Statistical Mechanics and Thermodynamics I. Spring 2012

"Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906, by his own hand. Paul Ehrenfest, carrying on the work, died similarly in 1933. Now it is our turn to study statistical mechanics."

- From the introduction to States of Matter by David L. Goodstein -

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Text: These books are required.

- **L.D. Landau, E.M. Lifshitz et al**, *Statistical Physics*, 3rd edition, Butterworth-Heinemann, ISBN 0750633727.
- **R. Kubo et al**, *Statistical Mechanics*, 12th repr. 1992 edition, Elsevier Science, ISBN 0444871039

Grading:

3 exams	60%
Final (comprehensive)	20%
Homework	20%

Evening exams on Feb 23, Mar 22, and Apr 19; 7:00-9:30 pm; MPHY 213
Final exam May 4, Friday 3:00pm – 5:00pm, MPHY 107

Syllabus:

Wk	Date	Topic	Sections in Text
1	Jan. 16	No Classes	
	Jan. 18	**First meeting. Introduction. Macroscopic systems. Thermodynamics. Entropy .**	LL 9
	Jan. 20	**Temperature. Macroscopic motion.**	LL9,10
2	Jan. 23	**Thermodynamic potentials : energy, enthalpy, Helmholtz free energy, and Gibbs free energy. Maxwell relations between thermodynamic derivatives and Jacobians.**	LL14,15,16
	Jan. 25	**HW 1 given. Relations between thermodynamic coefficients. Equation of state and specific heats. Thermodynamic inequalities.**	LL 12-16
	Jan. 27		
3	Jan. 30	**Maximal work and Carnot cycle. Nernst's theorem. Thermodynamic potentials in the presence of external fields**	LL1-2 LL 19, 23,15
	Feb. 1	**HW 2 given. Number of particles as an external parameter. Chemical potential. Solving problems in thermodynamics.**	LL 16,21
	Feb. 3	**Mixture of gases**	LL 93
4	Feb. 6	**Classical statistical mechanics. Phase space. Distribution function. Statistical independence of subsystems. Fluctuations of additive observables.**	

	Feb. 8	**HW 3 given. Statistical ensemble. Liouville theorem. Microcanonical distribution. Quantum statistical mechanics. Statistical matrix. Density of states. Statistical weight of the system.**	LL 24-25 LL 3-7
	Feb. 10	**Entropy. Level spacing of macroscopic system. The law of increase of entropy.**	LL 7-8
5	Feb. 13	**Microcanonical distribution. Canonical (Gibbs) distribution. T-P distribution. Curie's law for independent 1/2 spins in magnetic field.**	LL 28, 36 K.1 ex 4,10
	Feb. 15	**HW 4 given. Grand canonical distribution. Fluctuations of thermodynamic quantities.**	LL 35-36
	Feb. 17		
	Feb. 20	**Thermodynamics and Gibbs distribution in the presence of external fields.**	LL 25, K.2 pr 3,4
6	Feb. 22	**HW 5 given. Thermodynamics and Gibbs distribution of rotating bodies. Thermodynamic perturbation theory (classical).**	LL 26, 34, 32
	Feb. 24		
	Feb. 27	**Thermodynamic perturbation theory (quantum). Boltzmann distribution.**	LL 32, 37, 38
7	Feb. 29	**HW 6 given. Boltzmann distribution for classical system. Comparison of partition funcitons for 1d quantum and classical oscillators. 'Frozen degrees of freedom'. Ideal Boltzmann gas. Equation of state. Ideal gas with constant specific heat.**	LL 38, 41-43
	Mar. 2		
	Mar. 5	**The law of equipartition. Monoatomic gases. Rotation of molecules. Polyatomic gases.**	LL 44, 45, 46, 47-51, K.3 ex 2
8	Mar. 7	**HW 7 given. Symmetry factors, identical atoms, nuclear spins, electronic states, anharmonicity etc. Ideal gases not in equilibrium. Gibbs paradox. Mixture of ideal gases. Chemical equilibrium.**	LL 46-51, 40, 101
	Mar. 9		
		Spring Break	
	Mar.19	**Chemical equilibrium. Chemical equilibrium between ideal gases. The law of mass action. Equilibrium constant. Non-ideal gases. Virial expansion.**	LL 101-103, 74-75
9	Mar.21	**HW 8 given. Van der Waals equation. Ideal quantum gases. Fermi and Bose statistics. Ideal quantum gases not in equilibrium.**	LL 76, 53-55
	Mar.23		
	Mar.26	**Fermi and Bose gases of elementary particles. A degenerate electron gas.**	LL 56-57
10	Mar.28	**HW 9 given. A degenerate electron gas. Specific heat. Magnetism of an electron gas. Bohr-van Leeuwen theorem.**	LL 57-59
	Mar.30		LL 59
	Apr. 2	**Magnetism of an electron gas. Pauli paramagnetism. Landau diamagnetism. De Haas-van Alphen effect.**	
11	Apr. 4	HW 10 given. **A degenerate relativistic electron gas. Electrons and holes in semiconductors. A degenerate Bose gas. Bose condensation.**	LL 61-62, K.4 ex 3-4
	Apr. 6	No Class	
12	Apr. 9	**Bose condensation. Singularities in thermodynamic potentials. Black body radiation. Planck's distribution. Planck's formula. Rayleigh-Jeans formula.**	LL 62-63

	Apr.11	**HW 11 given. Black body radiation. Kirchhoff's law. Phonons in crystals. Debye's law. Debye's interpolation formula.**	LL 63, 64, 66
	Apr.13		
13	Apr.16	**Phase equilibrium. Phase diagrams. Metastable states. Triple points. Latent heat of a transition. The Clapeyron-Clausius formula. The pressure of a saturated vapor. The phase transitions of the first kind and free energy landscape. The critical point.**	LL 81-84
	Apr.18	**HW 12 given. Phase transitions of the second type. Spontaneous symmetry breaking. Order parameter. The discontinuity of specific heat. Effect of an external field on a phase transition.**	LL 142-144
	Apr.20		
14	Apr.23	**Effect of an external field on a phase transition. Fluctuations of the order parameter. Applicability of Landau theory of phase transitions. Levanyuk-Ginzburg criterion.**	LL 144-149
	Apr.25	**Fluctuation range. Critical indices. Scaling hypothesis. Critical phenomena. What next?**	
	Apr.27		
15	Apr.30		
	May 1		

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