PHY-806 Thermal Physics

Credit Hours: 3-0
Prerequisite: None

Objectives and Goals: This course covers fundamentals of thermodynamics and statistical mechanics. The first part of this course develops fundamental ideas of thermodynamics and is aimed to develop students' ability to deal with various thermodynamic systems. The second part introduces principles of statistical mechanics to study both classical and quantum mechanical thermodynamic systems.

Core Contents: The zeroth, first, second and third laws of thermodynamics and the concepts of temperature, heat and entropy; the internal energy and extensive and intensive variables; laws of radiation; the Maxwell relations. The thermodynamic potentials. Phase and phase transitions. Probability distributions; the Maxwell distribution; distributions in phase space; fluctuations. Ensembles; Liouville's theorem; statistical interpretation of entropy; the microcanonical, canonical and grand canonical ensembles; quantum statistics, Fermi-Dirac and Bose-Einstein distributions; fermions and bosons; Fermi and Bose degenerate gases.

Detailed Course Contents: Microscopic view of matter, viewing the world at different scales, thermodynamics, the thermodynamic limit, thermodynamics transformations, classic ideal gas, first law of thermodynamics, magnetic systems, heat, and entropy, the heat equations, application to ideal gas, Carnot cycle, second law of thermodynamics, absolute temperature, temperature as integrating factor, entropy, entropy of ideal gas, the limits of thermodynamics, using thermodynamics, the energy equation, some measurable coefficients, entropy and loss, TS diagram, condition for equilibrium, Helmholtz free energy, Gibbs potential, Maxwell relations, chemical potential, the Statistical approach, the atomic view, random walk, phase space, distribution function, Ergodic hypothesis, statistical ensemble, correct Boltzmann counting, distribution entropy: Boltzmann's H, the most probable distribution, determining the parameters, pressure of ideal gas, equipartition of energy, distribution of speed, entropy, derivation of thermodynamics, fluctuations, the Boltzmann factor, canonical ensemble, review of microcanonical ensemble, classical canonical ensemble, the partition function, connection with thermodynamics, energy fluctuations, minimization of free energy, classical ideal gas, grand canonical ensemble, the particle reservoir, grand partition function, number fluctuations, connection with thermodynamics, parametric equation of state and virial expansion, critical fluctuations, quantum statistics, thermal wavelength, identical particles, occupation numbers, spin, microcanonical ensemble, Fermi statistics, Bose statistics, determining the parameters, pressure, entropy, free energy, equation of state, classical limit, quantum ensemble, incoherent superposition of states, density matrix, canonical ensemble (quantum mechanical), grand canonical ensemble (quantum mechanical), occupation number fluctuations, photon benching, Fermi energy, ground state, fermi temperature, low-temperature properties, particles and holes, electrons in solids, semiconductors, the bose gas, photons, bose enhancement, phonons, Debye specific heat, electronics specific heat, conservation of particle number

Course Outcomes: At the end of this course, students will be able to understand,

- fundamental ideas of thermodynamics and statistical mechanics for various systems
- concept of entropy
- Ensemble theory
- Quantum statistics of identical particles

Textbook: Kerson Huang, Introduction to Statistical Mechanics, Chapman and Hall CRC 2009.

Reference Book: Walter Greiner, Ludwig Neise, Hort Stocker, Thermodynamics and Statistical Mechanics, Springer 1995.

Weekly Breakdown		
Week	***Section***	***Topics***
	1.1-1.7	Microscopic view of matter, viewing the world at different scales, thermodynamics, the thermodynamic limit, thermodynamics transformations, classic ideal gas, first law of thermodynamics, magnetic systems
	2.1-2.9	Heat and Entropy, the heal equations, application to ideal gas, Carnot cycle, second law of thermodynamics, absolute temperature, temperature as integrating factor, entropy, entropy of ideal gas, the limits of thermodynamics
	3.1-3.9	Using Thermodynamics, The energy equation, some measurable coefficients, entropy and loss, TS diagram, Condition for equilibrium, Helmholtz free energy, Gibbs potential, Maxwell relations, chemical potential
	5.1-5.6	The Statistical approach, the atomic view, random walk, phase space, distribution function, Ergodic hypothesis, statistical ensemble
	5.7-5.10	Correct Boltzmann counting, distribution entropy: Boltzmann's H, the most probable distribution
	6.1-6.8	Determining the parameters, pressure of ideal gas, equipartition of energy, distribution of speed, entropy, derivation of thermodynamics, fluctuations, the Boltzmann factor
	8.1-8.7	Canonical ensemble, review of microcanonical ensemble, classical canonical ensemble, the partition function, connection with thermodynamics, energy fluctuations, minimization of free energy, classical ideal gas
	9.1-9.6	Grand canonical ensemble, the particle reservoir, grand partition function, number fluctuations, connection with thermodynamics, parametric equation of state and virial expansion, critical fluctuations
	14.1-14.7	Quantum statistics, thermal wavelength, identical particles, occupation numbers, spin, microcanonical ensemble, Fermi statistics, Bose statistics
	14.8-14.13	Determining the parameters, pressure, entropy, free energy, equation of state, classical limit
	15.1-15.6	Quantum ensemble, incoherent superposition of states, density matrix, canonical ensemble (quantum mechanical), grand canonical ensemble (quantum mechanical), occupation number fluctuations, photon benching

	16-1-16.5	Fermi energy, ground state, fermi temperature, low-temperature properties, particles, and holes
	16.6-16.7, 17.1-17.3	Electrons in solids, semiconductors, the bose gas, photons, bose enhancement, phonons
	17.4-1.6	Debye specific heat, electronics specific heat, conservation of particle number
		Revision