Data Provided: None

The University Of Sheffield.

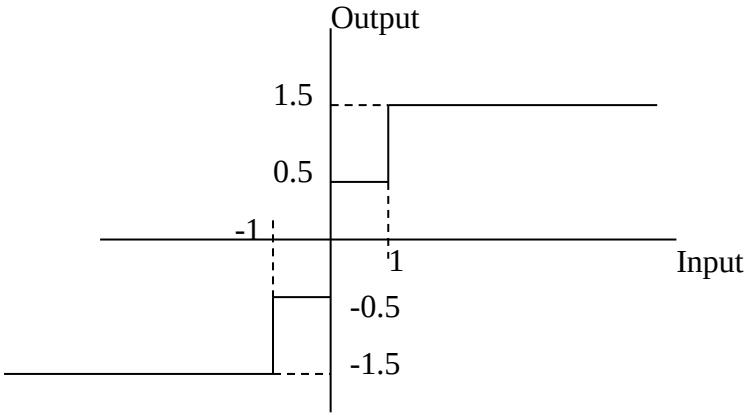
DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2015-16 (3.0 hours)

EEE6222 Principles of Communications

Answer **FOUR** questions. **No marks will be awarded for solutions to a fifth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. The sample function of a Gaussian process with zero mean and unit variance is uniformly sampled and then applied to a uniform quantiser having the input-output amplitude characteristic shown in the following figure.



(i) Calculate the entropy of the quantiser output. (4 marks)

Given:

$$\frac{1}{\sqrt{2\pi}}\int_{x}^{\infty} e^{-y^2/2}\,dy = \begin{cases} 0.5 & \text{if } x = 0 \\ 0.1611 & \text{if } x = 1 \end{cases}$$

(ii) The output of the above quantiser can take four different values and we use the symbols A, B, C, D to represent them respectively. Given a particular digital channel with a bandwidth of 3kHz and a signal to noise ratio (S/N) of 40dB, calculate the maximum number of symbols (A, B, C, D) per second we can transmit through this channel without error. (4 marks)

(8)

b. What is the Shannon limit on the minimum bit energy per noise density ($\frac{E_b}{N_o}$) below which there is no error-free communication? Derive the expression for this limit and show all working.

(6)

c. x and y are two independent random variables with their probability density functions given by $f_X(x)$ and $f_Y(y)$, respectively. Derive the probability density function of their sum z=x+y in detail. **(6)**

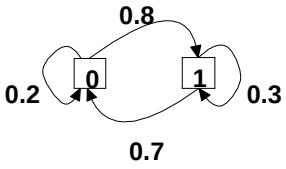
2. **a.** Given four persons, find the probability of at least two of them born in the same month.

(4)

b. Suppose the probability that a lawyer has a car accident in one year is p_1 and for a miner is p_2. If there are 5 times as many miners as lawyers, find the probability that one person selected at random from the combined group will have an accident in the second year if the person has had one in the first year.

(6)

c. A particular information source can be represented by the following Markov model:



(i) Determine the entropy of this source. (5 marks)

(ii) Since this is a source with memory, extension codes can be used to develop a more efficient coding scheme. Determine such a unique, prefix-free coding scheme. (4 marks)

(iii) Determine the coding efficiency for this coding scheme. (1 mark)

(10)

3. **a.** What is Additive White Gaussian Noise (AWGN) and why it is a suitable model for noise in many situations?

(4)

b. MIMO stands for Multiple Input Multiple Output and refers to wireless systems that use more than one antenna at both the transmitter and the receiver. Give a narrowband example to show how the potential of a MIMO system can be exploited in practice.

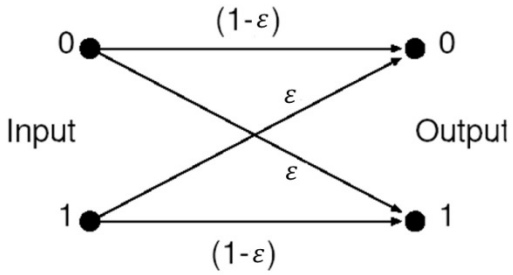
(6)

c. Given a binary symmetric channel with crossover probability ε=0.02 (as shown below), with equally probable inputs, find the mutual information

(i) between a 1 transmitted and a 1 received; (3 marks)

(ii) between a 1 transmitted and a 0 received; (2 marks)

(iii) between the overall input and the overall output.(5 marks)



(10)

4. **a.** The RSA algorithm is a widely used public key technique for implementing the secure sockets layer (SSL) protocol, which uses a combination of public key and conventional encryption techniques for secure communication.

(i) Give a simple outline of the SSL protocol and indicate for which steps the public key techniques are required. (4 marks)

(ii) Alice operates a public key encryption system that uses the RSA algorithm with e = 3, d = 7, N = 33. Assuming that Alice and Bob have never previously met or communicated with each other and Bob wants to send the message M=9 to Alice. Describe each of the steps required to send this message to Alice without anyone else being able to intercept it. (4 marks)

(8)

b. (i) With the aid of an example, explain on which condition a source will reach its maximum entropy. (4 marks)

(ii) Give a proof for the validity of this condition. (8 marks)

(12)

5. **a.** A linear block coding system uses the following codes to send eight different messages.

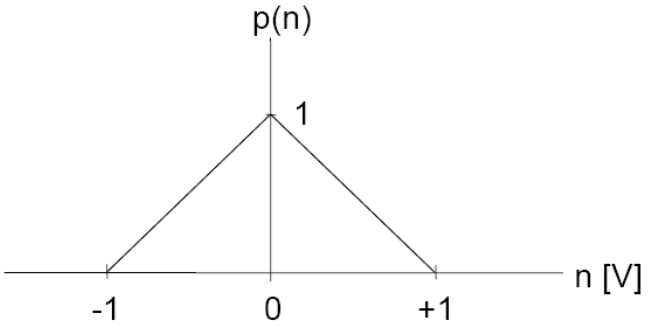
0000	1001	1010	0011	1100	0101	0110	1111

(i) How many bit errors per codeword can be detected at the receiver? **(2)**

(ii) Is forward error correction possible with this code? Why? **(2)**

(iii) Find the code rate for this code. **(2)**

b. A ternary communication system sends three different symbols, S_1, S_2 and S_3, with equal *a priori* probabilities using the voltages –1.6V, 0V and +1.6V, respectively. The transmission channel is subject to additive noise with the probability density function shown in the following figure.



(i) Under the assumption of no attenuation along the transmission channel, determine the decision rule for a maximum likelihood (ML) detector. **(4)**

(ii) Find the overall probability of error for the ML detector in (i). **(6)**

(iii) If a *maximum a posteriori* (MAP) detector is used, the *a priori* probability of S_2 approaches 1, and those of S_1 and S_3 approach 0 (i.e., $P(S_2) \rightarrow 1$, $P(S_1) \rightarrow 0$, and $P(S_3) \rightarrow 0$), then what will change to the decision rule of (i)? What is the probability of error in this case? **(4)**

6. **a.** In a spread spectrum system, the information is transmitted using a much larger bandwidth than required for the baseband data. Pseudo-noise (PN) sequences are usually used as the spreading code.

(i) What are the basic properties that can be applied to test the randomness of a PN sequence? **(3)**

(ii) Illustrate a circuit that can be used to generate a PN sequence. **(3)**

b. There are M users in a multiple-access channel, which supports a total data rate of R bits/s. For a transmission period of T seconds, find the message delays occurred in an FDMA system and in a TDMA system, respectively. **(8)**

c. With the aid of a diagram, explain how a correlation receiver works. **(6)**

WL/XC/MV