Phys 642: Advanced Topics: Statistical Mechanics II
Fall 2021

THE UNIVERSITY OF TENNESSEE KNOXVILLE
DEPARTMENT OF PHYSICS & ASTRONOMY

Course Description & Syllabus

Faculty Contact Information

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Meeting Time

Monday/Wednesday/Friday 1:00 - 1:50 PM in P306

Office Hours

Friday 3:00 - 4:30 PM

Course Description

Statistical Mechanics employs the tools of probability to understand the average behavior of macroscopic bodies, that is systems consisting of large numbers of individual interacting components (atoms, molecules, etc.). Although we can write down physical laws which are obeyed at the microscopic level, solving the resulting equations of motion (for either classical or quantum degrees of freedom) may note be possible when N, the total number of particles is large. The tools of statistical mechanics will allow us to understand the emergence of observable macroscopic properties including such concepts as heat, temperature and entropy.

This graduate level course builds on undergraduate training in thermodynamics and statistical mechanics and will utilize and expand upon foundational concepts including phase space and state variables. We will focus on the theoretical description of the phases of matter and the transitions between them, paying special attention to the universal physics that arises at continuous second order phase transitions. Modern computational techniques will be employed including Monte Carlo methods for studying models of magnetism.

An outline of topics that will be covered includes:

1. Review: thermodynamics, statistical physics, partition function, Liouville's theorem.
2. Phases and Models: solids, liquids and gases, magnetism and the Ising model, and symmetry breaking.
3. Exact Solutions: Ising model in 1 and 2 spatial dimensions.

4. Approximation Methods: mean field theory, low and high temperature expansions.
5. Critical Phenomena in Fluids: phase coexistence, the van der Waals equation and critical exponents.
6. Landau Theory: order parameters, continuous phase transitions and correlation functions.
7. Fluctuations: breakdown of Landau theory and the Gaussian approximation.
8. Anomalous Dimensions: the failure of simple dimensional analysis
9. The Renormalization Group: real space block spins, fixed points and scaling.
10. Extra Topics: continuous symmetry and the Kosterlitz-Thouless transitions, quantum phase transitions, advanced numerical methods.

Prerequisites

To be successful in this course you will need an understanding of thermodynamics and statistical mechanics at the undergraduate level. We will spend the initial few weeks reviewing the relevant concepts, e.g. partition functions and statistical ensembles.

Student Learning Outcomes

This course aims to provide students with the skills needed to analyze experiments in condensed matter and materials science. Students will learn methods and algorithms for studying magnetic lattice models at zero and finite temperature, including the derivation of effective classical field theory descriptions.

Value Proposition

Students will develop the intuition needed to construct effective models of complicated real-world systems and understand the role of universality in physics.

Course Format and Expectations

Lectures: Three in-class meetings per week which will include the introduction of theory, mathematical formalism and techniques as well as opportunities for in-depth discussion of experimental phenomenology. Detailed lecture notes will be provided.

Assignments: Your understanding of the material covered in lectures and the assigned reading will be tested via bi-weekly assignments requiring complete solutions to 4-5 problems. You will be graded on completeness and correctness as well as organization of your solutions.

Midterm: A take-home midterm exam will require you to apply methods we have discussed in lecture to a challenging problem. You should budget 10 hours to complete the test.

Final Project: The final project will be assigned after the midterm and it is expected that you will spend 2-3 hours per week working on it independently, culminating in a research report and possible software solution to be handed in during the final week of classes.

Canvas

All course details, assignments, lecture notes and announcements will be available on Canvas at `https://utk.instructure.com/`. You are required to be aware of anything posted to the course website on Canvas and monitor your `netid@utk.edu` email address.

Reference Materials

I will provide copies of my lecture notes on Canvas. There is no specific textbook for the course but we will follow a number of sections from: N. Goldenfeld, *Lectures on Phase Transitions and the Renormalization Group*, Addison-Wesley (1992).

A list of suggested additional references include:

- H. Nishimori and G. Ortiz, *Elements of Phase Transitions and Critical Phenomena*, Oxford University Press, Oxford (2010).
- N. Goldenfeld, *Lectures on Phase Transitions and the Renormalization Group*, Addison-Wesley (1992).
- R. J. Pathria, *Statistical Mechanics*, Butterworth-Heinenmnann (2001).
- L.D. Landau and E.M. Lifshitz, *Statistical Physics*, Vol. 1, 2. (1976).

Grading & Policies

Participation	10%
5 Assignments	40%
Midterm Exam	25%
Final Project	25%

No late assignments will be accepted. The lowest assignment grade will be dropped at the end of the semester.

Religious Holidays

Students have the right to practice the religion of their choice. If you need to miss class to observe a religious holiday, please submit the dates of your absence to me in writing via email by the end of the second full week of classes. You will be permitted to make up work within a mutually agreed-upon time.

Statement on Civility & Community

The Department of Physics & Astronomy at the University of Tennessee is committed to creating an environment that welcomes all people, regardless of their identities. We value the diversity that enriches our department. We understand the importance of free and open dialogue that includes the free exchange of ideas. We do not tolerate uncivil speech or any form of discourse that infringes on others' rights to express themselves, or has a negative impact on their education, or work environment. We actively promote an environment of collegiality and an atmosphere of mutual respect and civility. We understand that respect includes being considerate of others' feelings, circumstances, and their individuality. We recognize the necessity of a civil community in realizing the potential of individuals in teaching, learning, research, and service. We believe these values extend beyond the department into our work within physics regionally, nationally, and internationally, as well as work and studies in the university, and the broader community. We encourage all members of the department to intervene and report any incidents involving bigotry, or that violate the university code of conduct.
`http://www.phys.utk.edu/about/civility-community.html`

Campus Syllabus

University Civility Statement

“Civility is genuine respect and regard for others: politeness, consideration, tact, good manners, graciousness, cordiality, affability, amiability and courteousness. Civility enhances academic freedom and integrity and is a prerequisite to the free exchange of ideas and knowledge in the learning community. Our community consists of students, faculty, staff, alumni, and campus visitors. Community members affect each other’s well-being and have a shared interest in creating and sustaining an environment where all community members and their points of view are valued and respected. Affirming the value of each member of the university community, the campus asks that all its members adhere to the principles of civility and community adopted by the campus.”
`https://civility.utk.edu/`

Emergency Alert System

The University of Tennessee is committed to providing a safe environment to learn and work. When you are alerted to an emergency, please take appropriate action. Learn more about what to do in an emergency and sign up for UT Alerts. Check the emergency posters near exits and elevators for building specific information. In the event of an emergency, the course schedule and assignments may be subject to change. If changes to graded activities are required, reasonable adjustments will be made, and you will be responsible for meeting revised deadlines.
`https://safety.utk.edu/`

Academic Integrity

Each student is responsible for his/her personal integrity in academic life and for adhering to UT’s Honor Statement. The Honor Statement reads: “An essential feature of the University of Tennessee, Knoxville is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.”

Your Role in Improving This Course Through Assessment

At UT, it is our collective responsibility to improve the state of teaching and learning. During the semester you may be requested to assess aspects of this course either during class or at the completion of the class. You are encouraged to respond to these various forms of assessment as a means of continuing to improve the quality of the UT learning experience.

Students with Disabilities

Any student who feels they may need an accommodation based on the impact of a disability should contact Student Disabilities Services in Dunford Hall, at 865-974-6087, or by video relay at, 865-622-6566, to coordinate reasonable academic accommodations.
`https://sds.utk.edu`

Accessibility Policy & Training

`https://accessibility.utk.edu`

Wellness

The Student Counseling Center is the university's primary facility for personal counseling, psychotherapy, and psychological outreach and consultation services. The Center for Health Education and Wellness manages 974-HELP, the distressed student protocol, case management, the Sexual Assault Response Team, and the Threat Assessment Task Force.
`https://counselingcenter.utk.edu/` and `https://wellness.utk.edu/`