Thermal and Statistical Physics I (Physics 533)
Syllabus

Course description

Physics 533 provides an introduction to thermodynamics and statistical mechanics for graduate students of physics and related disciplines. Einstein famously said that, of all major theories of physics, only thermodynamics would never be overthrown. It is a “meta-theory” concerned with general relationships among macroscopic properties of systems in equilibrium. Statistical mechanics builds on atomistic models to predict thermodynamic properties of physical systems. Topics covered include thermodynamic equilibrium, conversion of heat into useful work, phase transitions, classical and quantum fluids, and the approach to equilibrium.

We will generally follow the order of topics in the text by Callen, starting with thermodynamics developed on the basis of a small number of fundamental postulates. Statistical mechanics will be introduced later. Topics beyond the level of this course are left to Phys 534 and/or self-study.

Resources

Instructor:	Gary S. Collins, Webster 554, mailto:collins@wsu.edu office: 509-335-1354, cell: 509-336-9225.
Office hours:	whenever my door is open or by appointment.
Class meetings:	MWF, 9:10-10:00 am, Webster B11.
Required text:	Thermodynamics and an Introduction to Thermostatistics, by Herbert Callen (Wiley, 1985, 2nd ed.) Available at Bookie or online.
Public web page:	http://www.wsu.edu/~collins/533-13 (links to syllabus, schedule, ...)
Angel web site:	http://lms.wsu.edu/ (class notes, readings, assignments, solutions.)

General Rules and Expectations

Grading will be on the basis of homework assignments, three in-class exams held on Monday evenings (see schedule), a final exam, and a “participation and attendance” grade based on occasional, unannounced reading quizzes and an evaluation by me of the quality of your participation in class. Grades will be assigned according to the absolute scale below. Exams will be closed-book, but you will be permitted to bring one 8x11-inch double-sided page of notes prepared individually to each exam. The final exam will be in-class.

A	90-100 %
A-	85-90 %
B+	80-85 %
B	75-80 %
B-	70-75 %
C+	65-70 %
C	60-65 %
C-	55-60 %
D+	48-55 %
D	40-48 %
F	0-40 %

Homework	32%
Three exams during the semester	32%
Final exam	32%
Participation and attendance	4%
Total	100%

Questions or comments about course material or homework? Feel free to email me with "Phys 533" at the beginning of the subject line. As appropriate, I will reply to you or to the entire class.

Studying. I encourage you to study with other students, but written homework exam solutions must be yours alone. Submitting solutions prepared by other students, from books, or from the web is *plagiarism*, and will not be tolerated! (WSU's *Academic Integrity Program* is detailed at http://academicintegrity.wsu.edu/default.asp?PageID=4614.)

Homework. There will be 8 assignments during the semester, announced one week ahead of the due date. This should be obvious but merits restatement: *Beyond careful study of the text, the best way to learn the subject matter well is through the hard, conscientious work needed to solve homework problems*. Attempt homework problems seriously. If you do not make progress after spending 15-30 minutes on a problem, ask for hints from me or fellow students. I will normally grade homework in a summary manner, scanning your solutions to see that you have made a good faith effort to solve the problems. Since solutions to homework problems are generally available over the web, this is fairer to students who do their own work. They will be the ones who learn! Do not copy solutions. Please provide your solutions to assignments in the assigned order, on single-sided pages, and stapled together. *Late homework will not be accepted*; no excuses! Solutions will be posted on the Angel web site. Always check your solutions against the posted ones; you are responsible for understanding solutions to all assigned problems.

Course Objective

The objective of this course is to learn how to apply thermodynamic principles in order to interpret thermodynamic systems and predict their behaviors. The principles used in this course are based on four postulates proposed axiomatically by Herbert Callen, author of the required text, and not the more familiar "laws of thermodynamics" developed historically. An additional objective is to become familiar with the use of simple statistical mechanical models to predict thermodynamic properties. Learning outcomes that support the objectives are listed below, numbered according to chapters in the text by Callen.

Learning Outcomes

1. To understand the four postulates, including definitions of state variables and the entropy. To understand the "seminal problem" and the "entropy maximum" principle.
2. To understand conditions of thermodynamic equilibrium, including thermal, mechanical and chemical equilibria. Understanding relationships between the equations of state and the fundamental relation of a system. Understanding how to express the fundamental relation in the energy or entropy representation.
3. To understand basic relations, including the Euler relation, Gibbs-Duhem relation, and "materials properties" that come from second derivatives of the fundamental relation. Also to learn the important properties of simple systems such as the ideal gas, van der waals fluid, electromagnetic radiation, and others. To know how to determine a fundamental relation that is consistent with given equations of state.
4. To understand the maximum work theorem and its applications to interpreting the usefulness and/or energy costs of thermodynamic processes, including cyclic ones such as in heat engines and refrigerators. To understand and distinguish among reversible, quasi-static
5. To derive the "energy minimum" principle from the "entropy maximum" principle. To learn how to reexpress thermodynamic functions in terms of alternative variables, for example in terms of pressure instead of volume, through Legendre transformations of variables.

6. To understand energy "potentials" such as the enthalpy, Helmholtz potential, Gibbs potential obtained by Legendre transformation. To be able to apply them in analyzing various processes. To be able to calculate thermodynamic functions based on standard tabulations of data.
7. To learn how to derive Maxwell relations among derivatives of thermodynamic variables, in order to reexpress thermodynamic relations in alternative ways that may be more useful. To know how to quickly obtain Maxwell relations using the "thermodynamic square". To be able to "reduce derivatives" to expressions that depend solely on the fundamental thermodynamic variables, state functions, and materials properties.
8. To understand conditions of stability of thermodynamic systems. The LeChatelier principle.
9. To understand first-order phase transitions such as the liquid-gas phase transition. To understand phase diagrams. To be able to apply the Gibbs' phase rule that governs the number of freely variable thermodynamic variables at a specified phase transition.
10. To understand second-order phase transitions, including power-law behavior of thermodynamic variables close to the transition. To understand the basic concept underlying scaling relations. To understand the Landau theory of phase transitions. To know definitions of the important critical exponents and scaling relations among them. Universality and scaling.
11. To understand properties of systems close to absolute zero.
12. To be able to summarize thermodynamic principles in a succinct, general form.
13. To understand applications of model systems, such as chemical reactions of ideal gases and properties of dilute solutions.
14. To understand basic principles of irreversible thermodynamics and the approach to equilibrium using the Onsager formulation.
15. To understand statistical mechanics of systems in the *microcanonical* formulation (systems having fixed total energy). Knowing the Einstein vibrational model of solids, the two-state model, and others.
16. To understand statistical mechanics of systems in the *canonical*, or Helmholtz, formulation (systems in equilibrium with a thermal reservoir at a fixed temperature). Factorizable systems. Densities of state. The Debye vibrational model of solids. The classical ideal gas.
17. To understand statistical mechanics of systems in other generalized canonical formulation, including the grand canonical formulation for systems in equilibrium with thermal and particle reservoirs at given temperatures and chemical potentials.
18. To understand statistical mechanics of quantum fluids (bosons or fermions). To understand the classical limit and strongly degenerate quantum systems, including Fermi gases and Bose-Einstein condensates.
19. To understand fluctuations of macroscopic properties of thermodynamic systems about their equilibrium values.
20. To become familiar with the Bogoliubov variational principle and how it can be used to approximate a complex statistical mechanical system with an unsolvable hamiltonian in terms of simpler system with a solvable hamiltonian. To become familiar with the basic idea of mean field theory.
21. To become acquainted with Callen's philosophical thoughts about the foundational role of symmetry in thermodynamics.

Evaluation of Learning Outcomes

Evaluation of the above learning outcomes will be made on the basis of your solutions to homework problems, exam problems in three exams during the semester, and final exam problems.

Resources

The Angel web site at http://lms.wsu.edu/ has homework assignments and solutions and sample exams for enrolled students. I will also make available rough class notes that I prepare for my own use in class, but they are not finished and are not intended to be comprehensive! You are responsible for understanding all subject matter in the text except when noted otherwise. The public web page contains links to some external pages that may be useful; let me know of dead links and good ones that you find!

Supplementary texts. Thermodynamics and statistical mechanics are introduced in many different ways. Supplemental readings may provide you with useful perspectives. A number of web-texts have links from the Angel web site (see "other resources" page). I also intend to place the following texts on two-day reserve in Owen Science Library:

Statistical Mechanics, Kerson Huang (Wiley, 1963). Good alternative to Callen.
Statistical Physics, L. Landau and E. Lifschitz (Oxford, 1938). Classic, advanced.
A Modern Course in Statistical Physics, L.E. Reichl (Wiley, 1980). More advanced.
Statistical Mechanics, D. A. McQuarrie (Harper 1975). More advanced.
Statistical Mechanics: a set of lectures, R.P. Feynman (Benjamin, 1972). Offbeat.

Other Matters

Students with Disabilities:
Reasonable accommodations are available for students with a documented disability. If you have a disability and need accommodations to fully participate in this class, please visit or call the Access Center (Washington Building 217; 509-335-3417) to schedule an appointment with an Access Advisor. All accommodations MUST be approved through the Access Center. For more information contact a Disability Specialist on your home campus: 509-335-3417 http://accesscenter.wsu.edu, Access.Center@wsu.edu. If you have a documented disability, please contact me during the first week of class.

Academic Integrity.
I encourage you to work with classmates on assignments. However, each student must turn in original work. No copying will be accepted from any source (fellow student, web, book, etc.) Students who violate WSU's Standards of Conduct for Students will receive an F as a final grade in this course, will not have the option to withdraw from the course, and will be reported to the Office of Student Standards and Accountability. Cheating is defined in the Standards for Student Conduct WAC 504-26-010 (3); see http://apps.leg.wa.gov/wac/default.aspx?cite=504-26-010 for definitions. It is strongly suggested that you read and understand those definitions. Specific Graduate School policy statements on Academic Integrity can also be found at this link: http://www.gradschool.wsu.edu/Documents/PDF/GuidelinesforSyllabus.pdf

Safety.
The campus safety plan is at http://safetyplan.wsu.edu/.
Preparation for emergencies is at http://oem.wsu.edu/emergencies.
The campus-wide alert system is at http://alert.wsu.edu/.
Personal emergency contact information can be entered at http://zzusis.wsu.edu.
In case of a fire alarm, exit through the back door of Webster and collect in the small parking lot behind the Waller Hall dormitory, to the south-west of Webster.

This syllabus is provisional and subject to change.

Gary S. Collins, 7 January 2014