PHYS 602: Statistical Mechanics

Spring 2017 Syllabus

Instructor

Prof. Sebastian Deffner
Physics, Rm. 311
deffner@umbc.edu

Time and Place

WeFr 1:00pm – 2:15pm
Meyerhoff Chemistry 256

Office hours

Fr 10:00am – 12:00pm

Textbook (required)

Introduction to Statistical Physics
K. Huang
Chapman and Hall/CRC, ISBN 978-1-4200-7902-9

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

Scope

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

Dates

- First day of class: February 01, 2017
- Last day of class: May 12, 2017
- No class on
  - March 15, 2017 (APS March Meeting)
  - March 17, 2017 (APS March Meeting)
  - March 22, 2017 (spring break)
  - March 24, 2017 (spring break)
- First midterm exam: March 06, 2017
- Second midterm exam: April 17, 2017
- Final exam: tbd

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. It is important that we do not move on until all the important issues are settled.

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.

Only hand-written original submissions will be accepted. Late homework and obvious copies will not be accepted (no exceptions). Homework will be submitted at the beginning of class on the date it is due.

Exams

There will be two midterm exams during the semester, covering specific sections of the material. The final exam will be cumulative. All tests are closed book, and the value of fundamental constants will be listed on the test sheet. If I ask a question that requires the knowledge of a complicated result – e.g. a H-atom wave function – I will provide that equation as part of the question.

If you miss a test for medical or other unavoidable reason, provide proof, and we will arrange for a make-up test. If you know that you will have to miss a test for a foreseeable reason (religious holiday, court date, family event, existing medical problem, etc.), make arrangements before the test, rather than after.

Grades

Your grade will be determined according to the following distribution of points:

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

2. In-class tests (2): 20 points each, weighted by a factor of 9.5; 380 points in total.

3. Final exam: 40 points, weighted by a factor of 9.5; 380 points in total.

This adds up to a possible total of 1000 points. Approximately, A will be given above 87.5%, B for at least 75%, C for at least 62.5%, and D for at least 50%.

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 correct 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.

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.

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 yourselves.