Syllabus for Special Topics in Physics - Condensed Matter Physics:
Advanced Computational Methods in Condensed Matter Physics
PHYS 790A

Andreas Glatz, Department of Physics, NIU
aglatz@niu.edu

Semester:	Spring 2026 (Jan 12th – May 8th)
Class Number	*7432*
Lectures:	Tue & Thu, 17:00 – 18:15
Location:	Online
Office hours:	Tue & Thu, 12:15 – 13:15 or by appointment, La Tourette Hall 217
Webpage:	http://www.aglatz.net/home/teaching/compphys_S2026/

(Planned) Contents

1. *Introduction*
    a. *Floating-point numbers and numerical accuracy*
    b. *Overview of Numerical Mathematics*
        i. *Linear algebra*
        ii. *Numerical integration*
        iii. *Root finding*
    c. *Explicit and implicit PDE discretization*
    d. *(Pseudo) random number generators*
    e. *Data analysis*
2. *Applied parallelization on Clusters and GPUs*
    a. *Introduction to CUDA*
    b. *Complex Ginzburg-Landau equation*
3. *Micromagnetic simulation*
    a. *Landau-Lifshitz-Gilbert equation*
    b. *umax3 simulations*
4. *Applied quantum computing*
    a. *Introduction to quantum computing*
    b. *Introduction to qiskit*
    c. *Examples*
5. *Quantum Monte-Carlo simulations*
    a. *Introduction*
    b. *Examples*
6. *Density Functional Theory/electronic structure calculations*

a. *Introduction*
b. *Applied DFT using quantum espresso*

Course Description and Learning Outcomes

1. *Programming skills and some familiarity with the C programming language are expected. The knowledge of a data plotting software will be very useful.*
2. *This course is does not follow a single textbook. Changes of some sections of the above lecture content are possible. In particular quantum computing requires access to simulators or real quantum processors.*
3. *The main purpose of this lecture is to provide an overview of some advanced methods in computational condensed matter physics and introduce latest developments. The main aim is to serve as a base for possible future computational research projects.*
4. *Format of the lecture: This course is fully online. The first introductory chapter serve as basis for the following content, which are taught as introduction + hands-on applications.*
5. *Course evaluation is based on a single project, which each student works on and gives a short presentation end of February/Beginning of March, an individual, graded midterm task to be solved in 48 hours end of March, and a final project – see below.*
6. *Each student will work on a final project during the last month of the course and present a 10 min presentation during the last class meeting of the semester. The presentation should cover the physics background, numerical realization, and results.*
7. *Lecture attendance is essential, see below.*

Preferred prerequisites: linear algebra, classical mechanics, ED, QM, and statistical physics

Textbook suggestions and resources

- *J. Franklin, Computational Methods for Physics, Cambridge University Press (July 15, 2013)*
- *Nicholas J. Giordano, Hisao Nakanishi, Computational Physics, Addison-Wesley; 2 edition (July 31, 2005)*
- *Alfio Quarteroni, Riccardo Sacco and Fausto Saleri, Numerical Mathematics, Springer; 2nd edition (October 19, 2006)*
- *Curtis F. Gerald and Patrick O. Wheatley, Applied Numerical Analysis, Pearson; 7 edition (August 10, 2003)*
- *Germund Dahlquist and Åke Björck, Numerical Methods in Scientific Computing: Volume 1, Society for Industrial and Applied Mathematics (September 4, 2008)*
- *Jason Sanders and Edward Kandrot, CUDA by Example: An Introduction to*

General-Purpose GPU Programming, Addison-Wesley Professional; 1 edition (July 29, 2010)

- *Mumax3: https://mumax.github.io/*
- *Qiskit: https://www.ibm.com/quantum/qiskit*
- *Quantum Espresso: https://www.quantum-espresso.org/*

See course website for additional textbook references and online resources.

Grading

The final grade is determined according to

- *20%: lecture attendance percentage*
- *20%: 1^{st} project*
- *20%: midterm task*
- *40%: final project*

*This results in a total score between 0 and 1, which is then multiplied by 12, rounded to the closed integer, divided by 3, and finally graded according to**
http://www.niu.edu/regrec/grading/gradingfaqs.shtml

** values below 2 are round to the closed integer*

Academic Integrity

Good academic work must be based on honesty. The attempt of any student to present as his or her own work that which he or she has not produced (including AI generated work) is regarded by the faculty and administration as a serious offense. Students are considered to have cheated if they copy the work of another during an examination or turn in a paper or an assignment written, in whole or in part, by someone else. Students are guilty of plagiarism, intentional or not, if they copy material from books, magazines, or other sources without identifying and acknowledging those sources or if they paraphrase ideas from such sources without acknowledging them. Students guilty of, or assisting others in, either cheating or plagiarism on an assignment, quiz, or examination may receive a grade of F for the course involved and may be suspended or dismissed from the university.

Accessibility Statement

Northern Illinois University is committed to providing an accessible educational environment in collaboration with the Disability Resource Center (DRC). Any student requiring an academic accommodation due to a disability should let his or her faculty member know as soon as possible. Students who need academic accommodations based on the impact of a disability will be encouraged to contact the DRC if they have not done so already. The DRC is located on the 4th floor of the Health Services Building, and can be reached at 815-753-1303 (V) or drc@niu.edu.