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 2
Course Author * Faculty proposing/revising the course	S. N. Piramanayagam
Course Author Email	prem@ntu.edu.sg
Course Title	Introduction to Spintronics
Course Code	PH3414
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	Nil
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to introduce magnetics and spintronics technologies, which are useful in hard disk drives and the emerging field of magnetic random access memories. The course has three parts. The first part provides the fundamentals of magnetism. The second part discusses the basics and recent developments of magnetic recording. The third part discusses the basics and recent developments of spintronics, including magnetic random access memory. The course is suitable for students of Physics, Materials Science and Electrical Engineering (Microelectronics). The course equips you with relevant skills to enable the students to find jobs in the electronics industry.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Explain the difference between ferromagnetic material and other types of materials
ILO 2	Explain what type of material properties are required for storing information
ILO 3	Apply the design principle of a magnetic random access memory to achieve desired performance
ILO 4	Explain the material properties required for a memory
ILO 5	Describe the roles and utilization of MRAM layers in various designs
ILO 6	Explain the physics behind magnetic random access memory
ILO 7	Design a stack of layers for magnetic random access memory
ILO 8	Apply known properties of materials used in memory and storage devices to determine their utility in MRAM and/or hard disk drives
ILO 9	Explain newly emerging topics in Spintronics
ILO 10	Summarize and critically analyse research papers
ILO 11	Present findings from the literature review

Course Content

1 Fundamentals of magnetism
- Introduction to the course
- Magnetism in Electrodynamics perspective
- Atomic magnetic moment
- Exchange interaction
- Ferromagnetic, ferromagnetic materials
- Antiferromagnetic materials
- Hysteresis loops
- Domains and domain wall motion
- Various types of anisotropies
- Hard and Soft magnetic materials

2 Magnetic Recording Technology
- Storage concepts
- Magnetoresistance (MR)
- Spin-valve sensors
- Magnetic recording medium
- Noise Reduction Techniques
- Layered configuration of medium
- Thermal Stability and Media Trilemma
- Emerging Recording Technologies

3 Magnetic Random Access Memory
- Overview of MRAM
- Magnetoresistance
- Various types of MRAM
- Spin-Torque Switching
- Challenges of MRAM
- Emerging Concepts for Storing Big Data
- Spintronics for other applications

Reading and References (if applicable)

1. Developments in Data Storage: Materials Perspective, S.N. Piramanayagam and Tow C. Chong, IEEE-Wiley Press, 2011 ISBN: 9781118096833 (electronic bk.)

2. Introduction to Magnetism and Magnetic Materials, D. Jiles, Chapman & Hall, 1998 ISBN:148223887X 9781482238877

NOTE: The above readings comprise 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	Introduction	1	In-person		Lecture Notes
2	Magnetism	1	In-person		Lecture notes, book by David Jiles
3	Storage concepts	2	In-person		Lecture notes, review paper and book
4	Magnetic Recording medium, Noise reduction techniques	3	In-person	Lecture	Lecture notes, review paper and book
5	Layered configuration of medium, Thermal Stability, Emerging recording technologies	8, 10	In-person	Mid-Term	Lecture notes, review paper and book
6	Read sensors based on giant magnetoresistance & tunnel magnetoresistance	3,5	In-person		Lecture notes, review paper and book
7	Overview of MRAM	4,5	In-person		Lecture notes, review papers and books
8	Various types of MRAM	6,7,9	In-person		Lecture notes, review papers and books
9	Spin-Torque Switching	7,10	In-person		Lecture notes, review papers and books
10	Challenges of MRAM	9, 10	In-person		Lecture notes, review papers and books
11	Emerging Concepts for Storing Big Data	11	In-person		Lecture notes, review papers and books
12	Spintronics for other applications	12	In-person		Lecture notes, review papers and books
13	Seminars	13,14	In-person	Presentations	Self-reading on papers provided by lecturer

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lecture	The lectures introduce condensed information on the subject, which cannot be found in text books or on the web. Class room lectures help you to achieve learning outcomes 1-12
Literature search	You would need to find relevant research articles using library database, thus addressing outcome 13
Presentations	Here, you are given a topic. You would need to go through literature and present a topic. This helps improve your self-learning and communication skills. Learning outcome 14 is achieved in this method

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	Summative Assessment (EXAM): Others([final examination])	1-12		50		Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz([quiz/test] Mid-term Test)	1-8		20		Individual	Holistic	Multistructural
3	Continuous Assessment (CA): Class Participation(Wooclap participation)	1-12		10		Individual	Analytic	Multistructural
4	Continuous Assessment (CA): Presentation([presentations])	13,14		20		Individual	Holistic	Multistructural

Description of Assessment Components (if applicable)

CA1 is a physical mid-term test (closed book), Exam is physical and closed book. CA via WooClap is a class participation activity (attendance is compulsory). CA presentations is done in-person.

Formative Feedback

1. Through the Wooclap assignment, I will regularly monitor and let you know your progress in learning
2. In the tutorial, I will give questions to test your understanding and give you feedback.
3. I will also observe how you perform in mid-term test and give you feedback.
4. In addition, I will go through your presentations, assess your presentation and give you feedback about your understanding.
5. Moreover, I will give regular feedback during the classes.

NTU Graduate Attributes/Competency Mapping

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

Attributes/Competency	Level
Collaboration	Basic
Communication	Basic
Creative Thinking	Intermediate
Problem Solving	Intermediate
Transdisciplinarity	Intermediate

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)

You are encouraged to attend in-person lectures as there are lecture demonstrations, which aid in understanding the topic very well. These demonstrations may not be available or impactful during video watching. Although the lecture may appear to be slow (and video watching enables high-speed listening), the topic is well comprehended by attending in-person lectures. Therefore, you are advised to watch videos only for reinforcing the concepts.

Policy (Absenteeism)

Only in the case of medical/emergencies, you may be absent for the tests or exams. In this exceptional case, there may be a re-test, but please avoid this.

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 Criteria for Rubrics

1. WooClap (Class Participation) gives the students an opportunity to recollect the lecture and reinforce their understanding. This is based on answering multiple choice questions (MCQ). Best 10 out of 13 scores will be taken.
2. Mid-Term test will be a mixture of MCQ and long-answer questions. The student will be tested on magnetism. The student must be able to provide clear and correct answers.
3. The following is the criteria for seminar (presentation).

Criteria	**Standards**		
	Fail standard **8 marks and below)**	**Pass standard** **(9-14 marks)**	**High standard** **(15-20 marks)**
Seminar and presentation (LO 12-14)	You demonstrated no or poor understanding on the paper that you have read. Not able to answer questions	You seem to have read the paper, understood it reasonably well by answering a few questions.	Good presentation Well prepared slides. Able to answer most of the questions accurately.