Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year (New format)	AY2026-2027
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Frederic Ezerman
Course Author Email	fredezerman@ntu.edu.sg
Course Title	Coding Theory
Course Code	MH4310
Academic Units	4
Contact Hours	51
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	MH1201 Linear Algebra II and MH1301 Discrete Mathematics
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	Some exposure to abstract algebra, for example at the level of MH2220 Algebra I, can be beneficial but not strictly required.

Course Aims

This course aims to introduce the topic of coding theory, which studies the design of mechanisms to ensure reliability of data transmission, which includes storage, in the presence of noise. In this course, we will learn about encoding and decoding of data. Our focus will be on linear codes, their properties and trade-offs. We will construct codes and measure their goodness based on meaningful metrics in ensuring data reliability in several modern use cases.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Describe the objectives of coding theory.
ILO 2	Define and give examples of linear codes.
ILO 3	Encode and decode by using linear codes.
ILO 4	Compute the minimum distance of a linear code.
ILO 5	Explain the trade-offs involving code parameters in specific scenarios.
ILO 6	Use linear codes for quantum error control.

Course Content

1. Objectives of error-control coding.
2. Linear codes, their lengths and dimensions.
3. Generator matrix, parity check matrix, and duals of a linear code.
4. Hamming distance/weight and how to compute it.
5. Bounds on code parameters.
6. How to encode and decode.
7. Well-known codes: Hamming codes, Perfect codes, Golay Codes, Reed-Mueller codes
8. Cyclic codes, including BCH codes.
9. Maximum distance separable (MDS) codes.
10. Reed-Solomon codes.
11. Quantum stabilizer codes.

Reading and References (if applicable)

The following two references are available in our library collection in printed and digital formats.

1. The main reference is C. Xing and S. Ling, *Coding Theory: A First Course*. Cambridge Univ. Press, 2004. ISBN-13: 978-0521529235ISBN-10: 0521529239.
2. A secondary reference is W. Cary Huffman and Vera Pless, *Fundamentals of Error Correcting Codes*, Cambridge Univ. Press. 2012. Online ISBN: 9780511807077, DOI: https://doi.org/10.1017/CBO9780511807077.

For introduction to quantum error-control coding, we use the following expositions as reading material. Students can access them through NTU digital library collection. Their respective pdf copies will also be made available in NTULearn's course site.

1. M. F. Ezerman, *Quantum error-control codes*, Chapter 27 in Concise Encyclopaedia of Coding Theory, Huffman, Kim, Sole (editors), Traylor & Francis, 2021. ISBN: 9781315147901 (ebk)
2. M. Grassl, *Algebraic quantum codes: Linking quantum mechanics and discrete mathematics*, International Journal of Computer Mathematics: Computer Systems Theory, 6:4, 243-259, 2021. DOI: 10.1080/23799927.2020.1850530

Note: The above listing comprises the foundational readings for the course and more up-to-date relevant readings will be provided when they are available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Background on modern information system, objectives of error-control coding: what it is and where it is used. Introduction to linear codes.	1,2,3,4	In-person	1. Course content and management briefing. 2. Lecture-based session. 3. Tutorial session	For the lecture: Chapters 1 and 2 of the main textbook and Lecture 1 Slide Deck. For the tutorial: Tutorial Set 0
2	Algebraic Tools	1,2,3	In-person	Lecture, discussion, and tutorial exercises on finite fields, focusing on F_2 and F_3, and polynomial rings over finite fields.	Chapter 3 of the main textbook, Lecture Slide 2, and Tutorial Set 1
3	Linear Codes Part 1	2 and 3	In-person	Lecture, discussion, and exercises on linear codes, generator and parity check matrices, encoding and decoding of linear codes.	Chapter 4 of main textbook, Lecture Slide 3, and Tutorial Set 2
4	Linear Codes Part 2	2, 3, and 4	In-person	Continue lecture, discussion, and exercises on linear codes: minimum distance, decoding techniques, and well-known families of codes.	Chapter 4 of main textbook, Lecture Slide 4, and Tutorial Set 3
5	Bounds in Coding Theory Part 1	4 and 5	In-person	Lecture, discussion and tutorial on various bounds and their roles.	Chapter 5, excepts Section 5.6 and 5.8, of the main textbook, Lecture Slide 5, and Tutorial Set 4.
6	Bounds in Coding Theory Part 2	4 and 5	In-person	Lecture, discussion and tutorial on various bounds and their roles.	Chapter 5, except Sections 5.6 and 5.8, of the main textbook, Lecture Slide 6, and Tutorial Set 5.

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
7	Construction Approaches	2, 4, 5	In-person	Lecture, discussion, and tutorial exercises on propagation rules, Reed-Muller codes. Matrix product construction will be discussed if time allows.	Chapter 6, except Section 6.3, of main textbook, Lecture Slide 7, and Tutorial Set 6.
8	Cyclic Codes	2,3,4	In-person	Lecture, discussion, and tutorial exercises on cyclic codes.	Chapter 7, except Section 7.5, of the main textbook. Lecture Slide 8 and Tutorial Set 7.
9	BCH Codes	3,4,5	In-person	Lecture, discussion, and tutorial exercises on BCH codes as a special class of cyclic codes.	Chapter 8, particularly Section 8.1, Lecture Slide 9 and Tutorial Set 8.
10	Reed-Solomon codes	3,4,5	In-person	Lecture, discussion, and tutorial exercises on Singleton bound and Reed-Solomon codes as a family of MDS codes.	Chapter 8, particularly Section 8.2, of the main textbook, Lecture Slide 10, and Tutorial Set 9.
11	Introduction to Quantum Error Control	5,6	In-person	Introduction to stabilizer formalism in quantum error-correcting codes	Two introductory papers on quantum codes, Lecture Slide 11 and Tutorial Set 10.
12	Quantum Stabilizer Codes	5,6	In-person	Lecture, discussion, and exercises on some good quantum stabilizer codes and how to construct them.	Two introductory papers on quantum codes, Lecture Slide 12 and Tutorial Set 11.

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
13	Open Discussion Session	1,5,6	In-person	This session is reserved for questions and discussion on topics covered as well as topics that many students are interested in. Pointers on some current research directions may be touched upon if time allows.	No prescription

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	During the lecture, concepts and tools are introduced and explained to you. In order to improve the effectiveness of learning, the following steps are taken: 1. While there are prerequisites, concepts needed from linear algebra will be recalled and reinterpreted in the context of the course. Concepts from abstract algebra will be explained as needed. 2. Emphasis will be given on examples and explicit computations, to help give examples of linear codes, compute their minimum distance, and the interplay of the code properties. 3. Motivations from real applications will be provided, to provide contexts where coding theory is being used. 4. Several demonstrations will be exhibited to render the concepts more concrete.
Tutorials	In tutorials, you will mostly be asked to compute codes and their properties, and to use them in different application scenarios. Some problems will ask you to prove or derive properties or construct specific codes from some given ingredients.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Test/Quiz(Mid-semester Quiz Short Answer Questions)	1, 2, 3, 4, 5		30	See the rubric appendix.	Individual	Analytic	Relational
2	Continuous Assessment (CA): Report/Case study(Report on a specific topic in coding theory. The topic can be chosen by the students, divided into small groups, with approval of the course instructor. The use of AI tools are encouraged but not required.)	1, 2, 3, 4, 5		10	See the rubric appendix.	Team	Analytic	Relational
3	Summative Assessment (EXAM): Final exam(Examination (Short Answer Questions))	1, 2, 3, 4, 5, 6		60	See the rubric appendix.	Individual	Analytic	Relational

Description of Assessment Components (if applicable)

Formative Feedback

Feedback will be given after the CA, so that you know where you stand, and what are the weakest points to be improved upon.
Since the class size for this class is not very large, you are welcome to ask for personal consultation should you want or need a more personalized feedback.
After the final exam, the Examiner's Report will be available on NTUlearn.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Creative Thinking	Basic
Curiosity	Basic
Problem Solving	Advanced
Sense Making	Intermediate
Transdisciplinarity	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

As for any class you attend, it is your responsibility to learn the material, whether you decide to attend the class or to read the material, as well as to try out the tutorial questions.

Policy (Absenteeism)

It is expected that we behave responsibly regarding lecture and tutorial attendance. Inform the course instructors if you know ahead of time of excusable absence, e.g., representing NTU for an event, or a prolonged absence of several weeks due to health or other reasons. The objective is ensure care and guidance for those who may need them without compromising privacy and confidentiality.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

Appendix 1: Assessment Rubrics

Rubric for Mid-semester Quiz: Short Answer Questions (30%)

The midterm is to check that the concepts taught in class, in particular the examples seen and the exercises, are clear to you. Therefore, most questions should be doable based on tutorial problem sets and examples already seen.

Rubric for Group Assignment (10%)

We are anticipating that students and teaching faculty members can access AI tools starting AY 2026. This assignment is rather experimental in nature, since we will encourage the use of AI tools for literature gathering, drafting, and verification of facts or known results. You will be divided into small groups of 2 to 3 each. Each group is to come up with a report, say up to 12-page length in a reasonable typeset and format, for evaluation purposes. The report covers a specific topic in coding theory or some families of codes which are not explicitly covered in the lectures and tutorial sections. A list of possible topics and the mechanism of grouping as well as the deadline for submission will be finalized in Week 1 after some feedback from the students. A group may propose a topic not in the list for approval by the course instructors.

Rubric for Examination: Short Answer Questions (60%)

The examination will be a bit different from the midterm in the sense that around 60% of the examination will be in the same spirit as the midterm, namely containing examples and exercises closely related to what was practiced in class. However, there might be around 40% of the examination which contains questions that are more challenging. They may require a deeper understanding of the topics taught. To get a sense if you are ready for these questions, ask yourself: Do I understand the topics enough to correctly and clearly explain to others what they are? Can I come up with new questions regarding the topics seen that were not explicitly covered in class?