1$ error.

(e) Yes, if the codeword received is not a valid codeword (one in the code), the channel must have introduced an error.

(f) The codeword most likely to have been transmitted is the codeword with the minimum distance to the received codeword. The bit differences and Hamming distances are shown below:

	000110	011011	101100	110001
111100	111010	100111	010000	001101
d	4	4	1	3
100110	100000	111101	001010	010111
d	1	5	2	4

and the decoder will choose the codeword at the smallest distance from the received codeword (101100 for the first example and 000110 for the second).

(g) It is more likely that we receive codewords with fewer errors. However, in the general case where each error is independent, any number of errors is possible. Since the channel could have introduced any number of errors it is possible that any other codeword could have been transmitted.

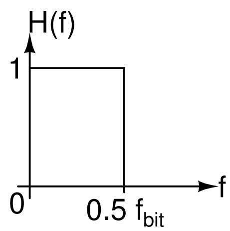
Question 6

(a) Stop and Wait ARQ would be best suited for a communication system operating over a short distance and requiring low-cost hardware because the short distance implies low delay between transmission and ACK. Stop and Wait ARQ also has the lowest implementation cost so it would be most suitable for this application.

(b) If the output data is on TxD (transmit data) the device is a DTE (terminal), if the output is on RxD it is a DCE (communications equipment – modem). A "null modem" (or "crossover cable") would allow these two devices to communicate.

(c) The maximum allowed cable length for a 10BaseT Ethernet link is 100m. If the dielectric constant of the cable is $\varepsilon_r = 2.2$ the velocity factor is $VF = \frac{1}{\sqrt{2.2}} = 0.66$ and the propagation delay is $\frac{100}{0.66 \times 3 \times 10^8} = 0.5\ \mu$s. Due to the error in the question, an answer with ε_r and VF exchanged would also be marked correct.

(d) The minimum channel bandwidth required to transmit a NRZ signal without ISI is half of the symbol rate (0.5 MHz for 1 Mb/s and 1 MHz for 2 Mb/s). A channel with the minimum bandwidth would have a "brick-wall" frequency response ($\alpha = 0$). This is constant from a frequency of 0 (DC) to half of the symbol rate and zero above that:



(e) A transformer is often used to implement a balun[1] for use on twisted-pair links (e.g. Ethernet over twisted pair).

(f) An audio amplifier amplifies baseband (rather than passband) signals so its distortion is more like to be specified and measured using THD.

[1] Refer to the "Transformers" section in Lecture 6 and the corresponding learning objective.