MSE 498: Magnetic Materials and Applications

Lectures: Tuesday and Thursday 11:00 am – 12:20 pm, location 305 MSEB
Lecture recordings and presentation slides will also be made available online via Canvas

Instructor: Prof. Axel Hoffmann
Office: Materials Research Laboratory 1021 **Email:** axelh@illinois.edu

Office Hours: Tuesdays and Thursdays 2:00 – 3:00 pm, or via prior appointment
All office hour meetings will be in-person in MRL 1021,
or via Zoom upon prior arrangement

Prerequisites
ECE 340, MSE 304 or PHYS 460. If you have not passed a prerequisite course, please see instructor before continuing.

Mulling Magnetism Monday Mornings (M^4)
Starting in **week 2**, **each Monday at 8:30 am** we will have 30 minutes, where we can informally discuss any random ideas that you may have with respect to magnetism, whether they are related directly to class topics or not. Feel free to bring your coffee and simply have fun with magnets! This session will be conducted via Zoom (Meeting ID: TBD; will be made available in class and on Canvas), and the meeting password will be made available in class.

Course Goals and Objectives
This course will introduce the fundamental concepts that underly the practical use of magnetic materials. We will discuss the different types of magnetic materials, and the basic energies that drive their physical behaviors. A particular focus will also be on the dynamic properties of magnetic materials and their interactions with electrical excitations. These concepts will be reinforced via a micromagnetic simulation project, which allows to directly explore the intricate interplay between different magnetic interactions. The course will discuss these magnetic phenomena in the context of different applications, ranging from biomedical applications to current information technologies. At the same time, we will discuss frontiers of magnetism research, which will be reinforced through the literature review of recently published results.

By the end of this course students will be able to:

- Understand how different magnetic interactions determine static and dynamic magnetic properties
- Use basic micromagnetic simulations
- Quantify fundamental magnetic materials properties
- Design basic components of magnetism based devices

Course Structure
This is a **3 credit hour** (**undergraduate**) or **4 credit hour** (**graduate**) course. Thus graduate students are expected to work approximately 9 hours apart from the total instruction time on the additionals tasks required for literature review and peer review. The course is **16 weeks long**.

You should dedicate approximately **6-8 hours per week** to working on the course itself, but actual time commitments will vary depending on your input, needs, and personal study habits. You are required to log on to the course website a minimum of 2 days per week, but as discussions develop, you will probably need to do so more frequently. For additional information about student commitment, please see the policies page.

Scope

- Fundamentals of magnetic materials
- Magnetic measurement approaches
- Soft- and hard-magnetic materials
- Magnetism and magnetic applications in biology and medicine
- Magnetic thin films
- Magnetization dynamics and spin transport
- Magnetic information technologies

Textbook:
Magnetism and Magnetic Materials
By J. M. D. Coey
Cambridge University Press (2012)
also available electronically from UIUC library

Course Components
This course will consist of the following components:

Live Lectures
Attendance and class participation is encouraged, although all lecture material will also be made available online via Canvas. All the material presented in class is fair game for the homework and examinations. Furthermore, you are expected to check Canvas and your email regularly for course updates.

Readings and Lectures
Each module will contain a list of lessons (recorded live lectures and lecture slides) and assigned readings. In some cases, optional or supplemental readings may be listed for further study. Lessons cover major topics from the readings but do not necessarily include all important information from the readings.

Discussions
Discussions and announcements related to course material will be facilitated by using Canvas. If you need to make a private post, then please email the instructor (axelh@illinois.edu) directly or contact him via Canvas.

Homework
Homework will be assigned weekly on Tuesdays. The homework should be worked on independently and is due within one week.

Micromagnetic Simulation Project
As discussed in detail below each student is expected to contribute to a micromagnetic simulation project, which allows more in-depth exploration of contemporary magnetic scientific problems.

Literature Review
Graduate students in this class are expected to discuss recent research work as explained below.

Lecture policy:
Attendance and class participation is expected, although all lecture material will also be made available online via Canvas. All the material presented in class is fair game for the homework and examinations. Furthermore, you are expected to check Canvas and your email regularly for course updates.

Expectations:
To succeed in this class, you will need to

- Read the assigned reading *before* coming to class, and formulate questions;
- Participate in class;
- Make sure you understand the homework problems and solutions;
- Be able to *correctly* solve problems;
- Seek out help when you have trouble.

Grading:

39575 (Undergraduate)		**39574 (Graduate)**	
Homework	30%	Homework	20%
Micromagnetic simulation project	20%	Micromagnetic simulation project	15%
Midterm	20%	Midterm	15%
		Literature review	15%
		Peer review	10%
Final	30%	Final	25%

All assessment scores will be stored in the gradebook in Canvas. Any errors in grade reporting appearing in the gradebook must be reported within 1 week of the grade being posted in the gradebook or by the last day of class, whichever is earlier. If you have a missing grade, contact the instructor.

Numerical total score corresponds to the following final grades:

A+	(97–100)	B+	(87–89)	C+	(77–79)	D+	(67–69)		
A	(93–96)	B	(83–86)	C	(73–76)	D	(63–66)	F	(0–59)
A-	(90–92)	B-	(80–82)	C-	(70–72)	D-	(60–62)		

Course Materials, Discussions and Announcements:
Course materials, including homework, lecture notes, and lecture recordings will be made available through our course Canvas website at https://canvas.illinois.edu. Furthermore, the

lecture recordings will also be accessible through a dedicated channel in Mediaspace. Discussions and announcements related to course material will be also facilitated via Canvas. If you need to make a private post, then please email the instructor (axelh@illinois.edu) directly or contact him via Canvas. If you have any problems or feedback for the Canvas developers then follow one of the different help options available on the Canvas website.

Homework policy:
Homework will be weekly assigned via the Canvas website on Tuesdays and will typically be due the following week on **Thursdays at 11:59 pm**. The homework will consist of an assignment sheet with problems and your solution must be submitted to Canvas via a PDF file. The *only format* that will be accepted for submission is a single, properly ordered PDF, in portrait format; your name must be printed legibly on the top of the first page. A PDF file consisting of a scanned version of your paper copy will be acceptable. Late submission will be penalized by 50% for each day late. The homework should be worked on independently. After grading, any regrade requests will have to be submitted within *one week* of receiving the graded homework.

Micromagnetic simulation project:
A micromagnetic simulation project will be assigned at the end of **week 3** to groups of 3 or 2 students. Using an online simulation tool will allow to investigate basic magnetic problems that have relevance to typical current research questions. During week 7 and week 9, we will schedule 30 minutes meetings with each project group to discuss progress with the projects. Presentation of the results will be given during class in **week 11** and reports will be due at the end of **week 11**.

Literature review (Graduate students only):
Objective: Read a recent (< 10 years old) journal article on a new magnetic phenomena, material or application. Provide a detailed report that fully discusses the approach, summarizes current state-of-the-art in the topic area, and evaluate novelty of the results.

Due dates: You will need to a select an article of your choice by the end of **week 3 (MM/DD)**. Dates for presentations will be assigned in week 4 and start in **week 5 (MM/DD)**. Written reports will be due within one week after the presentation.

Length and formatting:
Maximum of 5 pages (8.5" x 11" paper with 1 inch margins and 11 point minimum font size);
Maximum of 2 figures
Cite all references; bibliography does not count towards page limit

Presentation:
15 minutes + 5 minutes for discussion (times may be adjusted depending on class attendance); presentations will be given at the end of each lecture starting in **week 5**.

Literature review papers and presentations will be graded on substance and clarity. The grade will be based by 50% on the evaluation from your peers and 50% by the instructor. Note that 10% of your own grade will be for submitting your own peer-evaluation within one week after submission of the literature review paper from your fellow students. Thus, expect to provide one peer evaluations per week starting in week 6.

Written reports:
Both the micromagnetic simulation project and the literature review (for graduate students only) will require the submission of written reports. Written reports are assigned to practice the communication of engineering concepts in writing. They will be graded based on presentation, neatness, correct use of symbols, quality of drawings and diagrams, and clarity of explanation

(60%). Reports should be neat and organized, hand-written or typed. Tables and graphical representations of results should be generated using some software program such as Excel, TecPlot, MatLab, Origin, etc., rather than being hand-drawn. Correct discussion of the scientific problem and correct conclusions are important (40%). Point breakdown for the written report:

- 20% Comprehensive motivation for the project/article
- 20% Correct presentation of the underlying fundamental science
- 20% Presentation quality
- 20% Clarity of discussion
- 20% Use of clear figures

Examinations:
There will be a Mid-Term Exam on **TBD**, and a Final Exam during the week of **TBD**. Both exams will be closed book and closed notes. The exams will be in-person in either the classroom during regular time (midterm) or in a space and time to be determined (final).

Obtaining Help:
The main two ways to obtain help are online via Canvas or in person at the office hours. In cases of emergencies related to exams (*e.g.*, illness) you should email your professor at the earliest possible opportunity.

https://forms.illinois.edu/sec/482802970

Absences:
Excused Absence Request Form: https://forms.illinois.edu/sec/482802970

1. Excuses from assessments will only be given in the following circumstances:
   a. Illness
   b. Personal crisis (*e.g.,* car accident, required court appearance, death of close relative)
   c. Required attendance at an official UIUC activity (*e.g.*, varsity athletics, band concert)
2. In all cases you must complete the online Excused Absence Request Form and upload a scan of the official written documentation explaining your absence.
3. In cases (a) or (b) an official excuse letter from the Dean on Duty must be submitted via the online form within 2 weeks of the due date of the missed assessment, but no later than reading day (December 9). In cases of extended or unusual illness, late submission of excuse documentation will be considered. See Student Assistance Center.
4. In case (c) an official letter from the designated university official must be submitted via the online form at least one week prior to the due date of the missed assessment.
5. If you will not be able to take an exam due to illness or any other reason, you must send email to your professor at the earliest possible opportunity. Excused exams will be replaced by a weighted average of the other exam scores at the end of semester.
6. Notwithstanding the above, at the professor's discretion you may be required to make up any excused work or attend substitute instruction or assessment.

Accommodations:
To obtain disability-related academic adjustments and/or aids, students should contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, e-mail disability@illinois.edu, or go to

the DRES website: https://www.disability.illinois.edu. If you are concerned you have a disability related condition that is impacting your academic progress, academic screening appointments are available on campus that can help diagnose a disability.

For rare circumstances, such as extended illness and family emergencies that make it difficult for you to keep up with coursework, you should contact Professor Hoffmann via an email (axelh@illinois.edu) private message as soon as possible to discuss options. In these cases, I encourage you to reach out to the Dean of Students office, which can help you contact and manage accommodations with all of your courses.

Academic Integrity:
Honesty and integrity are fundamental to our community. Guidelines for academic integrity are detailed in Article 1, Part 4 of the Illinois Student Code. Any confirmed violations of that code will be taken seriously and may result in failure for the course.

Changes to syllabus:
May occur as deemed necessary by the instructor; they will be announced.

Calendar and Topics:
Changes to the schedule will be announced; see the MSE 498 website on Canvas for exact schedule, assignments, and to remain up to date.

Course outline: (topics may be adjusted as needed)

Week 1 8/23 and 25	Introduction to magnetism, magnetic order, dipolar fields, anisotropy	Homework #1 assigned
Week 2 8/30 and 9/1	Basic energies, reversal and thermal stability, single domain particles, domain formations	Homework # 2 assigned Homework # 1 due
Week 3 9/6 and 8	Dynamics and micromagnetic modeling	Homework # 3 assigned Homework # 2 due μ-mag sim. projects assigned
Week 4 9/13 and 15	Spin waves and magnetic excitations	Homework # 4 assigned Homework # 3 due Literature review presentation dates assigned
Week 5 9/20 and 22	Biomagnetism and magnetic nano-particles, biomedical application	Homework # 5 assigned Homework # 4 due Start of literature review presentations
Week 6 9/27 and 29	Magnetic imaging and microscopy	Homework # 6 assigned Homework # 5 due
Week 7 10/4 and 6	Permanent magnets and soft magnets	Homework # 7 assigned Homework # 6 due Progress report μ-mag sim.
Week 8 10/11 and 13	Midterm review and Midterm Exam	
Week 9 10/18 and 20	Interfacial and surface effects, magnetic heterostructures	Homework # 8 assigned Homework # 7 due Progress report μ-mag sim.
Week 10 10/25 and 27	Interlayer exchange coupling, giant and tunneling magnetoresistance, spintronics	Homework # 9 assigned Homework # 8 due
Week 11 11/1 and 3	Student presentations on micromagnetic simulation projects	
Week 12 11/10	Spintronics	Homework # 10 assigned Homework # 9 due
Week 13 11/15 and 17	Spintronics and magnetic recording	Homework # 10 due
Week 14	No classes	Happy Thanksgiving!
Week 15 11/29 and 12/1	Magnetic solid-state memory	
Week 16 12/6	Final Review and Final Exam	