PHYS 403: TOPICS for the FINAL EXAM 2021

As I already said on numerous occasions, the material for the exam will be based on the slides which were given during the course. Material in the course notes which was not covered in the slides will not be covered in the exam. However, needless to say, the material in course notes amplifies on the material in the slides, and you will find it extremely useful to go through the notes.

Having said this, I should emphasize that there will certainly be questions which deal with things that are **not** found explicitly in the slides, but which **use** the material given in the slides.

The following list of topics you could compile for yourself just by going through the slides.

(1) Basic ideas of Combinatorial probability, for distinguishable and indistinguishable objects. Binomial and multinomial distributions.

(2) Basic Thermodynamics. Intensive and extensive quantities, laws of thermodynamics, reversible and irreversible processes. Thermodynamics of gases, heat flow and entropy, thermodynamic potentials, notably free energy; Maxwell relations. Chemical potential, and particle exchange.

(3) Microstates and macrostates. Energy levels and states for simple systems (oscillator, rotator, free particles, spins). Examples of N non-interacting 2-level systems, binary allows. Single particle and N-particle density of states.

(4) Microcanonical ensemble. Multiplicity Ω (ie., number of microstates), and extensivity of $\ln \Omega$. Relationaship of $\ln \Omega$ to entropy S. Examples - N 2-level systems, alloys, 1-d polymer.

(5) Canonical Distribution, and canonical partition function, and its derivation. Energy, free energy, entropy, and also fluctuations in energy. Partition function for multiple independent systems. Examples: N qubits (and negative temperatures), optical phonon modes (oscillators), distinguishable free particles in a box, DNA zipper model, 1-particle density of states for particle in a box (1, 2, 3 dimensions).

(6) Grand Canonical Ensemble, and grand canonical partition function, and its derivation. Energy, free energy, entropy, fluctuations in energy and fluctuations in particle number. Examples of atmosphere, and of partially ionized gases. Application to stellar spectra, and also to electron-positron gas.

(7) Quantum and classical Gases. Distinguishable and indistinguishable particles. Fermionic partition function and 1-particle distribution. Ideal Fermi gas (no interactions), relation between number and chemical potential. Ideal Bose gas (no interactions), relation between number and chemical potential; Bose condensation for massive particles. Ideal Maxwell-Boltzmann gas (no interactions), relation between number and chemical potential. Energy, free energy, velocity distribution, for MB gas; Gibbs paradox and necessity of using indistinguishable particles for MB gas.

(8) Bose liquids and Superfluids. Doing Bose condensation properly. Properties of superfluids and superconductors. Properties of superfluid ^{4}He, and its superflow properties. Neutron star superfluids.

(9) Photon Gas. Chemical potential for photons. Density of states, Planck distribution and its properties. Photons in the universe, Black bodies.

(10) Fermi liquids. Low-T degenerate fermions; the Sommerfeld expansion. Low-T chemical potential, energy, specific heat, pressure. Metals, normal ^{3}He, Stars and White dwarfs