M. E. Electronics & Telecommunication Engineering Examination 2025
(1st Year, 2nd Semester)
Information and Coding Theory

Time: 3 Hours **Full Marks: 100**

Use separate answer script for each part
Answer all the parts of a question in the same place

PART I
CO-1

Answer any two questions (Marks: 2×10)

Q1. a) Consider a Discrete Memoryless Source (DMS) 'X' having 'm' number of symbols x_1, x_2, x_3, ... x_m. Define Entropy H(X) corresponding to the source 'X'.

b) State the significance of the following property of H(X):

$0 \leq H(X) \leq \log_2(m)$

c) Define the Information Rate 'R' of the source 'X'.

d) An analog signal is bandlimited to f_m Hz and sampled at Nyquist rate. The samples are quantized into four levels, where each level represents one symbol. Thus, there are four symbols altogether. The probabilities of occurrence of these four levels (symbols) are given below:

$P(x_1) = P(x_4) = 1/8$; $P(x_2) = P(x_3) = 3/8$

i) Calculate the Entropy H(X) of the source 'X'.

ii) Obtain the Information Rate 'R' of the source 'X'.

(2+3+1+4)

Q2. a) Write down the Channel Matrix corresponding to the Discrete Memoryless Channel (DMC) having an input 'X' (consisting of 'm' no. of input symbols $x_1, x_2, x_3, ... x_m$) and output 'Y' (consisting of 'n' no. of output symbols $y_1, y_2, y_3, ... y_n$). Also, state the important properties of this matrix.

b) Describe the following channel models in terms of the channel diagram as well as the channel matrix:

i) Binary Symmetric Channel (BSC)

ii) Lossless Channel

iii) Deterministic Channel

(4+6)

Q3. A DMS 'X' has five symbols x_1, x_2, x_3, x_4, and x_5, where each of the symbols has a probability of 0.2.

i) Draw a neat sketch to construct the Huffman Tree showing each stage clearly. Hence, list down the code words corresponding to each of the above symbols. (no description is needed)

ii) Also, calculate the average code word length, entropy of the DMS 'X' and efficiency of the code.

(6+4)

CO-4

Answer any two questions (Marks: 2×15)

Q4. a) The maximal length sequence (m-sequence) can be generated using Linear Feedback Shift Register (LFSR) and Modulo-2 adder. It is given that the Characteristic Polynomial of an LFSR generator is a primitive polynomial of degree 3 over GF (2) and represented by $G(x) = 1 + x^2 + x^3$. Initialize the 3-stage LFSR with 111 and generate the maximal length sequence (m-sequence) by clearly mentioning the state at the output of each stage of the LFSR after each clock, considering the following hardware structures:

i) Simple Shift Register Generator (SSRG)

ii) Multiple Return Shift Register Generator (MRSRG)

b) Consider a 7-length m-sequence, 1110010, and explain the following properties:

i) Run property ii) Auto-correlation property

(9+6)

Q5. a) State the conditions to be satisfied so that two m-sequences sequences, a and a' should form a preferred pair. Also, write down the Gold Code set corresponding to the preferred pair a and a'. Finally, compare the performances of m-sequence and Gold sequence of length 7 with respect to the number of generated codes as well as auto and cross-correlation properties.

b) Establish that the number of large Set Kasami Sequences is $M = 2^{3n/2}$ for $n = 0 \pmod 4$, stating each step clearly (consider $n = 4$).

(5+10)

Q6. a) State the general properties of Walsh function. Draw 2^n Walsh functions considering the value of n as 2.

b) State the necessity of generating Variable Length Orthogonal Codes in WCDMA system. Generate a set of Variable Length Orthogonal Codes by developing the Code Tree Structure from a matrix C_N of size N X N, which denotes the set of N binary spreading codes of chip length N. Also, list down your observations on this.

(5+10)

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PART II

CO-2

Answer any three questions (Marks: 3×10)

1. a) What do you mean by coding gain? Write the properties of linear block code.
   b) Consider the (7, 4) linear block code whose generator matrix is

$$G = \begin{bmatrix} 1\,0\,0\,0\,1\,0\,1 \\ 0\,1\,0\,0\,1\,1\,1 \\ 0\,0\,1\,0\,1\,1\,0 \\ 0\,0\,0\,1\,0\,1\,1 \end{bmatrix}$$

   Determine the codeword for input [1 0 1 1] and find the parity check matrix H.

(2+3+5)

2. a) Consider a (7, 4) cyclic code with $g(x) = x^3 + x + 1$. Obtain the codeword polynomial in systematic and non-systematic forms for the input sequence [1 0 1 0]. Also determine the syndrome for the received codeword polynomial.

$$r(x) = x^5 + x^4 + x^3 + x^2 + 1$$

   b) Show that syndrome in a cyclic code solely depends on error pattern.

(8+2)

3. a) If the minimal polynomials of α, α^3 and α^5 are $\phi_1(x) = x^4 + x + 1$, $\phi_3(x) = x^4+x^3+x^2+x+1$ and $\phi_5(x) = x^2+x+1$ respectively, then determine the generator polynomial of a BCH code of $d_{min} \geq 7$.

   b) If $r(x) = x^{11}+x^{10}+x^8+x^7+x^6+x^3$ is a received codeword polynomial of a double error correcting BCH code over GF (2^4), then determine syndromes, where the field is defined by the primitive polynomial $p(x) = x^4+x+1$.

(5+5)

4. a) Define conjugates of an element. Find the conjugates of β^7, where β is a primitive element of GF (2^4). The field is defined by the reduction polynomial $p(x) = x^4+x+1$.
   b) What do you mean by minimal polynomial? Find the minimal polynomial of β^7 in the same field.

(5+5)

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CO-3

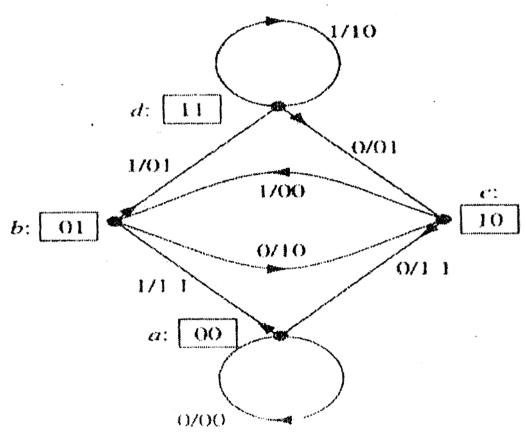
Answer any two questions (Marks: 2×10)

5. a) What do you mean by non-binary error correcting codes? Write the properties of Reed-Solomon (RS) code.
   b) Construct the generator polynomial of a RS (15, 13) error correcting code and determine the non-systematic codeword corresponding to an information block ($0\ 0\ \alpha\ 0\ 0\ 1\ \alpha^7\ \alpha^2\ 0\ 0\ 1\ \alpha\ \alpha^2$) where α is a primitive element over GF (2^4), such that $\alpha^4 + \alpha + 1 = 0$.

(4+6)

6. a) Explain the concept of Maximum Likelihood decoding.
   b) For the state transition diagram of a convolutional encoder shown below suppose the first eight received bits are 01110010. Explain the process of decoding using Viterbi's algorithm.

(2+8)



7. a) Write the advantages of turbo codes. Draw a turbo encoder block diagram and briefly explain its operation.
   b) Write the basic principle of polar codes.

(7+3)