Math / Electrical and Computer Engineering Course Syllabus

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Class Room:	Hudson Hall 218	**Class Time:**	TTH 1:25 - 2:40 PM

Course Name:	**ECE 590.10 / MATH 590**
Course Title:	**Error Correcting Codes**
Prerequisite(s):	MATH 230/340 probability and MATH 401/501 abstract algebra recommended
Required Text(s):	*Course notes on Sakai*
Other Text(s):	*Error Correction Coding: Mathematical Methods and Algorithms* by Moon (ECCMMA) *Algebraic Codes for Data Transmission* by Richard Blahut (ACDT) *Error Control Coding* by Shu Lin and Daniel J. Costello (ECC) *Information Theory, Inference, and Learning Algorithms* by David MacKay (ITILA)

Course Objectives:

This course will introduce students to error-correcting codes and focus both on their mathematical construction and their many applications. The presentation will target undergraduate seniors and first-year graduate students in mathematics and/or computational science. Our goal is to develop the ability to design and analyze classical and modern methods of error-control coding. We will focus on linear codes, graphical representations, low-density parity-check codes, polar codes, and coding for quantum computing. The treatment is largely self-contained and close connections with abstract algebra and probability theory will be emphasized. This course will:

1. Introduce coding and discuss "What is coding?" and "Why do we use it?". Discuss the Hamming code, simple error models, Hamming distance, and coding gain.
2. Introduce linear codes in terms of generator and parity-check matrices. Discuss coset decomposition and syndrome decoding. Gain the ability to encode and decode simple linear codes. Understand the performance of linear codes using weight enumerator functions.
3. Introduce binary low-density parity-check (LDPC) codes, their graphical representation, and their iterative decoding of via belief propagation (BP) on the Tanner graph.
4. Introduce finite fields, cyclic codes, Reed-Solomon codes, and BCH codes.
5. Introduce quantum error correction via stabilizer codes. Discuss how these codes interact with quantum computing.
6. Introduce polar codes and the information-theoretic idea behind their design and decoding.

Student Evaluation:

- Evaluation will be equally weighted (20% each) between homework, a midterm, computer projects, a final exam, and a final project.
- The midterm exam will be in-class and the final exam will be take home.

Rules and Guidelines:

The class shall follow all established policies of Duke University.

Course Topics:

Unit	Topics	Hours
1	Introduction to Coding / Binary Linear Codes	6.25
2	Graphical Representation and LDPC Codes	5
3	Finite Fields, Cyclic, RS, and BCH Codes	5
4	Quantum Error Correction	6.25
5	Polar Codes	6.25
6	Review and Exams	3.75
	Total Hours	32.5

Schedule:

Date	Lecturer	Topic	Reading	Assignment
01/09/25	Pfister	Introduction: Codes and Distance	Intro Coding	
01/14/25	Pfister	Linear Codes	Intro Coding	
01/16/25	Yao	Covering and Packing Bounds	Notes	Homework 1
01/21/25	Yao	Introduction to Reed-Solomon Codes	Notes + Intro RS	
01/23/25	Yao	Introduction to Reed-Muller Codes	Notes + Symmetry	Project 1
01/28/25	Pfister	Graphical representations of codes	Graphical Representation	
01/30/25	Pfister	LDPC codes and iterative decoding	LDPC, FG, and BP	Homework 2
02/04/25	Pfister	Factor Graphs	LDPC, FG, and BP	
02/06/25	Pfister	Density Evolution	DE	Project 2
02/11/25		canceled		
02/13/25		canceled		
02/18/25	Yao	Cyclic Codes	TBD	
02/20/25	Yao	Finite Fields	Finite Fields and ...	Homework 3
02/25/25		Canceled for QIP		
02/27/25		Canceled for QIP		
03/04/25	Yao	RS Codes	TBD	
03/06/25	Yao	BCH Codes	TBD	Project 3
03/11/25		Spring break (no class)		
03/13/25		Spring break (no class)		
03/17/25*	Yao	Algebraic Decoding		
03/18/25	Pfister	Review		
03/20/25		Midterm		
03/24/25*	Pfister	Introduction to Quantum Error Correction	TBD	
03/25/25	Pfister	Stabilizer and CSS Codes	TBD	Homework 4
03/27/25	Pfister	Hypergraph and Lifted Product Codes	TBD	
04/01/25	Pfister	Decoding	TBD	Project 4
04/03/25		Additional QEC Topics	TBD	
04/08/25	Yao	Polar Codes	TBD	
04/10/25	Yao	Polar Decoding	TBD	Homework 5
04/15/25	Yao	Analysis of Polar Decoding	TBD	
04/17/25	Yao	List Decoding and Dynamic Frozen Bits	TBD	Project 5
04/22/25		Review		

Final Exam Period 7-10 PM on Friday, May 2nd