1. Course Profile:

Course Syllabus for ETE-311

1. Title: Information Theory and coding

2. Credits: 3 (3 lectures of 50 minutes per week) **Session:** 2018-19

3. Course Teacher: Eftekhar Hossain, Lecturer, Dept. of ETE, CUET

4. Learning Resources:
Textbook(s):

1. Ranjan Bose – Information Theory, Coding and Cryptography, Second Edition
2. Thomas M. Cover – Elements of Information Theory

5. Course Syllabus : Introduction to Information Theory: Information Rate, Applications of Information Theory. Probability Distribution and Discrete Source, Memory less source. Uncertainty and information.
Entropy: Joint, conditional & relative Entropy, Self and mutual information, Chain rules of Entropy and information, Jensen's inequality and it's consequences, Log sum inequality. Entropy of stochastic process, Markov chain.
Source coding: Fixed and variable length coding, prefix free coding, Source coding theorem, Huffman coding, optimality of Huffman code, Shannon-Fano-Elias coding, Arithmetic code, Lempel Ziv algorithm, Run length code, Efficiency of each code, Rate distortion function.
Channel Capacity and Coding: Channel types and modelling, Capacity of continuous channel, Binary Symmetric Channel, Z channel, Noisy channel coding, Critical rate, Information capacity of various channels, Decoding sphere packing concept, Shannon's limit on communication, Capacity of MIMO systems.
Error control coding: Parity Check, Automatic detection and correction, Linear block Codes & matrix description, hamming code, decoding of linear block code, LDPC codes, Minimum Distance Separable codes, Bounds of minimum Distance.
Cyclic Codes: Introduction and Matrix description, Cyclic Redundancy Check (CRC) codes; Convolutional coding, Tree and Trellis codes, Viterbi decoding of convolutional codes, Trellis Coded Modulation, Mapping by Set partitioning, TCM decoder.
Channel Model: The Gaussian Channel, Band limited channels, parallel Gaussian Channels, Channels with coloured Gaussian noise, Gaussian channel with feedback.

6. Prerequisite(s): Basic Communication

7. Course Designation as Elective or Required: Required

8. Course Objectives:

(a) Introduce with the fundamental concept of entropy and information.
(b) Provide a profound knowledge about core theories and laws of information theory.
(c) Learn the concepts of channel capacity and various source coding and channel coding schemes.
(d) Be able to design and analyze a channel models using channel matrix.
(e) Be able to construct efficient error correction codes for data on imperfect communication channels.

9. Student Learning Outcomes: After successfully completing the course with a grade of D (2.0/4.0) or better, the student should be able to do the following

No.	Course Learning Outcomes (CLOs)	POs#
1	Apply basic information theory concepts to examine various communication projects.	1
2	Explore the significance of Channel Capacity theorem and also can analyze the effectiveness of a designed communication channel.	3
3	Apply different coding and compression techniques in suitable cases such as data storing or communication.	2
4	Design and apply appropriate error correction techniques to minimize the channel imperfection.	3

10. Program Outcomes Addressed: 1, 2 and 3.

CLO#	**Program Outcome (PO)**	**PO#**
1	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of **complex engineering problems**	**1**

3	Identify, formulate, and analyze ***complex* engineering problems** reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences	**2**
2 & 4	Design solutions for **complex engineering problems** and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations	**3**

CLO—PO Mapping

No.	Course Learning Outcomes (CLOs)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
1	Apply basic information theory concepts to examine various communication projects.	X											
2	Explore the significance of Channel Capacity theorem and also can analyze the effectiveness of a designed communication channel.			X									
3	Apply different coding and compression techniques in suitable cases such as data storing or communication.		X										
4	Design and apply appropriate error			X									

	correction techniques to minimize the channel imperfectio n. registers and counters of different type												

11. Assessment Strategy: According to the Undergraduate Academic Rule of the University

Class Tests/Assignments/ Projects:	20%
Attendance:	10 %
Term final :	70%

Lesson Plan

with

Lesson Learning Outcomes (LLOs)

`	Topic	Lesson Learning Outcomes (at the end of the lesson students will be able to …)	Teaching-Learning Methodology	Assessment Method
Lesson-01	Overview of the course	• Summarize the objectives and outcomes of the course	Lecture with whiteboard	Not applicable
Lesson-02	An Overview of the Probability and communication barriers	• Fundamentals of probability, random variable and its characteristics, • Importance of information theory and its applications	Lecture with whiteboard and PPT	Test, exams, quiz, etc
Lesson-03	Introduction to different terms of information theory [1]	• Difference between uncertainty and information • Significance of mutual information and average mutual information • How to interpret the mutual information of binary channel	Lecture with PPT	Test, exams, quiz, etc

Lesson-04	Entropy [1]	• Describe the significance of Entropy • Calculation of Entropy and information • Interpretation of different types of Entropy.	Lecture with PPT	Test, exams, quiz, etc
Lesson-05	Mutual Information [1]	• Describe the relation between Joint Entropy and mutual information. • Mathematical Problem solving	Lecture with PPT	Test, exams, quiz, etc
Lesson-06	Problem solving	• Problems on Entropy and information rate calculation	Lecture with whiteboard and PPT	Assignment
Lesson-07	Relative Entropy and chain rules [2]	• Explain the relation between relative entropy and mutual information. • Chain rules for entropy, relative entropy, and mutual information	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-09	Markov Source [1]	• Markov statistical model for information sources • Markov source entropy calculation using tree diagram and state probabilities.	Lecture with PPT	Test, exams, quiz, Assignment, etc
Lesson-10 & 11	Channel Models, Channel Matrix and Problem Solving [2]	• Construction of channel matrix form channel models • Find different entropy from the channel matrix • Solving problems related to channel matrix	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-12	Source Coding [1]	• Explain the significance of source coding. • Difference between VLC and FLC and its use cases. • Describe the source coding theorem	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-13	Huffman and Shannon Fano Coding [1]	• Explain the concept of prefix code. • Perform source coding using Huffman and Shanon Fano encoding techniques	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-14 &15	Arithmetic Encoding and Decoding [1]	• Describe the procedures of arithmetic encoding and decoding • Utilize arithmetic coding scheme to encode and decode a source symbols	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-16	Lempel Ziv Algorithm [1]	• Explain the concept of Lempel Ziv encoding and decoding scheme • Problem Solving	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-17 & 18	Convex and Concave function, Jensen Inequality [2]	• Explain the underlying importance of convex and concave function on information theory. • Apply Jensen inequality to solve special cases of convexity and concavity	Lecture with whiteboard	Test, exams, quiz, etc

Lesson-19	Compression and Rate Distortion Theory [1]	• Realize the impact of rate distortion theory in compression • Describe the theorem of rate distortion functions	Lecture with whiteboard	
Lesson-20	Channels and Channel Capacity [1]	• Analyze the channel capacity of a binary channel • Describe different special types of channels • Problem Solving	Lecture with whiteboard	
Lesson-21	Channel Coding [1]	• Explain the concept of channel coding • Use this to describe the noisy channel coding theorem	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-22 & 23	Gaussian channel and information capacity theorem [1]	• Explain the difference between gaussian and AWGN channel. • Describe the information capacity theorem • Analyze the tradeoff between SNR and bandwidth • Use this to find the Shannon limits in communication	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-24	Introduction to Error Correcting Codes [1]	• Explain the basic idea behind error correcting codes • Introduce with different type error correcting techniques	Lecture with whiteboard	Test, exams, quiz, assignments, etc
Lesson-25	Linear Block Codes [1]	• Describe the construction linear block codes • Generate codewords that follows the linear block code properties	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-26	Matrix Description of Linear Block Codes and Equivalent codes [1]	• Describe the construction of generator matrix • Use this to generate linear block codes	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-27	Parity Check Matrix [1]	• Describe the properties and construction of parity check matrix	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-28	Problem solving of codeword generation [1]	• Solve various problem related to linear block code generation.	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-29	Fundamentals of Singleton Bound and Nearest Neighbor Decoding [1]	• Realize the minimum distance limit in linear block codes • Describe the nearest neighbor decoding scheme • Examples with problem solving	Lecture with whiteboard	Test, exams, quiz, etc

Lesson-30	Standard Array [1]	• Construction of linear codewords using coset leader and standard array concept.	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-31 & 32	Syndrome Decoding [1]	• Construction of syndrome decoding technique • Problem solving	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-33	Hamming Codes [1]	• Employ Hamming properties to generate hamming codes • Problem solving	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-34	LDPC and Bit Flipping Algorithm [1]	• Design LDPC Codes • Construction of tanner graph to decode a LDPC code using bit flipping algorithm.	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-35	Solving problems of linear block codes [1]	• Solve various problem related to linear block codes, parity check matrix and syndrome decoding.	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-36	Cyclic Codes [1]	• Describe the concept of cyclic codes • Generate cyclic codes using generator polynomials • Construction of syndrome table for cyclic codes encoding and decoding.	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-37	Convolutional Codes [1]	• Describe the concept of convolutional codes • Construct code tree and trellis diagram from convolutional codes • Problem Solving	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-38	Viterbi Algorithm [1]	• Decoding codewords form trellis diagram using Viterbi algorithm	Lecture with whiteboard	Test, exams, quiz, etc
Lesson-39	Makeup classes	• Review of the course		Test, exams, quiz, etc