Physics 7230  Statistical Mechanics  Spring 2012

Professor:  Paul Beale,  paul.beale@colorado.edu, 492-0297
Office:  Duane E1B32 (the Chair’s office is inside the physics department office)
Text:  Statistical Mechanics, third edition by R.K. Pathria and Paul D. Beale,  
Available at the bookstore, or online, or as an ebook.
Website:  http://www.colorado.edu/physics/phys7230/phys7230_sp12

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 statistical mechanics: two 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.

IV. Applications of statistical mechanics
Classical ideal gas of particles with structure: electronic, rotational, and vibrational specific heats. 
Chemical equilibrium. 
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. 
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. 
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, 
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. 
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. Fifty-five 
percent (55%) of the course grade will be determined by the homework grades, and 45% 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, and a final written version. 
Each student will give individual or shared 10-minute oral APS-style presentation (10 minutes plus 2 
minutes for questions) (15% each). I will post suggested topics later in the semester.