Syllabus
Thermodynamics and Statistical Mechanics
(Physics 815)
Spring Semester 2013

Instructor
Prof. Jens Oberheide, 102B Kinard Lab, Dept. of Physics and Astronomy, Clemson University, Tel. 864-656-5163, Email: joberhe@clemson.edu

Class Hours
MWF 11:15 – 12:05, 116 Kinard.

Office Hours
MWF 1:30 – 2:30; Th 10:00 – 12:00; or simply come on an as needed basis.

Scope of Course
An advanced graduate level foundation for any research involving statistical mechanics.

Prerequisite
There is no formal prerequisite for this course. However, I will assume that students know about undergraduate level thermodynamics, and graduate level mechanics and quantum mechanics.

Required Texts
Statistical Mechanics (Third Edition) by Pathria & Beale; Elsevier, ISBN 978-0-12-382188-1, 718 pages, 2011; List Price US$ 94.95; it is important that you have the 3rd edition. **The major part of the lecture will follow this book!** For errata see: http://www.elsevierdirect.com/v2/companion.jsp?ISBN=9780123821881

Thermodynamics and Statistical Mechanics by Greiner, Neise, Stöcker; Springer, ISBN 0-387-94299-8, 463 pages, 1994; List Price US$ 79.20. **The first part of the course (review of thermodynamics) will follow this book before switching to Pathria & Beale.** It also provides a comprehensive summary of statistical mechanics although on a somewhat lower level than Pathria & Beale.

Recommended Texts
Statistical Mechanics by R. Kubo; North Holland Personal Library (now Elsevier), ISBN 0-444-87103-9, 425 pages, 2004; Lots of problems with solutions: excellent for practicing; not suitable as stand-alone textbook.

Other commonly used texts are: *Statistical Mechanics and Thermal Physics* by Reif; *Statistical Mechanics in a Nutshell* by Peliti; and *Statistical Physics* by Landau and Lifshitz

Course Outline

1. Review of thermodynamics (about 2 weeks): introduction, macroscopic vs. microscopic variables, extensive and intensive thermodynamic variables, densities and fields, kinetic theory of the ideal gas, first and second laws of thermodynamics, reversible and irreversible cycles, entropy, thermodynamic assemblies and potentials, stability, Legendre transformations between assemblies, Maxwell relations, coexistence, Clausius-Clapyron equation, van der Waals equation of state, Maxwell construction.
2. Statistics (about 1 week): random variables, averages and variances, binomial distribution, continuous distributions, normal distribution, central limit theorem, pseudo-random numbers.
3. Foundations of statistical mechanics (about 2 weeks): quantum mechanical averages, pure states, time-averages, ensembles, density matrix, equilibrium, classical limit, partition function, canonical ensemble, grand canonical ensemble, Laplace transformations between ensembles, relationship between thermodynamic assemblies and statistical ensembles, monatomic ideal gas, Gibbs paradox, energy and particle number fluctuations, entropy.
4. Applications of statistical mechanics (remainder of the semester):
    i. Classical ideal gas of particles with structure: electronic, rotational, and vibrational specific heats.
    ii. Chemical equilibrium.
    iii. Imperfect gases and fluids: low density virial expansion.
    iv. Correlation functions: one-body density, two-body density, pair correlation function, fluctuation compressibility relation, virial and compressibility equations of state.
    v. Correlations and scattering: structure factor and relation to the pair correlation function.
    vi. Quantum statistical mechanics: Bose-Einstein distribution, black body radiation, phonons in crystals, Bose–Einstein condensation, Fermi-Dirac distribution, density of states, applications to metals, thermodynamics of the early universe.
    vii. Magnets: ideal paramagnets, Curie law, ferromagnets, Ising model, one-dimensional Ising model solution, correlations, mean field theory and Landau theory, Ising model and lattice gases.
    viii. Critical points: singular behavior of thermodynamic quantities, correlation length, critical exponents and the failure of Landau theory, two-dimensional Ising model, low and high temperature expansions, Onsager's solution.
    ix. Nonequilibrium statistical mechanics: Brownian motion, linear response, temporal correlations, fluctuation dissipation theorem.

Homework

Homework will be assigned on a weekly basis. The lowest two homework grades will be dropped at the end of the semester before the final course grade is calculated. Homework is due on the date assigned. Late homework will not be accepted without a very good excuse.

Course Grades and Weights

- 25% Homework
- 30% Mid-term exam
- 45% Final exam

A: 85-100; B: 70-85; C: 55-70; D: 40-55; F: 0-40

Attendance Policy

Attendance is required for the first class. Thereafter, it is not required but is *strongly recommended*. It is the responsibility of the student to be aware of what is announced in class, including changes to homework assignments. Please also see the general statement on attendance in the Graduate Announcements.

Class Web Page

The course web site can be accessed via Blackboard. Course announcements, assignments, instructional material etc. can be found there.

Academic Integrity Policy

The Clemson University statement on academic integrity applies, as posted in the Graduate Announcements. In addition, students may discuss homework problems with other students, but only in general terms. **Students may not look at another student's written solution before the due date, and the work the student turns in must be entirely his/her own.**

Disability Access Statement

It is University policy to provide, on a flexible and individualized basis, reasonable accommodations to students who have disabilities. Students are encouraged to contact Student Disability Services to discuss their individual needs for accommodation.