Physics 7230  

Statistical Mechanics  

Spring 2008

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Text:  
No required text but here are some suggested texts.


Course Outline

I.  Thermodynamics: two weeks
Introduction, macroscopic vs. microscopic variables, extensive and intensive thermodynamic variables, densities and fields, 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.

II.  Statistics: one week
Random variables, averages and variances, binomial distribution, continuous distributions, normal distribution, central limit theorem, pseudo-random numbers.

III.  Foundations of Classical Statistical Mechanics: two weeks
Hamiltonian equations of motion, phase space, time averages, ensembles, Liouville’s Theorem, ergodicity, time-independence and Boltzmann’s equilibrium hypothesis, 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.

IV.  Applications of Classical Statistical Mechanics
Ideal gas of particles with structure: electronic, rotational, and vibrational specific heats.  
Coupled classical harmonic oscillators: general treatment of quadratic Hamiltonians.  
Imperfect gases and fluids: low density virial expansion.  
Correlation functions: one-body density, two-body density, pair correlation function, fluctuation-compressibility relation, virial and compressibility equations of state.  
Correlations and scattering: structure factor and relation to the pair correlation function.  
Computer simulations: Monte Carlo, molecular dynamics.  
Magnets: ideal paramagnets, Curie law, ferromagnets, Ising model, one-dimensional Ising model solution, correlations, mean field theory and Landau theory.  
Lattice Gases: relation to the Ising model.  
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.

V.  Quantum Statistical Mechanics
Quantum mechanical averages: pure states, ensembles, density matrix, equilibrium, classical limit.  
Ideal Fermi and Bose gases: Fermi-Dirac distribution, density of states, applications to metals, Bose-Einstein distribution, black body radiation, early universe, phonons in crystals, Bose –Einstein condensation.

VI.  Nonequilibrium statistical mechanics: Brownian motion, linear response, temporal correlations, fluctuation-dissipation theorem.
Prerequisites: undergraduate level thermodynamics and graduate quantum mechanics.

Homework and Term Paper: Homework assignments will be distributed about every two weeks. Forty percent (40%) of the course grade will be determined by homework grades, and 60% will be determined by your grade on a term project. You may work in small groups on the homework but you must acknowledge your collaborators and hand in independent solutions. Your individual term project will be graded on the scientific merit and quality of presentation of a written draft, a final written version, and a 10 minute oral presentation (20% each). Suggested topics will posted soon.