PHYS 602: Statistical Mechanics

Spring 2024 Syllabus

Instructor

Prof. Sebastian Deffner
Physics, Rm. 311
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Time and Place

MoWe 1:00pm – 2:15pm
Janet & Walter Sondheim 105

Office hours

Mo 9:00am – 11:00am
Physics, Rm. 311

Textbook (required)

Statistical Mechanics in a Nutshell
L. Peliti
Princeton University Press, ISBN 978-0-6911-4529-7

Literature (highly recommended)

- **Thermodynamics and an Introduction to Thermostatistics (2nd edition)**
  H. B. Callen
  John Wiley & Sons, ISBN 978-0-4718-6256-7
- **Statistical Physics I**
  M. Toda, R. Kubo, & N. Saitô
  Springer, ISBN 978-3-5405-3662-8
- **Statistical Physics II**
  R. Kubo, M. Toda, N. Hashitsume
  Springer, ISBN 978-3-5405-3833-2
- **Introduction to Statistical Physics**
  K. Huang
  Chapman and Hall/CRC, ISBN 978-1-4200-7902-9

Scope

Review of statistical mechanics of ideal systems, non-ideal gases, phase transitions, Monte Carlo methods, non-equilibrium systems.

Dates

- First day of class: January 29, 2024
- Last day of class: May 14, 2024
- No class on
  - March 04, 2024 (APS March meeting)
  - March 06, 2024 (APS March meeting)
  - March 18, 2024 (spring break)
  - March 20, 2024 (spring break)
- Written exam: March 13 – March 27, 2024

Course Objectives and Learning Goals

This course will provide a general overview of the main subjects in modern statistical physics. It will discuss key concepts and methods, introduce the relevant terminology, and develop the main ideas of theoretical understanding. You will solve quantitative and complex problems and develop rigorous derivations. As an advanced course special emphasis will be put on deep understanding and mathematically thorough reasoning.

At the end of the course, you should be familiar with:

1. **Methods of Statistical Physics**
   - Probability theory and distributions
   - Thermodynamics (phenomenology and exact differential equations)
   - Meanfield theory, in particular Ginzburg-Landau theory
   - Stochastic processes (Brownian motion and Langevin dynamics)
   - Evolution in phase and probability space (Louisville, diffusion and Fokker-Planck equations)
   - Monte-Carlo method
2. **Systems in thermal equilibrium**
   - Fundamentals of thermodynamics (laws of thermodynamics, quasistatic processes, equilibrium response functions, equations of state for ideal and non-ideal gases, Maxwell relations)
   - Statistical approach (random walks, ergodic hypothesis, statistical ensemble, Maxwell-Boltzmann distribution and thermodynamic ensembles)
   - Equilibrium phase transitions (phase equilibrium, Clayperon equation, Maxwell construction, Ginzburg-Landau theory, critical exponents)
   - Quantum statistics (Fermi-Dirac and Bose-Einstein distribution)
   - Quantum states of matter (photon bunching, Bose-Einstein condensation, superfluidity, superconductors)

3. **Systems close to thermal equilibrium**
   - Linear response and Onsager relations
   - Transport phenomena (sound waves, heat conduction, Navier-Stokes equation)
   - Nonequilibrium phase transitions (Kibble-Zurek mechanism)
4. **Systems far from thermal equilibrium**
   - Maxwell's demon
   - Fluctuation theorem and Jarzynski equality

Course Format

PHYS 602 is a traditional lecture course. Nevertheless, individual reading will play an important role, probably more so than in any other physics course. Only the most important principles and connections will be discussed in class, whereas a big part of the content will be left for reading.

Feel free to ask questions during the lectures, whether you have difficulties with a concept, notice an error, or want to hear more details about an aspect of the material.

Homework

There will be a homework assignment **every** week. The assignments will be posted on Blackboard every Wednesday after class, and submission is due the following Wednesday at 1:00pm.

A homework assignment will consist of two parts:

- Three more complex problems that have to be worked out and written up in detail at home as a usual homework assignment and submitted. These problems will be graded to 4 points each. It will be expected that the submitted problems be written up in a clear, legible, and organized fashion, complete with appropriate verbal comments and figures, very much like examples in the textbook.
- A reading assignment complementary to the material discussed in class. The homework assignments will contain four questions about the reading material, which will amount to another 8 points.

You are allowed, in fact, encouraged, to form study groups and discuss the material and homework questions with each other. However, at the end, the homework solution must be your own work, not a group product. I will give no credit for obvious copies. After all, you are left to your own devices at the tests and in real life. Learn from each other, but be able to work on your own.

Late homework will not be accepted (no exceptions). Homework will be submitted at the beginning of class on the date it is due. Only submissions in OUR OWN HANDWRITING will be accepted. Submission are to be submitted IN PERSON before class on Wednesdays.

Exams

There will be two exams, one written and one oral. The written exam (over spring break) will be "take home". For this exam you will have 2 weeks to work on the solutions. Expect the exam to be rather challenging and make good use of the 2 weeks, i.e., do not start working the day before you have to submit.

The oral exam will be conducted during the final exam period at the end of the semester. During this exam you will be asked questions to test your conceptual understanding, and you will work out a few simple derivations on the white board.

Grades

Your grade will be determined as weighted average of your written (65%) and your oral (35%) grades.

For the written grade, there is the following point distribution.

1. Homework assignments (12): 20 points each; 240 points in total.

2. Written exam: 50 points, weighted by a factor of 8.2; 410 points in total.

This adds up to a possible total of 650 points. A will be given above 90%, A- for at least 85%, B+ for at least 80%, B for at least 75%, B- for at least 70%, C+ for at least 65%, C for at least 60%, C- for at least 55%, and D for at least 40%.

Full credit requires complete and correct solutions. Similarly to the homework assignments each problem in the exams will be graded to 4 points each. This grading scheme might appear rather generous. However, full credit requires complete and mathematical rigorous solutions. Since PHYS602 is an advanced course, mathematical rigor and physically sound reasoning will be expected.

"Incomplete" is given only in exceptional cases. To be considered for an "I", you must have taken at least one midterm exam, submitted 10 homework solutions, and have C or better standing at the time of incapacitation.

> An example: Assume you have achieved 500 points in your written assignments. This translates to 77%, and hence a B letter grade. Now, assume you get a C+ in your oral exam, then your final grade is determined as
>
> $$3.0 * 0.65 + 2.3 * 0.35 = 2.76\,. \tag{1}$$
>
> Hence, your final grade is a B-.

Academic Integrity

"By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating on a test could result in disciplinary action that may include, but is not limited to, suspension or dismissal." More on the requirements of academic integrity can be found at http://www.umbc.edu/gradschool/procedures/integrity.html

Applied to this course, a proven case of misconduct during a test or a blatant copy or plagiarism of a homework solution "earns" zero on the assignment in question. A second offense will result in failing the course.

On my end, I promise well-prepared lectures, careful and timely grading, and openness.

Title IX

As an instructor, I am considered a Responsible Employee, per UMBC's Policy on Prohibited Sexual Misconduct, Interpersonal Violence, and Other Related Misconduct. While my goal is for you to be able to share information related to your life experiences through discussion and written work, I want to be transparent that as a Responsible Employee I am required to report disclosures of sexual assault, domestic violence, relationship violence, stalking, and/or gender-based harassment to the University's Title IX Coordinator.

As an instructor, I also have a mandatory obligation to report disclosures of or suspected instances of child abuse or neglect.

The purpose of these reporting requirements is for the University to inform you of options, supports and resources; you will not be forced to file a report with the police. Further, you are able to receive supports and resources, even if you choose to not want any action taken. Please note that in certain situations, based on the nature of the disclosure, the University may need to take action.

COVID-19

Please see this Google doc for UMBC Policies and Resources during COVID-19.

Disabilities

- If you have any condition such as a physical or learning disability, which will make it difficult for you to carry out the work as described or which will require academic accommodations, please notify me ASAP, but definitely during the first two weeks of classes.
- If you are taking the exam with Student Disability Services, remind me by email 48-96 hours before every exam to give me time for proper preparation. You also need to schedule the exam with Student Disability Services.