CHANNEL CAPACITY PROBLEM SHEET

(extracted from *Digital Communications* by Andy Bateman- Addison Wesley pp46-47)

1. A data link sends information in packets at a rate of 100 bits in 2.2 ms.

   (a) What is the information rate supported by the channel during the packet burst?

f_d = N bits / transmit time = $100/(2.2\text{x}10^{-3})$ = 45.45 kbits/s

   (b) If packets can only be sent every 5ms, what is the information rate for the channel?

f_d = N bits / transmit time =$100/(5\text{x}10^{-3})$ = 20 kbits/s

2. The information rate for a channel is 2400bps. How long will it take to transfer 1Mbyte of information between 2 computers, over that channel?

t = N bits / f_d = $(10^6\text{x}8)$ / 2400 = 3333s

3. A communication system represents 4 bits by each transmitted symbol. If the system is required to deliver a channel capacity of 9600bps, what symbol rate must the channel be able to support?

f_s = C / b = 9600/4 = 2400Baud

4. If the symbol period as measured on a transmission cable is seen to be 2.5ms, and the system specification states that each symbol represents 6 information bits, what is the channel capacity?

f_s = 1/T = $1/(2.5\text{x}10^{-3})$ 400Baud
C = bf_s = 2.4kbits/s

5. A mobile radio can support a data rate of 28,000 bps within a bandwidth of 25 kHz by encoding 2 bits in each symbol. What is the bandwidth efficiency of the radio link, and what is the baud rate on the channel?

η_B = C/B = 28/25 = 1.12bits/s/Hz
f_s = f_d/b = 28000/2 = 14kBaud

6. A data modem transfers information at the rate of 56 kbps, using 128 signalling states. What is the symbol rate for this application?

f_s = C/b = $C/\log_2 M$ = $56000/\log_2 128$ = 8kBaud

7. If a radio link is required to send digital voice at 4,800 bps (typo here previously), but can only support a symbol rate of 1200 Baud, how many symbol states can be used for this implementation?

$b = C/f_s = 4800/1200 = 4$
$M=2^b = 16$

8. A telephone transmission link has a usable channel bandwidth extending from 0kHz to 3.1kHz and can be assumed to be perfectly flat and distortion free. It is required to send information at a rate of 28.8kbps over this channel. What is the minimum number of symbol states that would be required to support this data rate? How many bits per symbol are required?

$C = 2B\log_2 M$
$\log_2 M = C/2B = 28800/6200 = 4.645$
$M = 2^{4.645} = 25.01 =$ Signalling states (Contradicts Bateman)

9. If a 64 symbol state modem is designed to transfer data at a rate of 2.048 Mbps, what is the minimum bandwidth for transmission assuming baseband signalling?

$C = 2B\log_2 M$
$B = C/2\log_2 M = 2.048\text{x}10^6/2\log_2 64 = 171\text{kHz}$

10. A modem is to be designed for use over a telephone link, for which the available channel bandwidth is 3.0kHz, and the average signal to noise is 30 dB.

    What it is the maximum error free data rate that can be supported on this channel and how many signalling states can be used?

$30\text{dB} = 1000$
$C = B\log_2(1+S/N) = 3000\log_2 1001 = 29.9\text{kbits/s}$
$C = 2B\log_2 M$
$\log_2 M = C/2B = 29901/6000 = 4.98$
$M = 2^{4.98} = 31.55 = 32$ Signalling States

11. A digital television system must support a data rate of 3.5 Mbps within a bandwidth of less than 1.4MHz. What is the minimum S/N ratio in dB that can be tolerated if the link is to provide error-free data communication?

$C = B\log_2(1+S/N)$
$S/N = 2^{C/B}-1 = 2^{3.5/1.4}-1 = 4.65 = 6.7\text{dB}$

12. An underwater communication link suffers from very high signal loss over short distance, such that the maximum E_b/N_0 value achievable is only –0.6dB. What is the maximum bandwidth efficiency that could be expected of this link at the extreme of range, and what is the information throughput that can be delivered in a bandwidth of 3,400 Hz?

-0.6dB = 0.87

$C/B = \log_2(1+E_bC/N_oB) = \log2(1+0.87C/B)$

This can be solved by iterative methods to give a value of C/B of approximately 0.6.

C = 0.6B = 0.6x3400 = 2.04kbits/s

13. The serial ports on 2 computers, which use binary signalling, are connected by a twisted pair cable. The cable has a flat frequency response up to 12 kHz, with negligible group delay distortion.
    (a) What is the maximum information rate that can be accommodated by the cable assuming a noise-free environment?
    (b) If the noise introduced by the cable is –40 dB with respect to the signal power, what is the resulting maximum information transfer rate?

$C = 2B\log_2 M = 2\text{x}12000\text{x}\log_2 2$ = 24kbits/s

N/S = -40dB

S/N = 10000

$C = B\log_2(1+S/N) = 12000\log_2(10001)$ = 159kbits/s

(Note that the second answer assumes non-binary signalling).