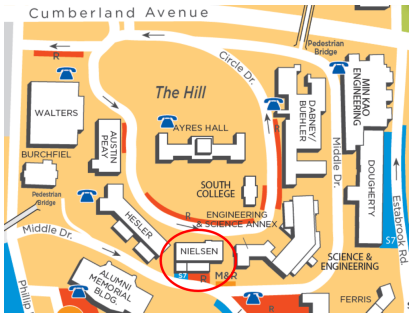
Physics 551: Statistical Mechanics, Fall 2022

University of Tennessee, Knoxville

Time: TR, 2:30 PM–3:45 PM
Place: Nielsen Physics Building - 306



Instructor: Maxim O. Lavrentovich

Office location: Nielsen 406A
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Course description: A course on graduate-level statistical mechanics. Thermodynamics. Ensembles. Kinetic theory. Quantum ideal gases. Interacting systems. Phase transitions. Fluctuations and out-of-equilibrium systems.
Credit Hours: 3
Course Section: 001
Notes: This is a graduate-level course! This course requires some familiarity with quantum mechanics and thermal physics at the undergraduate level. A knowledge of graduate-level classical and quantum mechanics is preferred, as well.

Overall Goals and Learning Objectives

Statistical mechanics is the study of the behavior of systems consisting of countless (10^{23} and more!) particles, including materials you encounter every day: solids, liquids, gases, and liquid crystals. Statistical mechanics derives coarse-grained, probabilistic descriptions of these systems starting from the fundamental laws governing the individual particles. As such, this course is a synthesis of all other physics topics which deal with single particles (quantum and classical mechanics) and fundamental forces (electricity and magnetism). By the end of the course, you will (hopefully) see how all of the different physics concepts you learned in other classes fit together. You will be able to:

- understand the statistical basis of thermodynamics, especially the second law
- explain how time-irreversible phenomena can arise from reversible microscopic laws
- describe the motion of a collection of particles using a phase space density
- give a precise definition of temperature
- use the virial expansion to calculate the effects of particle interactions in gases
- apply quantum mechanics to derive properties of fermion and boson gases
- appreciate the universal aspects of systems near phase transitions and the conceptual

beauty of scaling and the renormalization group

- model thermal fluctuations and deviations away from equilibrium

How to Be Successful in This Course

Perhaps the most important figures in the development of statistical mechanics (not incidentally both working during the *fin de siècle*) are Josiah Gibbs and Ludwig Boltzmann. In the almost 150 years since, there have been countless books written on this topic. You should feel free to find a source or multiple sources which work best for you. The class lectures will also present topics in a unique way, so it will be important to *regularly attend class and take your own notes.* Recording your own notes will help reinforce the concepts in your memory. If you have to miss a lecture, please contact the instructor for information about what was covered. Supplemental reading material will also be provided during the course from time to time.

The majority of the learning will take place during the *completion of the homework assignments.* You should start on the assignments as early as possible, and not hesitate to ask questions about the problems. The homework should take up the majority of the work for this course outside of the classroom. You are expected to discuss with your fellow classmates, but any work you turn in should be your own. DO NOT copy solutions to problems from Internet sources. This is an act of **plagiarism** and is a serious offense as detailed in the Academic Honesty Policy.

Finally, please be sure to contact the instructor immediately about any concerns about credits earned on exams, homework, and the participation-related grade.

Materials and Textbooks

Since it is best to have some organizational principle for the topics covered, we will have a single "required" book, which is written in a modern style. However, if you find the required book unhelpful, please feel free to look at different books!

- Required textbook: *Statistical Mechanics* by R. K. Pathria and Paul D. Beale, Academic Press; 4th Ed. ISBN: 978-0-08-102692-2. This is a brand new edition (2022) of this classic textbook. It is comprehensive and now covers important recent topics, including fluctuation theorems and non-equilibrium dynamics.
- Optional textbook more popular in other versions of this course: *Statistical Physics of Particles* by Mehran Kardar, Cambridge University Press; 1st Ed. ISBN: 978-0-521-87342-0. This book is more terse, but a very popular choice. Previous versions of this course use this book.
- There is a new book that tries to cover many different topics, probably according to the taste of the author: *Statistical Mechanics: Entropy, Order Parameters, and Complexity* by James P. Sethna, Oxford University Press; 2nd Ed. ISBN: 978-0-19-886524-7. This book might be a good source of examples and avenues for exploration

beyond the confines of the class.

- You are under no obligation to follow the required book! If you do not like it, feel free to use another resource. I will be able to tell you which sections to read in your book of choice. Just ask! I recommend you search around for the resource that works best for you! I will also be posting my notes on the Canvas site.

Homework Assignments

Homeworks will be assigned roughly every two weeks. The homeworks will be due on Tuesdays at the start of class. *Electronic* copies must be turned in to the instructor on the due date before midnight. Homework submitted after the deadline *will not count.*
Exception: students who are typesetting their homework using LaTeX will receive an extra 48 hours to complete the assignments. They may turn their homework in electronically via e-mail (pdf and TeX formats).

Remember that these assignments will constitute the most important component of the course. Please take your time and put down as many details as possible for the problems. Partial credit will be awarded for demonstrating a correct train of thought. On certain homework assignments, extra credit opportunities will be available.

Quizzes

Participation is an important component of any classroom. I strongly encourage you to attend class and to ask questions! To help you motivated to come to class, short quizzes will be given on certain lecture days on the class Canvas website. These are intended to make sure you are regularly attending the lectures and following the class material. The quizzes will be graded based on completion.

Exams

There will be a midterm and final exam. These exams will be open textbook and open notes. Both of the exams will be timed take-home exams where you get a 24 hour period to complete and send in the exam. The times and dates of these two exams will be announced later.

Grades

The homework is the most important component of your success in the course. The grade distribution reflects this philosophy.

Grade Distribution	
Homework	30%
Quizzes/Participation	10%
Midterm Exam	30%
Final Exam	30%

Letter Grade Distribution			
≥ 90.00	A	70.00 - 72.99	C
87.00 - 89.99	A−	67.00 - 69.99	C−
83.00 - 86.99	B+	63.00 - 66.99	D+
80.00 - 82.99	B	60.00 - 62.99	D
77.00 - 79.99	B−	57.00 - 59.99	D−
73.00 - 76.99	C+	≤ 56.99	F

Note that in some tests and homework assignments, a scaling may be applied. The scaling will not lower your grade.

Announcements

Please check the Canvas site for the course regularly for announcements and postings!

Academic Integrity

Working together on homework assignments and discussing with classmates outside of class is encouraged! However, work you turn in should be your own. Please take the time to demonstrate your own thoughts about the solutions and derivations. This is in keeping with the university honor statement:

> 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.

Accommodations

Please contact the instructor about any concerns or any need for accommodations! The official statement on accommodations is:

> Any student who feels s/he may need an accommodation based on the impact of a disability should contact Student Disability Services in Dunford Hall, at 865-974-6087, or by video relay at 865-622-6566, to coordinate reasonable academic accommodations.

Additional contact information:

Disability Services
915 Volunteer Blvd/100 Dunford Hall
Knoxville, TN 37996-4020
e-mail: `ods@utk.edu`
website: `http://ods.utk.edu/`

Tentative Schedule of Topics

Weeks	**Topic**	**Chapters**
1-2	statistical foundations of thermodynamics, entropy, micro/macrostates, classical ideal gas	1
3-4	phase space dynamics, kinetic theory of gases, BBGKY heirarchy, Boltzmann equation	2, other sources
5-6	canonical and grand canonical ensembles, phase equilibria	3-4
7-9	quantum ideal gases, bosons, fermions	5-9
10-11	interacting particles and fields, virial/cluster expansion	10-11
12-14	phase transitions, criticality, scaling, renormalization group, spin models (Ising, spherical)	12-14
15	fluctuations, Langevin theory, Onsager relations, non-equilibrium statistical mechanics	15