Phys 912- Statistical Physics

Tuesday and Thursday, 9:30AM-10:45 AM Jorgensen Hall 247

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Office Hours: drop in or better make an appointment, e.g. in person after class

Brief overview:

No matter what area of physics you decide to pursue in your career one thing is for sure, you will need knowledge about thermodynamics and statistical physics because all phenomena take place at $T > 0$. This course starts with a very brief reminder of the basics of thermodynamics followed by an introduction into statistical physics.

Thermodynamics started as the science dealing with the transformation of heat into mechanical work and vice versa. However, as the subject developed, its scope became much broader. Today, thermodynamics is a phenomenological theory concerned with the macroscopic or large-scale properties of matter in general. The thermodynamic relations, for instance the relation between the heat capacity measured at constant pressure and the heat capacity determined at constant volume, are derived from a small number of principles which are generalizations of experimental experiences. The results of thermodynamics are fundamental and probably more widely used throughout science and engineering than any other theory.

Statistical physics aims on the microscopic foundation of thermodynamics. It seeks not only for the derivation of the general laws of thermodynamics from first principles but also for the derivation of specific thermodynamic functions. Having that said, we will emphasize throughout the course that statistical mechanics cannot derive e.g., the second law of thermodynamics without ad hoc assumptions which cannot be deduced from first principles. Nevertheless, the formalism of statistical mechanics closes an important gap left by thermodynamics. Statistical mechanics allows calculating equilibrium properties such as the temperature dependence of the heat capacity of solids on the basis of a given microscopic Hamiltonian.

Outline of what we intend to cover this semester

1. Introductory remarks

2. **Brief reminder to thermodynamics**
   2.1 Laws of thermodynamics
   2.2 Consequences from the existence of entropy
   2.3 Thermodynamic potentials
   2.4 Thermodynamics in static electric and magnetic fields

3. **Kinetic Theory**
   3.1 The classical limit and ideal gas equation of state
   3.2 Boltzmann transport equation and H-theorem

4. **Statistical mechanics**
   4.1 Concept of the Gibbsian ensemble
   4.2 Microcanonical ensemble
   4.2.1 Information entropy
   4.2.2 Thermodynamics in the microcanonical ensemble

   4.3 **Canonical ensemble**
   4.3.1Partition function and Helmholtz free energy
   4.3.2 Thermodynamics of interaction free systems

   4.4 **Grandcanonical ensemble**
   4.4.1 Partition function and grandcanonical potential
   4.4.2 Quantum statistics of free particles
   4.4.3 Bose-Einstein distribution function
   4.4.4 Fermi-Dirac distribution function
   4.4.5 Ensemble equivalence in the thermodynamic limit

5. **Selected topics and applications of the formalism**
   (*Most likely we will not find time to make it through the complete list beyond 5.3.3***)**
   5.1 **photons, phonons & magnons**
   5.1.1 Photons and Planck's black body radiation law
   5.1.2 Atomic Vibrations in Solids: phonons
   5.1.3 Equipartition theorem
   5.1.4 Spin waves and magnons
   5.2 Electrons in metals

   5.3 **Magnetic model systems**
   5.3.1 Paramagnetism
   5.3.2 Ising chain
   5.3.3 Mean-field theory
   5.3.4 Low and high-temperature expansions

5.4 **Phase transitions**
5.4.1 Phase diagrams
5.4.2 Landau theory
5.4.3 Critical phenomena

6. **Mathematical appendix**
   6.1 Thermal averages using the density operator
   6.2 Probability theory
   6.3 Counting microstates

Classes begin	August 25
Fall Semester Break (student holiday)	October 19-20
Thanksgiving Vacation	November 26-November 29
Last day of classes	December 10

Homework: There will be about 10 assignments during the semester. All homework problems have an equal weight of 10 points unless indicated otherwise. The solutions should clearly explain all the important steps. You may discuss ideas and approaches with other students after you have spent some time thinking about these problems. However, you are required to complete all the technical steps yourself. Remember that homework is an important part of your learning. You will very likely fail your exams if you don't do it carefully.
Homework should be handed in personally during class. Late homework will be accepted only as an exception. Homework is likely to be graded by a teaching assistant. If you believe your grade is incorrect or unfair please first approach the TA before you approach me with your appeal. An appeal must take place prior to the due date of the next homework, after which it becomes final.

A general piece of advice:
Over the years I have frequently witnessed that students get the wrong impression regarding the difficulty of thermal physics when they linearly extrapolate from the first homework assignments and perhaps even the first midterm. It is the nature of the subject, which utilizes knowledge from mechanics to electrodynamics and quantum mechanics and integrates it into the context of statistical physics, which gives rise to the fact that this course must evolve into a demanding but also potentially rewarding learning experience. Please make sure that this insight doesn't catch you by surprise half way through the course by giving it your full attention from the start while keeping the tension up.

Exams:

Midterm Test1	October 13 (Tuesday, during regular class hours)
Midterm Test2	November 10 (Tuesday, during regular class hours)
Final Exam	December 16 (10:00 to 12:00 noon Wednesday)

Equation sheets with other useful information might be provided as part of the exam. All exams are closed book and comprehensive.

Missed tests: You must notify the instructor if you miss a test or exam for a legitimate reason (illness, family emergency, or job-related absence such as attending a conference). You will either be given a make-up test, or the weight of the missed test will be reallocated to other assignments, at the instructor's discretion.

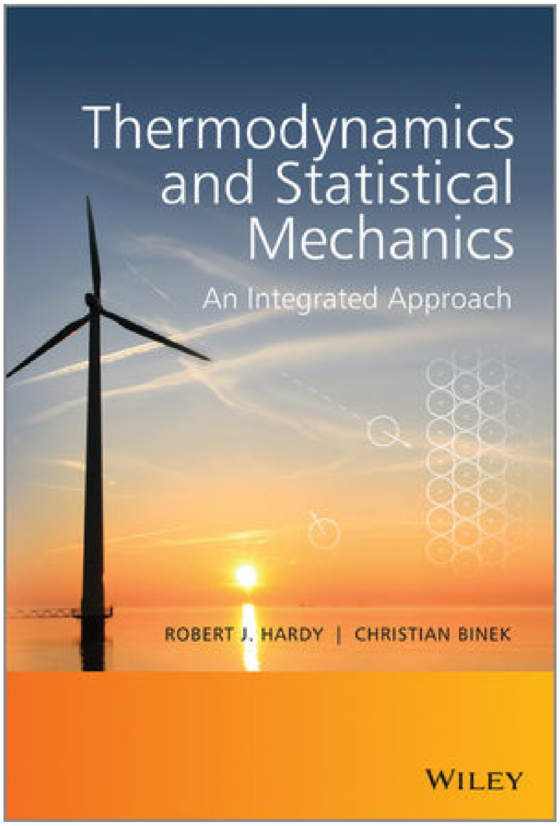
Final grade:

Homework	25%
Midterm Test1	20%
Midterm Test2	20%
Final Exam	30%
Participation	5%

97	%	to	100	%	will display as	A+
94	%	to	97	%	will display as	A
90	%	to	94	%	will display as	A-
87	%	to	90	%	will display as	B+
84	%	to	87	%	will display as	B
80	%	to	84	%	will display as	B-
77	%	to	80	%	will display as	C+
74	%	to	77	%	will display as	C
70	%	to	74	%	will display as	C-
67	%	to	70	%	will display as	D+
64	%	to	67	%	will display as	D
60	%	to	64	%	will display as	D-
0	%	to	60	%	will display as	F

The participation grade: I encourage you to ask questions and offer comments at any time. As a general rule, you need to be regularly visible in class in order to get full credit for participation.

Text:



Robert J. Hardy and Christian Binek**,** *Thermodynamics and Statistical Mechanics: An Integrated Approach*, ISBN: 978-1-118-50101-6, 536 pages, June 2014

Further references:
My lecture notes are available on-line at http://physics.unl.edu/~cbinek/Phys912.html
Although I highly recommend reading in our textbook and will refer to specific chapters in class, I also like to remind you that it is always a good idea to look at a problem from various perspectives. You have entire libraries and electronic sources for more information. Take advantage of that and don't limit yourself to just one source. Next I give a list of other useful texts and on-line sources. Find out what works best for you in addition to all the information you find in our textbook, in class, and from my lecture notes.

- K. Huang, Statistical Mechanics, New York, Wiley [1963]
- L. D. Landau and E. M. Lifshitz, Statistical Physics
- H. Gould and J. Tobochnik, Thermal and Statistical Physics, available online at http://stp.clarku.edu/notes, and simulations at http://stp.clarku.edu/simulations.
- E. Fermi, Thermodynamics (http://gutenberg.net.au/ebooks13/1305021p.pdf)
- R. K. Pathria, Statistical Mechanics
- **F. W. Sears and G.L. Salinger** *Thermodynamics, Kinetic Theory, and Statistical Thermodynamics* (Massachusetts, Addison-Wesley 1975)

Changes: This syllabus represents a reasonably accurate outline of the course. However, we may deviate from it especially at the end of the semester depending on our progress.

Students with disabilities are encouraged to contact the instructor for a confidential discussion of their individual needs for academic accommodation. It is the policy of the University of Nebraska-Lincoln to provide flexible and individualized accommodation to students with documented disabilities that may affect their ability to fully participate in course activities or to meet course requirements. To receive accommodation services, students must be registered with the Services for Students with Disabilities (SSD) office, 132 Canfield Administration, 472-3787 voice or TTY.