GE REVISED COURSE CONTENT

Academic Year	2023-2024	**Semester**	1
School/Programme	SPMS		
Course Coordinator	Asst Prof Chang Guoqing		
Course Code	PH7020		
Course Title	Magnetism and Spintronics		
Pre-requisites	No pre-requisites		
No of AUs	4		
Contact Hours	52 Hours		
Proposal Date ***i.e. date proposal was drafted***	Sep 2023		
Expected Implementation date of new/revised course	Jan 2024		
Suggested Class Size	20		
Any cross-listing? ***Is course opened to all Postgraduate students (including IGP) or specific program (please indicate)?***	Yes, SPMS Master by Research		

Course Aims

This course aims to introduces the fundamental physical concepts of spin electronics and the application in technology. This course aims for students who are interests in the research of spintronics. It is also helpful in increasing the chances of students getting hired in the magnetics/spintronics industry. The course is self-contained and there are no prerequisites.

Intended Learning Outcomes (ILO)

By the end of this course, you should be able to:

(1) Understand the fundamental of magnetism
(2) Understand micromagnetism, magnetic textures, and magnetization dynamics
(3) Understand spin transport and dynamics in real materials
(4) Familiar with spintronics technology
(5) Be aware of the frontier of recent research

Course Content

In the course, we will include:

1. History of Spintronics and Magnetism
   - History and overview
   - Classical and quantum spin
   - Spin-orbit interaction
   - Spintronics and magnetism

2. Introduction to magnetic moment
   - Magnetism and filed
   - Classical magnetic moment

- Quantum magnetic moment

3. Isolated magnetic moment
   - Magnetic susceptibility
   - Diamagnetism
   - Paramagnetic
   - Hund's rules
   - Adiabatic demagnetization
   - Nuclear spins
   - Hyperfine structure

4. Environment
   - Crystal field
   - Orbital Quenching
   - The Jahn-Teller effect
   - Nuclear magnetic resonance
   - Electron spin resonance

5. Interactions
   - Magnetic dipolar interaction
   - Exchange interaction
     - Origin of exchange
     - Direct exchange
     - Indirect exchange
     - Double exchange
     - Anisotropic exchange
     - Continuum approximation

6. Order and magnetic structure
   - Ferromagnetism
   - Antiferromagnetic
   - Ferrimagnetism
   - Helical order
   - Measurement of magnetic order

7. Orders and broken symmetry
   - Broken symmetry
   - Landau theory
   - Heisenberg and Ising Model
   - Consequence of broken symmetry
   - Phase transition
   - Rigidity
   - Excitations
     - Domains

8. Magnetism in metals
    - The free electron model
    - Pauli paramagnetic
    - Spin-split bands
    - Spin-density functional theory
    - Landau Level
    - Landau diamagnetism
    - Spin density wave

9. Recent advances in research
    - Topological materials
    - Skyrmions
    - Spin-orbit torque
    - Spin caloritronic
    - Magnonics

Assessment (includes both continuous and summative assessment)

Note: It is advised that Group component and class participation should not be more than 40% and 20% respectively, unless with good justification.

Component	ILO Tested	Weighting	Team/Individual	Assessment Rubrics
1. Class participation	1, 2, 3, 4	20%	Individual	N/A
2. CA1: Presentation	5	40%	Individual	Appendix 1
3. CA2: Project report	1, 2, 3, 4, 5	40%	Individual	Appendix 2
Total		100%		

Description of Assessment Components:

Class participation (20%):
You will be given questions to solve, and the solutions will then be discussed in class. There are 10 sets of questions which will be spread across the teaching weeks. Points will be given as long as you submit your solutions. This is to check your overall understanding of the lectures.

CA1 (40%):
You have to read up on research papers and summarize the recent research progress into a presentation.

CA2 (40%):
The project report contains 2 parts. The first part will be a review of the frontier research and the second part will be your proposal on what could be done in the next 5-10 years.

Formative feedback

You will receive both written and verbal feedback from me about your presentations and final research project report.

Learning and Teaching Approach

Note: Please include and indicate TEL component.

Approach	**How does this approach support you in achieving the learning outcomes?**
Lecture	You will be introduced to fundamental physical concepts of spin electronics and the application in technology via the lectures. Lectures will be used to fill in detail and allow students opportunities for questioning and critique.
Student presentations	You will present your research and findings to the whole class. This supports peer-learning as well as developing research and presentation skills.
Project work	You will engage in project work during class time, under guidance from the instructor. This will permit sharing of ideas amongst students and instant feedback on project work.
Technology-Enhanced Learning (TEL)	This course will use PowerPoint slides with videos embedded and lecture recordings to enhance learning.

Reading and References

- Magnetism in condensed matter, Stephen Blundell Oxford Master Series in Physics
- Introduction to Magnetism and Magnetic Materials, D. Jiles, Chapman & Hall, 1998.

Course Policies and Student Responsibilities

(1) General

You are expected to complete all assigned pre-class readings and activities, attend all seminar classes punctually and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements for seminar sessions they have missed. You are expected to participate in all seminar discussions and activities.

(2) Absenteeism

Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

If you miss a lecture, you must inform the course instructor via email prior to the start of the class.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Guoqing Chang	SPMS-PAP-04-08	81325877	guoqing.chang@ntu.edu.sg

Industry Participation

Company Name	Description of involvement (e.g., co-curation of course, speaker or instructor), include no. of course hours if known.	Contact Person	Email

This course focuses on fundamental physics and related theory. Thus, it does not have industry participation.

Planned Weekly Schedule

Week	Topic	ILO	Readings/ Activities
1	Introduction	1	Lecture notes & Reading and References
2	Introduction to magnetic moment	1	Lecture notes & Reading and References
3	Isolated magnetic moment	1	Lecture notes & Reading and References
4	Environment	2	Lecture notes & Reading and References

5	Interactions	2	Lecture notes & Reading and References
6	Order and magnetic structure	3	Lecture notes & Reading and References
7	Orders and broken symmetry	3	Lecture notes & Reading and References
8-9	Magnetism in metals	3	Lecture notes & Reading and References
10-13	Recent advances in research	4,5	Reading and References

Other information(s)

Nil

Appendix 1: Assessment Criteria for <u>Presentation</u>

Criteria	Standards

	Fail standard (17 marks and below)	Pass standard (18-29 marks)	High standard (30-40 marks)
Knowledge of papers (15 marks)	Demonstrated no or poor understanding	Demonstrated some understanding	Demonstrated full understanding with good presentation and slides
Q&A (15 marks)	Not able to answer questions	Able to answer some questions	Able to answer most of the questions accurately
Participation (10 marks)	Not able to raise any question for other students' presentation during seminar	Raised 1-2 questions for other students' presentation during seminar	Raised 3 or more questions for other students' presentation during seminar

Appendix 2: Assessment Criteria for <u>Project report</u>

Criteria	Standards		
	Fail standard (17 marks and below)	**Pass standard (18-29 marks)**	**High standard (30-40 marks)**
Background (15 marks)	Not well explained	Clear to experts	Clear to general readers
Proposal (15 marks)	No further insight on future research	Some insights on future research	Deep insight on future research
Readability (10 marks)	Many misspellings and typos that greatly affect reading	Some misspellings and typos but not affect reading	Almost no misspellings and typos