Physics 5500: Thermodynamics and Statistical Physics
Fall 2011

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Lectures: (to be decided Sept. 4)
Office hours: Thursday 2 –3 p.m. or by Appointment

Texts
Harvey Gould and Jan Tobochnik, Statistical and Thermal Physics, Princeton University Press, 2010, ISBN 978-0-691-13744-5

Addition References
Fermi – Thermodynamics
Callen – Thermodynamics and Statistical Physics
Kittel and Kroemer – Thermal Physics
Zemansky and Dittman – Heat and Thermodynamics

Course Description
PHY 5500 course is devoted to the study of systems made of a large number of particles, an area of thermal physics and statistical mechanics, which governs transformations of heat into mechanical work, phase transitions, properties of gases and solids, and many other fundamental phenomena. Statistical physics is one of a few indispensable subjects widely used in chemistry, biology, geology, meteorology, environmental science, cosmology, low-temperature physics, solid state physics, atomic physics, and engineering (heat engines, vacuum technology, electronic devices, etc). Therefore, thorough knowledge of statistical mechanics is of utmost importance to the aspiring scientist or engineer.

List of Topics
1. Introduction. The scope of thermal physics. Microstates vs. microstates. Multiplicity. Pressure and temperature (Ch. 1).
2. The ensemble average. The ideal gas; the ideal gas law. The role of simulations (Ch.1)
3. Thermodynamic concepts and processes. Thermodynamic equilibrium. Temperature. Equation of state. (Ch. 2)
4. Thermodynamic processes. Work and heat. The first Law of thermodynamics. Isothermal and adiabatic processes. Energy equation of state. Heat capacities and enthalpy. The Second Law of thermodynamics. Entropy. The Thermodynamic temperature. Heat Engines. The Carnot cycle (Ch.2)
5. Examples of entropy changes. Free expansion of gas. Equivalence of Thermodynamics and Ideal gas temperature scales. The thermodynamic pressure. Fundamental thermodynamics relationship (Ch.2).
6. The entropy of an ideal classical gas. The third law of thermodynamics Free energy (Gibbs, Helmholtz). The grand potential (Landau potential) (Ch.2).
7. Thermodynamics derivatives. The Maxwell relations (Ch.2). The chain rules (lecture notes). Relation between heat capacities. Joule –Thompson process (Ch.2).
8. Concept of probability. Mean values. Binominal distribution. Stirling's approximation. Continuous probability distribution. The central limit theorem (Ch.3).
9. Formulation of statistical mechanics. The role of energy. Thermal interaction. Einstein solids. Non-interacting spins. 1D harmonic oscillator. A particle in a box. Calculating the number of microstates. Semi-classical limit (Ch.4).

10. The microcanonical ensemble. Entropy. The canonical ensemble. The Boltzmann distribution. The partition function. Connection between thermodynamics and statistical mechanics. Distinguishable and indistinguishable particles. (Ch.4).
11. Grand canonical ensemble. Fluctuations (Ch.4)
12. Magnetic systems. Noninteracting magnetic moments. The Ising Model (1D). 2D Ising model – computer simulation, mean field theory. (Ch.5).
13. Many particle systems. Ideal gas (semiclassical limit). The entropy of an ideal classical gas. The Sahur-Tetrode equation. Entropy of mixing. The Gibbs paradox. The equipartition theory. The Maxwell velocity distribution. (Ch.6)
14. Fermi and Bose statistics. Distribution functions of ideal Bose and Fermi gases. Density of states. Photons. Non-relativistic and ultra-relativistic limits. Black body radiation. Ideal Fermi gas. The Einstein solid. (Ch. 6)
15. Ideal Bose gas. Bose Einstein condensation. Fluctuations in a number of particles (Ch. 6).
16. Chemical potential and phase transformations. Phase diagrams. Clausius – Clapeyron equation. Van Der Waals equation of state. (Ch.7)
17. Percolation effects (time permitting) Ch. 9.

Course Objectives

The principal objectives of this introductory course are for you to learn fundamental concepts of thermodynamics and statistical physics and to develop the problem-solving skills to apply these fundamentals. Since professional scientists and engineers must be proficient problem solvers, and it is impossible to really understand any area of physics without solving problems, homework assignments are an integral part of this course. Sufficient knowledge of calculus of many variables is required.

Homework

Homework will be assigned weekly on the first class of the week and are due in a week. It is acceptable (and can be very useful) to discuss homework problems with each other and compare different possible solutions. However, copied homework will not be credited. Late homework will generally not be accepted.

Quizzes

Quizzes will be give every week on the material discussed earlier in class or/and Homework Assignments. Typically will require 15 – 20 mins.

Bonus Problems

Bonus problems (typically qualitative problems) will be given in class. Students will be able to discuss them with each other and ask the lecturer additional questions. By the end of the class students will have to answer the question based on their assessment of the arguments.

Grade

First Exam – 20%
Midterm – 20%
Final Exam – 35%
Quizzes – 25%
Bonus problems – 5%
Homework – 5%

Total –110%